UNIVERSITY OF SOUTHAMPTON

ACCREDITED INSTITUTION – UNIVERSITY OF CHICHESTER

Sports Sciences / PE

Volume 1 of 1

The Effects of Acute Cold Exposure on Human Postural Control

by

Christopher Ian Hodgson

Thesis for the degree of Doctor of Philosophy

January 2014

UNIVERSITY OF SOUTHAMPTON

ABSTRACT

ACCREDITED INSTITUTION – UNIVERSITY OF CHICHESTER

Sports Sciences / PE

Thesis for the degree of Doctor of Philosophy

THE EFFECTS OF ACUTE COLD EXPOSURE ON HUMAN POSTURAL CONTROL

Christopher Ian Hodgson

This investigation explored the impact of acute cold exposure on postural control during static balance tasks. The aims were to establish the impact of short term cold exposure on human postural control, identify key processes that lead to performance changes, and to examine approaches to maintaining performance of postural control during acute cold exposure. In study 1 the reliability of Centre of Pressure (COP) measurements using the RS Scan International Footscan® Plate System during quiet standing was tested. Quiet standing balance tests were compared over 5 days using a repeated trials protocol and intraclass correlational analysis. It was concluded that 3 practice trials result in consistent performances in room temperature conditions (21°C). In study 2 the effects of 30 minutes of cold exposure at −20 °C were established. No change was found for core body temperature. Head and calf skin temperatures were reduced. Foot temperatures reduced from 26.1 °C to 10.1 °C. Heart Rate Variability (HRV) measures showed effect sizes indicative of a generalised stress response but no significant differences. Postural control measures showed increased COP paths (≅ 100%) and decreased sway rates (20 – 25%) for two footed balance tests compared to room temperature performances. Single footed balance tests showed no change in sway rate but a 40 – 50% increase in COP path. In study 3 an ice bath protocol was employed to replicate foot skin temperatures of 10 °C, as had occurred during whole body cooling. Postural control variables indicated reduced performance but these changes were less pronounced than during whole body cooling. COP paths increased by 22 – 29% but sway rates were not significantly different. It was concluded that part of the impairment in postural control during acute cold exposure is due to anesthetised mechanoreceptors in the feet. In study 4 active heated footbeds were employed as a protective measure during 15 minutes of cold exposure. Performance was compared during 3 conditions: room temperature, −20 °C, and −20 °C with footbeds. Foot temperatures dropped to 11.2 °C after 15 minutes during both cold conditions. HRV analysis showed decreases in RR and LF/HF ratio during both cold exposure conditions. Postural control variables responded in the same manner as study 2 with no difference between cold conditions. Heated footbeds did not provide thermoregulatory, comfort or postural control advantages in this study. In conclusion cold exposure results in reduced accuracy in postural control which may increase accident risk during cold climate activities. A reduction in somatosensory feedback is a key factor in reduced performance but changes during initial whole body exposure suggest that attention may also play a key role in the processing of postural responses in the cold.

Contents

Contents .... **i**

List of tables .... **vii**

List of figures .... **ix**

Glossary .... **xiii**

Declaration of authorship .... **xv**

Acknowledgements .... **xvii**

1. Chapter 1 Introduction **1**

2. Chapter 2 Literature review **5**

Human Physiological Responses to Cold 6
Performance in the Cold 9
Adaptation and Habituation to Cold 14
Body Temperature Assessment 17
Measurement of Thermal Sensation and Thermal Comfort 18
Postural Control 20
Postural Sway Assessment 25
Postural Sway and Athletic Performance 28
Postural Sway, Activity and Aging 30
Postural Sway in Cold Conditions 32
Muscle Temperature and Postural Sway 35
Stress and Stress Response 36
Physical Stress Reponses and Assessment 39
Heart Rate Variability 40
Heart Rate Variability and Cold Stress 43
Conclusion 45

3. **Chapter 3 Reliability of Centre of Pressure Measurements With The RS Scan International Footscan® Plate System during Quiet Standing 47**

Introduction 47
Balance Tests 48
Reliability 49
Rationale 50
Method 52
Participants 52
Equipment 52
Experimental Design 52
Data Acquisition 53
Data Analysis 55
Results 56
Two Feet Eyes Open Quiet Standing Balance Test 56
Two Feet Eyes Closed Quiet Standing Balance Test 58
Single Footed Quiet Standing Balance Test 60
Discussion 62
Conclusion 63

4. **Chapter 4 The Effects of Acute Cold Exposure on Body Temperature, Postural Sway Dynamics during Quiet Standing, and Heart Rate Variability 65**

Introduction 65
Method 67
Participants 67
Overall Experimental Design 67
Measurement 69
Protocol 71
Statistical Analysis 74
Results 75
Body Temperature 75
Thermal Comfort Rating 76
Heart Rate Variability 77
Two Feet Eyes Open Quiet Standing Balance Test 81
Two Feet Eyes Closed Quiet Standing Balance Test 85
Single Footed Quiet Standing Balance Test 89

Discussion 93
Body Temperature and Thermal Comfort.. 93
Heart Rate and Heart Rate Variability.. 95
Postural Control.. 97
Conclusion... 100

5. **Chapter 5 The Effects of Isolated Cooling of the Feet on Postural Control Dynamics.. 101**

Introduction... 101
Method 103
Participants... 103
Overall Experimental Design 103
Ice bath and cooling protocol... 103
Familiarisation 105
Protocol 105
Measurement.. 108
Statistical Analysis... 109
Results 110
Foot Temperature 110
Two Feet Eyes Open Quiet Standing Balance Test 111
Two Feet Eyes Closed Quiet Standing Balance Test.................................. 113
Single Footed Quiet Standing Balance Test 115
Discussion 117
Ice Bath Cooling and Skin Temperature 117
Postural Control... 118
Conclusion.. 121

6. **Chapter 6 The Impact of Active Heated Footbeds during Acute Cold Exposure on Body Temperature, Heart Rate Variability, and Postural Sway Dynamics during Quiet Standing 123**

Introduction... 123
Method 125
Participants... 125
Overall Experimental Design 125
Measurement.. 126
Protocol 128
Statistical Analysis... 130

Results 131
Body Temperature 131
Heart Rate and Heart Rate Variability 136
Two Feet Eyes Open Quiet Standing Balance Test 141
Two Feet Eyes Closed Quiet Standing Balance Test 145
Single Footed Quiet Standing Balance Test 149
Discussion 153
Body Temperature 153
Thermal Comfort 154
Heart Rate and Heart Rate Variability 155
Postural Control 156
Conclusion 159

7. Chapter 7 Conclusions and Implications 161

Validity and Reliability of Postural Control Measures 161
Thermoregulation during Acute Cold Exposure 161
Measurement of Skin Temperatures 163
Thermal Comfort 164
Heart Rate Variability as a Cold Stress Biomarker 166
The Effects of Acute Cold Exposure on Postural Control 168
Postural Control System Compensation 172
Implications and Generalizability of Results Beyond the Laboratory 175
Conclusion 176
Areas for Future Research 177

List of References 179

Appendices 193

Appendix 1 Ethical Application 193
Appendix 2 Consent and Medical Information Sheet 202
Appendix 3 Postural Sway Calculations 206
Appendix 4 Reliability Analysis 210
Appendix 5 Heart Rate Variability Study 2 233
Appendix 6 Body Temperature Study 2 241
Appendix 7 Postural Sway Analysis Study 2 248
Appendix 8 Postural Sway Analysis Study 3 288

Appendix 9 Body Temperature Study 4 304
Appendix 10 Heart Rate Variability Study 4 322
Appendix 11 Postural Sway Analysis Study 4 339

List of tables

Table 4.1 Perception of Thermal Comfort Rating Scale 70
Table 6.1 Perception of Thermal Comfort Rating Scale 127

List of figures

Figure 2.1 A simplified model of the thermoregulatory system 9
Figure 2.2 The location and morphology of mechanoreceptors in hairy and hairless (glabrous) skin 13
Figure 2.3 A schematic representation of the postural control system from a control theory perspective 22
Figure 2.4 “Independent channel” model of sensory integration in postural control showing a weighted addition of contributions from visual, proprioceptive, and graviceptive systems 24
Figure 2.5 McGrath’s process model of occupational stress 38
Figure 2.6 The ECG tracing of the RR interval divided into the P wave, PR interval, QRS complex, QT interval, ST segment, T wave, and U wave 40
Figure 2.7 Functional architecture of the human heart 42
Figure 3.1 Quiet standing balance tests: top right – two feet eyes open; top left – two feet eyes closed; bottom left – right foot eyes open; bottom right – left foot eyes open 54
Figure 3.2 Mean (SD) distance travelled (mm) by the Centre of Pressure (COP) over five trials for the two feet eyes open balance task 57
Figure 3.3 Sway rate over five trials for the two feet eyes open balance task 57
Figure 3.4 Distance travelled by the Centre of Pressure over five trials for the two feet eyes closed balance task 59
Figure 3.5 Sway rate over five trials for the two feet eyes closed balance task 59
Figure 3.6 Distance travelled by the Centre of Pressure over five trials for the single footed eyes open quiet standing balance test 61
Figure 3.7 Sway rate over five trials for the single footed eyes open quiet standing balance test 61
Figure 4.1 Overview of the experimental protocol: room temperature and –20 °C condition 69
Figure 4.2 Mean (SD) body temperature (°C) during the room temperature condition (21 °C) and during 30 minutes cold condition exposure (–20 °C) 75
Figure 4.3 Thermal comfort rating in the room temperature condition (21 °C) and during 30 minutes cold condition exposure (–20 °C) 76
Figure 4.4 Mean (SD) of the Mean RR Interval during room temperature conditions, on initial cold exposure and after 30 minutes cold exposure at –20 °C 78
Figure 4.5 Mean (SD) of the Mean RR SD (SDNN) during room temperature conditions, on initial cold exposure and after 30 minutes cold exposure at –20 °C 78

Figure 4.6 Mean (SD) of the LF (0.04 – 0.15 Hz) and HF (0.15 – 0.4 Hz) power during room temperature conditions, on initial cold exposure and after 30 minutes cold exposure at −20 °C 80

Figure 4.7 Mean (SD) of the LF/HF Ratio during room temperature conditions, on initial cold exposure and after 30 minutes cold exposure at −20 °C 80

Figure 4.8. Mean (SD) lateral sway rate in cold and room temperature conditions for both eyes open balance test 82

Figure 4.9. Mean (SD) fore / aft sway rate in cold and room temperature conditions for both eyes open balance test 82

Figure 4.10 Mean (SD) total lateral distance travelled by the COP in cold and room temperature conditions for both eyes open balance test .. 84

Figure 4.11 Mean (SD) total fore / aft distance travelled by the COP in cold and room temperature conditions for both eyes open balance test 84

Figure 4.12 Mean (SD) lateral sway rate in cold and room temperature conditions for both eyes closed balance test 86

Figure 4.13 Mean (SD) fore / aft sway rate in cold and room temperature conditions for both eyes closed balance test 86

Figure 4.14 Mean (SD) total lateral distance travelled by the COP in cold and room temperature conditions for both eyes closed balance test 88

Figure 4.15 Mean (SD) total fore / aft distance travelled by the COP in cold and room temperature conditions for both eyes closed balance test 88

Figure 4.16 Mean (SD) Lateral sway rate in cold and room temperature conditions for single footed quiet standing balance test........... 90

Figure 4.17 Mean (SD) fore / aft sway rate in cold and room temperature conditions for single footed quiet standing balance test........... 90

Figure 4.18 Mean (SD) total lateral distance travelled by the COP in cold and room temperature conditions for single footed quiet standing balance test 92

Figure 4.19 Mean (SD) total fore / aft distance travelled by the COP in cold and room temperature conditions for single footed quiet standing balance test 92

Figure 5.1 Basic laboratory sequence for both room temperature and cold conditions... 107

Figure 5.2 Mean (SD) foot temperature (°C) at room temperature (21 °C) and during the ice bath cooling cold condition.............................. 110

Figure 5.3 Mean (SD) sway rates in cold and room temperature conditions for the two feet eyes open quiet standing balance test........... 112

Figure 5.4 Mean (SD) distance travelled of the COP in cold and room temperature conditions for the two feet eyes open quiet standing balance test 112

Figure 5.5 Mean (SD) sway rates in cold and room temperature conditions for the two feet eyes closed quiet standing balance test.......... 114

Figure 5.6 Mean (SD) distances travelled by the COP in cold and room temperature conditions for the two feet eyes closed quiet standing balance test 114
Figure 5.7 Mean (SD) sway rates in cold and room temperature conditions for the single footed quiet standing balance test.................... 116
Figure 5.8 Mean (SD) distances travelled by the COP in cold and room temperature conditions for the single footed quiet standing balance test 116
Figure 6.1 Overview of the experimental protocol: room temperature, cold (-20 °C) and cold with footbeds conditions (-20 °C) 129
Figure 6.2 Mean (SD) core body temperature (°C) during 15 minutes cold condition exposure (-20 °C) with and without heated footbeds 131
Figure 6.3 Mean (SD) head temperature (°C) at room temperature and during 15 minutes cold condition exposure (-20 °C) with and without heated footbeds... 132
Figure 6.4 Mean (SD) calf temperature (°C) at room temperature and during 15 minutes cold condition exposure (-20 °C) with and without heated footbeds... 133
Figure 6.5 Mean (SD) foot temperature (°C) at room temperature and during 15 minutes cold condition exposure (-20 °C) with and without heated footbeds... 134
Figure 6.6 Thermal comfort rating at room temperature and during 15 minutes cold condition exposure (-20 °C) with and without heated footbeds... 135
Figure 6.7 Mean (SD) of the Mean RR Interval during room temperature, cold (-20 °C) and cold with footbeds conditions (-20 °C) 137
Figure 6.8 Mean (SD) of the Mean RR SD (SDNN) during room temperature, cold (-20 °C) and cold with footbeds conditions (-20 °C)........ 137
Figure 6.9 Mean (SD) of the LF (0.04 - 0.15 Hz) power during room temperature, cold (-20 °C) and cold with footbeds conditions (-20 °C).. 139
Figure 6.10 Mean (SD) of the HF (0.15 - 0.4 Hz) power during room temperature, cold (-20 °C) and cold with footbeds conditions (-20 °C).. 139
Figure 6.11 Mean (SD) of the LF/HF power ratio during room temperature, cold (-20 °C) and cold with footbeds conditions (-20 °C)........ 140
Figure 6.12 Mean (SD) lateral sway rate for both eyes open balance test in room temperature, cold (-20 °C) and cold with footbeds conditions (-20 °C)... 142
Figure 6.13 Mean (SD) fore / aft sway rate for both eyes open balance test in room temperature, cold (-20 °C) and cold with footbeds conditions (-20 °C)... 142
Figure 6.14 Mean (SD) total lateral distance travelled by the COP for both eyes open balance test in room temperature, cold (-20 °C) and cold with footbeds conditions (-20 °C)................................... 144

Figure 6.15 Mean (SD) total fore / aft distance travelled by the COP for both eyes open balance test in room temperature, cold (−20 °C) and cold with footbeds conditions (−20 °C)....................................144

Figure 6.16 Mean (SD) lateral sway rate for both eyes closed balance test in room temperature, cold (−20 °C) and cold with footbeds conditions (−20 °C) 146

Figure 6.17 Mean (SD) fore / aft sway rate for both eyes closed balance test in room temperature, cold (−20 °C) and cold with footbeds conditions (−20 °C) 146

Figure 6.18 Mean (SD) total lateral distance travelled by the COP for both eyes closed balance test in room temperature, cold (−20 °C) and cold with footbeds conditions (−20 °C)....................................148

Figure 6.19 Mean (SD) total fore / aft distance travelled by the COP for both eyes closed balance test in room temperature, cold (−20 °C) and cold with footbeds conditions (−20 °C)....................................148

Figure 6.20 Mean (SD) lateral sway rate for single footed quiet standing balance test in room temperature, cold (−20 °C) and cold with footbeds conditions (−20 °C)..150

Figure 6.21 Mean (SD) fore / aft sway rate for single footed quiet standing balance test in room temperature, cold (−20 °C) and cold with footbeds conditions (−20 °C)..150

Figure 6.22 Mean (SD) total lateral distance travelled by the COP for single footed quiet standing balance test in room temperature, cold (−20 °C) and cold with footbeds conditions (−20 °C)........................152

Figure 6.23 Mean (SD) total fore / aft distance travelled by the COP for single footed quiet standing balance test in room temperature, cold (−20 °C) and cold with footbeds conditions (−20 °C) 152

Figure 7.1 A schematic representation of the postural control system from a control theory perspective..172

Figure 7.2 “Independent channel” model of sensory integration in postural control showing a weighted addition of contributions from visual, proprioceptive, and graviceptive systems 174

Glossary

Adaptation A physiological effect where previous exposure to environmental stress results in physical functioning changes that provide performance advantages for that specific situation.

Body Temperature An objective measure of thermal status which will normal relate to a specific location or be an average of related locations, for example core temperature, mean skin temperature, or skin temperature at the temple.

Distraction Hypothesis An explanation of performance degradation in the cold due to the competing stimuli of thermal discomfort.

Familiarisation A process where participants are exposed to a protocol enough that learning does not impact on the performance of experimental tasks.

Habituation A psychological effect whereby participants are more able to tolerate environmental stress with less subjective discomfort.

Heart Rate Variability An analysis of cardiac control based on the relationship of the intervals between heart beats.

Hypothermia A condition where body temperature falls below that necessary for normal functioning.

Postural control The process of maintaining an upright position against the influence of gravity through continuous corrective movements.

Psychological Cold Tolerance The ability of cold habituated personnel to ignore thermal discomfort that might otherwise impair performance through distraction.

Somatosensory system The complex sensory system responsible for identification of physical inputs from the body including touch, temperature and position.

Stress A non-specific response to external stimuli, or stressors, that results in physiological changes in the body of an organism.

Thermal Comfort A subjective judgement based on the desirability of the thermal state in comparison to an ideal desired state.

Thermal Sensation The sensory experience related to temperature. Thermal sensation is not a value judgement or a comparison with a desired state.

Thermoregulation The process by which a homoeothermic organism maintains and regulates its body temperature even when the environmental temperature is different.

Visual Analogue Scale (VAS) A scale that represents a continuum with an upper and lower boundary rather than numbers to score phenomena such as thermal perception.

DECLARATION OF AUTHORSHIP

I, Christopher Ian Hodgson

declare that the thesis entitled

The Effects of Acute Cold Exposure on Human Postural Control

and the work presented in the thesis are both my own, and have been generated by me as the result of my own original research. I confirm that:

- this work was done wholly or mainly while in candidature for a research degree at this University;
- where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
- where I have consulted the published work of others, this is always clearly attributed;
- where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
- I have acknowledged all main sources of help;
- where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
- none of this work has been published before submission.

Signed: ……………………………………………………………………..

Date: ……………………………………………………………………….

Acknowledgements

Firstly I would like to thank the participants who took part in each of the studies in this thesis, particularly those who took part in the environmental chamber studies who were required to tolerate uncomfortable conditions. Without these contributions it would have been impossible to complete the project. I appreciate the efforts of every participant having stood alongside you in the −20 °C conditions of the environmental chamber.

I would like to thank a number of people who have worked in the laboratory with me through different phases of the project: Guy Mannering who helped collect data in study 2, Tom Shattock who helped throughout the piloting and data collection of study 3, and Sophie Hedges who helped collect data in the final study. The protocols of these studies meant that running the laboratory equipment and collecting data was a two person job and each of you put a significant amount of time and work into the project. I would also like to thank Richard Cooper for taking the photographs in chapter 3. Dr Charles Minter and Mr Phil Stephens have also provided technical support throughout the project preparing the labs and equipment.

I have had a lot of support from colleagues during the project and this has ranged from practical help to much less tangible, but equally important, social support: thank you. Finally I would like to thank my supervisors Professor Terry McMorris and Dr Neal Smith for their support and guidance throughout the project.

CHAPTER 1

INTRODUCTION

An upright posture and almost exclusively bipedal gait are one of the characteristics that human beings exhibit that distinguish them from other primates and mammals. Lovejoy (1988) describes upright locomotion as one of the top three defining characteristics of the human species along with tool use and our large brains. He suggests that our upright posture predates the expansion of the brain and was well established by three million years ago around the time of the hominid Australopithecus, the best example of which, A.L. 288-1, is known informally as 'Lucy'. He also argues that an upright posture was necessary before the development of tool use by early humans and allowed the specialisation of the upper limbs that made this possible. There are at least 12 theories as to why human beings initially developed bipedalism to this extent including the transportation of food (Hughes, 1961), changes in the environment, the advantages of an elevated eye position, to reduce sun exposure, increased travelling efficiency and to allow effective wading (Morgan, 1982). Dawkins (2004) has even suggested that it may just have been a fashion that caught on, but what is undoubtedly true is that it has allowed us to develop our hands for tool use to an unprecedented level facilitating human development something that even Darwin (1871, p. 52) acknowledged "Man could not have attained his present dominant position in the world without the use of his hands, which are so admirably adapted to the act of obedience of his will."

Bipedalism in humans comes with a cost. Standing on our hind legs is an inherently unstable posture and this means that free standing human beings undergo constant balance adjustments to maintain this position. These adjustments need to be calculated and executed effectively for us to remain upright. Human balance systems require effective and continuous sensory input, response formulation and motor execution in order to maintain an upright posture. Any impairment to this control system increases the risk of falling and associated injury. Issues such as aging (Shupert & Horak, 1999) and fatigue (McMorris, Harris, Howard, Langridge, Hall, et al., 2006) can result in significant deficiencies in the human balance systems that greatly increase this risk. Even other tasks requiring high levels of attention can reduce the effectiveness of the postural maintenance system (Donker, Roerdink, Greven, & Beek, 2007).

Mountaineering is an example of an activity where failure to maintain balance during standing and walking, even for a moment, can have potentially fatal consequences. Kirkman and Hartley (1968) reported that simple slips and trips had been attributed as the cause of the accident in 109 of 155 incidents where a cause could be identified. Goel and Addison (1992) attributed 24 out of 69 injuries to slips whilst walking. No attempt is made in the literature to establish a cause for trips and slips and falls, perhaps because it would be virtually impossible to do in many cases since a casualty is likely to be fatigued and cold by the time they are rescued even if this wasn't a contributory factor in the initial incident. It seems quite probable that cold can increase the likelihood of balance related issues in mountaineers and hill walkers and that in turn these can result in just the kind of slips and trips that end in a mountaineering accident during locomotion or during more static activities like belaying or map work.

Although there has been some interest in training the balance abilities of skiers (Mahieu, Witvrouw, Van de Voorde, Michilsens, Arbyn, et al., 2006) and ice skaters (Alpini, Botta, Mattei, & Tornese, 2009) there has been little interest in any impairments to balance abilities that operating in cold climates may elicit, or mechanisms for managing this. A study that simulated the conditions of a submarine incident found postural control differences during prolonged exposure to compound stressors including a temperature of 4 °C maintained over 5 days (Cymerman, Young, Francis, Wray, Ditzler, et al., 2002). Inspired by this study Mäkinen, Rintamäki, Korpelainen, Kampman, Pääkkönen, et al. (2005) examined postural sway during the single environmental stressor of moderate cold exposure at 10 °C and found a significant decline in performance when compared to a 25 °C reference condition. The mechanisms behind changes in postural sway were not examined in either of these studies but could include arousal levels, neurological efficiency, biochemical changes, sensory impairment and muscle efficiency.

The experimental studies within this thesis investigate the impact of cold exposure on postural control during static balance tasks. The primary aim of this thesis was to establish the impact of short term cold exposure on human postural maintenance. The second aim was to identify key processes that lead to performance changes. The third aim was to examine approaches to maintaining performance of postural control during acute cold exposure.

This work is expected to be of interest to people who are required to work or participate in athletic and stationary activities in profoundly cold conditions such as mountaineers, skiers, ski resort workers, food production and storage personnel, scientists, and military personnel. At present the thermal element of protective equipment for these activities is designed to prevent cold injuries and improve comfort for participants but there appears to have been much less interest in the contribution of thermal protection to human motor control performance. Technical performance of equipment is mainly considered to relate to ergonomics and weight.

The initial study in this thesis (Reliability of centre of pressure measurements with the RS Scan International Footscan® plate system during quiet standing) establishes the effects of practice / habituation on postural control parameters during static balance tasks. Postural control parameters were measured using a 0.5m RS Scan International Footscan® plate running through a Footscan® 3D box into a laptop PC running Microsoft Windows and Footscan® 7. The Footscan® system was selected because it is highly portable and it was expected that it could operate in the extreme conditions of the University of Chichester environmental chamber at -20 °C.

The second study (The effects of acute cold exposure on body temperature, postural sway dynamics during quiet standing, and heart rate variability) compares static balance performance at -20 °C and room temperature (21 °C) conditions. Participants completed 35 minutes of exposure in the -20 °C Cold condition. Physiological responses to the environmental stressor including core body temperature, peripheral skin temperatures and heart rate variability were measured. Subjective responses to the thermal environment were also assessed using a thermal rating scale.

The third study (The effects of isolated cooling of the feet on postural control dynamics) isolates the effect of cold feet in order to examine the singular impact of cold induced impaired tactile sensitivity on postural control. This study replicates the skin temperatures for participants' feet in the second study without the additional effects of whole body cooling. The rationale for this study was that reduced skin temperatures in study 2 indicate that a large proportion of the changes in balance performance of participants in the cold chamber at -20 °C may be due to the inability of participants to regulate their responses as skin based somatosensation may have been impaired through cooling. An adapted ice bath cooling protocol was used to reduce participants' foot skin temperatures to 10 °C during this study. Quiet standing balance tasks were identical to studies 1 and 2.

The final study (The impact of active heated footbeds during acute cold exposure on body temperature, heart rate variability, and postural sway dynamics during quiet standing) examines the use of a technological solution to the problems identified in studies 2 and 3. As study 3 had shown that cooling the feet leads to reductions in postural control performance it was decided to trial heated footbeds in the environmental chamber at -20 °C. It was expected that active warming of the underside of the feet with battery powered footbeds (Warmawear™, Meika Limited, Winnersh, UK) would help maintain performance and improve the comfort of participants in cold conditions. Actively heated clothing is a relatively new technology but may offer a very specific way of addressing the performance and safety implications of cold extremities. Study 4 compares performance at room temperature, a -20 °C cold condition and a -20 °C cold condition where low power electrically heated footbeds were used as protective equipment.

This thesis provides a significant contribution to knowledge in the following areas:

- It describes changes in postural control dynamics during short term exposure to extreme environmental temperatures much lower than the 'cold work based' environment of the existing literature.
- It establishes heart rate variability (HRV) as a potential biomarker for thermal stress during short term, whole body extreme low temperature exposures.
- It examines the efficacy of using the recent development of low output personal protective devices such as heated footbeds during extreme cold exposure to prevent thermal stress and maintain motor performance.

CHAPTER 2

LITERATURE REVIEW

This thesis examines the effects of cold exposure on postural maintenance. By necessity a project of this nature will require a multidisciplinary approach (DeLucia, 2013) that draws from a number of fields that are often studied in isolation. In this case the postural control component has involved both a biomechanical and motor control approach. The cold physical environment has required a physiological approach and the nature of thermal stress indicated that from psychophysiological element would be important (sometimes considered to be multidisciplinary in its own right). In any study of human beings under stress a cognitive approach needs to be considered as human responses are often more varied than in other species because of the cognitive processing of the individuals situation.

Because the range of academic and applied areas that might impact and explain performance changes to postural maintenance in the cold is wide it has been necessary to limit the degree to which the project can specialise in any one area. Literature on the physiological effects of cold has been limited to cold air exposure and generally excludes cooling through cold water immersion which is a common technique for applying cold stress but also creates hydrostatic loads (Šrámek, Šimečková, Janský, Šavlíková, & Vybíral, 2000). Studies of physical exercise in the cold have also been excluded as this changes the nature of cold exposure considerably; thermal homeostasis can be achieved in sub-zero air temperatures given appropriate clothing and an appropriate exercise load (Stocks, Taylor, Tipton, & Greenleaf, 2004).

A psychophysiological component has been included as biological stress markers can be effective in identifying the degree of strain that participants are subjected to (Chida & Hamer, 2008). However this has mainly been limited to cardiovascular responses and more specifically heart rate variability. Biomechanics is included but this is limited to the specific area of upright postural maintenance and associated centre of pressure measurements which are considered the gold standard for measuring this phenomenon (Hrysomallis, 2011).

Human Physiological Responses to Cold

Cold is a somewhat subjective term (Pilcher, Nadler & Busch, 2002); generally a cold environment is one that promotes a net heat loss from the human body. In cold air environments exposure to air at 5 °C or less is often described as cold but depending on clothing and activity level that environment could be comfortable or even result in overheating (Parsons, 2003; Stocks et al., 2004). Cold stress occurs when the surrounding environment threatens the body's ability to maintain normal body temperatures (Cappaert, Stone, Castellani, Krause, Smith, et al., 2008). Cold stress initially produces severe discomfort and eventually can lead to falls in body temperature (Parsons, 2003). Reduced core body temperature (hypothermia) can be very serious and potentially fatal if unchecked (Cappaert et al., 2008; Wilkerson, 1992). Localised cooling of peripheral body tissues can lead to freezing or non-freezing cold injuries. Parsons reported normal core body temperature (rectal) as 37.6 °C. At 36 °C the metabolic rate increases in order to compensate for heat loss and 33 °C indicates severe hypothermia. Human thermoregulation in the cold is so effective that any fall below 36 °C should be regarded as severe. Heat is lost from the human body through conduction, convection, radiation and evaporation (Draper & Hodgson, 2008) and normally the human body is able to regulate core temperature within one degree.

When exposed to a cold environment an early response is vasoconstriction which reduces blood flow to the skin and as a result reduces heat loss by radiation and convection (Wilkerson, 1992). Charkoudian (2010) describes this response as the first line of defence against cold environmental stress. There are two key mechanisms at play controlling vasoconstriction / dilation: the sympathetic noradrenergic vasoconstrictor system and a non-noradrenergic active vasodilator system (Nakamura & Morrison, 2011). Displacing blood from the peripheral systems and reducing blood flow in the cutaneous vessels delays the cooling of deeper tissues (Stocks et al., 2004). Extremities including the hands and feet contain specialised organs, arterio-venous anastomoses, which constrict up to three times a minute in thermoneutral conditions but remain closed during cold stress reducing heat loss instantaneously (Stocks et al., 2004). Blood flow to the head is affected very little by vasoconstriction. Cutaneous vasoconstriction is a key thermoregulatory response in humans because of our relatively hairless skin (Morrison & Nakamura, 2011). Pilo erection is a further heat loss response which is effective in fur covered animals and is still present in humans, however the raising of goosebumps does not result increased insulation in man as there is insufficient body hair to provide an effective insulative layer (Draper & Hodgson, 2008).

Metabolic heat production can be increased in order to maintain homeostasis; a process known as thermogenesis (Stocks et al., 2004). Heat production is initially achieved through asynchronous firing of muscle fibres that results in increased muscle tone (Draper & Hodgson, 2008) but if this is not effective then the synchronous firing of muscles at 10 – 12 Hz known as shivering will occur (Parsons, 2003). Reduced skin temperatures are the initial trigger for thermogenesis but core temperature plays a greater role in determining the magnitude of the response in humans (Stocks et al., 2004). During intense shivering metabolic process can be increased up to five times that expected at rest and 40% of $VO_{2\ max}$ (Haman, 2006). Thermogenesis occurs primarily in three tissues: brown adipose tissue, cardiac muscle, and skeletal muscles (Morrison & Nakamura, 2011). Morrison and Nakamura report that cardiac thermogenesis may result in increased heart rates during cold stress.

Cold induced vasodilation (CIVD) is a further response where after vasoconstriction has taken place vasodilation can occur and this can become a cyclical process, particularly likely if temperatures fluctuate around 12 °C (Parsons, 2003). This cyclical response, sometimes known as ‘the hunting reaction’ (Draper & Hodgson, 2008), is claimed to offer some advantages for maintaining motor functioning in the cold and offer some protection to the extremities but at the expense of retaining core temperature and in some environments such as cold water immersion it can actually reduce survival times. The extent to which the CIVD response is seen during cold exposure has been debated and despite early writers suggesting it was a very common phenomenon (Daanen, 2009) recent research has suggested conditions need to be very specific for CIVD to occur (Flouris & Cheung, 2009; Van der Struijs, Van Es, Raymann, & Daanen, 2008). Van der Struijs et al. report that CIVD is much less common in air cooling conditions than during cold water immersion. Daanen also suggests that still air (devoid of wind-chill) is even less like to provoke this response. Researchers such as Flouris and Cheung consider CIVD to be a response to core body temperature increases during cold exposure, for example during exercise when the body can sacrifice some thermal energy to rewarm peripheral tissues.

The control centre for thermoregulation is generally accepted to be the hypothalamus (Parsons, 2003). The hypothalamus not only contains a thermal sensor in its own right but integrates information from internal sources such as medulla, spinal cord and other sources as well as signals from peripheral thermal sensors in the skin (McIntyre, 1980). This results in an integrated response where systems don't compete against each other (seen in figure 2.1). Information on environmental temperature is collected by cutaneous thermal receptors in the skin (Morrison & Nakamura, 2011). Morrison and Nakamura also report that thermoreceptive mechanisms also exist in core body structures such as the brain (preoptic area), spinal cord and abdomen and these provide information about homeostatic function and core temperature maintenance. Responses are believed to be coordinated by the hypothalamus and there is some evidence that even muscular responses such as shivering are a result of hypothalamic control of supraspinal premotor neurons (Nakamura & Morrison, 2011). Nakamura and Morrison (2011), and Sawasakia, Iwasea and Manoa (2001), report that responses such as vasoconstriction and brown adipose tissue thermogenesis are communicated through the sympathetic nervous system.

Overt physical exercise can produce additional heat but in fact in many cases it also increases overall heat loss (Stocks et al., 2004). This effect is due to two key factors: increased contact with cold air or water and increased peripheral blood blow. Physical exercise effects are generally out of the scope of this thesis which examines static exposure. Parsons (2003) remarks that historically investigations into cold stress have had military and expedition based influences but that there is an increasing interest in indoor application such as large scale food storage plants.

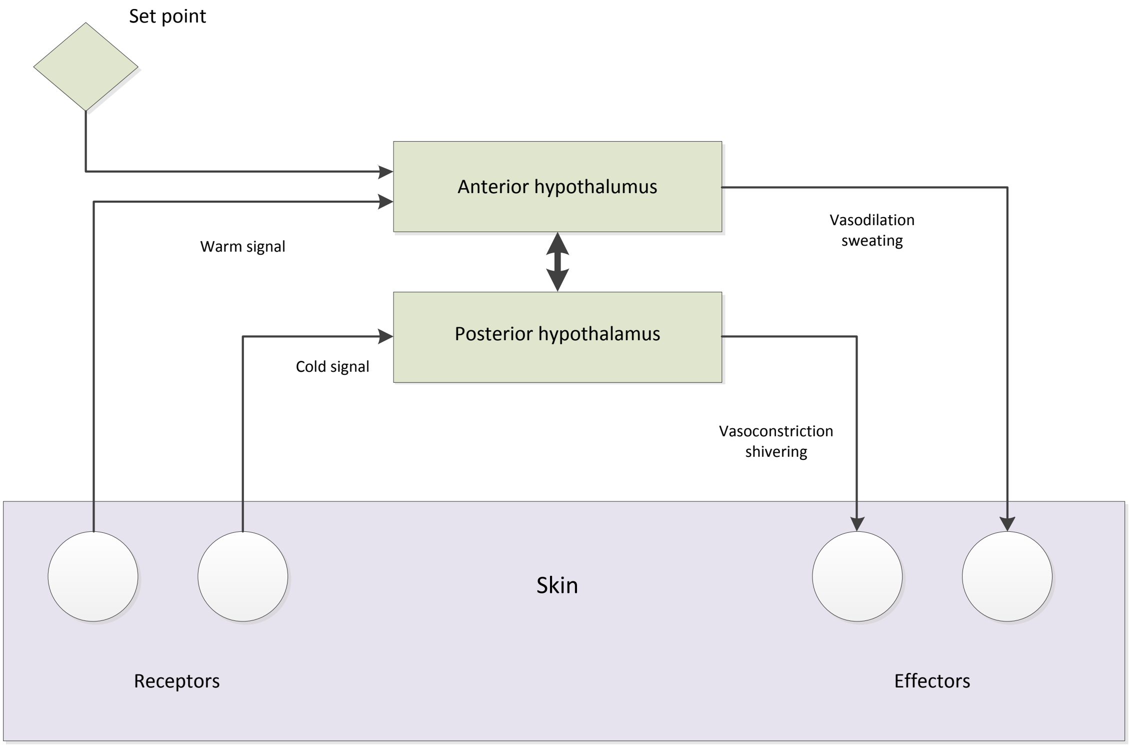


Figure 2.1. **A simplified model of the thermoregulatory system.**

Note. Adapted from D.A. McIntyre, (1980). *Indoor Climate.* London: Applied Science.

Performance in the Cold

Performance in the cold has often been divided into separate categories depending on the task (Ellis, 1982). Typically studies target either mental performance, psychomotor performance, or physical (exercise) performance. Of course in many applied tasks reality these areas interact.

Mental and cognitive performance

Teichner (1958) was the first researcher to examine mental performance in cold conditions in a formal experiment. Reaction times were measured in 620 military personnel who completed tasks in one of 14 different sets of climatic conditions consisting of combinations of cold and wind. The most extreme conditions were at -37 ° C and 32 kph. The men were dressed in clothing described as ‘appropriate’ and performed a number of tasks including a bout of ‘mild exercise’. Teichner concluded that reaction time (measured at 45 minutes and 65 minutes) was not affected by low temperatures in the study but did decay in a linear manner in response to wind chill. Teichner believed that performance impairment was due to the competition between stimuli and that the environmental stressor produced stimuli that reduced attention on the primary task. He coined the term ‘distraction hypothesis’ to explain this phenomenon.

Cold stress has been shown to impair performance on a range of tasks whilst having little or no effect on others (Ellis, 1982). Ellis suggests that the nature of the task has a critical impact on the influence of cold stress. During two related studies Ellis tested participants’ ability to complete serial choice reaction time tests, simple reaction time and the Stroop word colour test whilst exposed to a temperature of -12 °C in an environmental chamber. Participants were seated during the exposure and wore only a pair of shorts. No significant differences were found when compared with performance at a comfortable room temperature although absolute scores were worse during the cold exposure. For example Stroop test completion time increased from 91.0 seconds to 113.4 seconds in the cold condition but the P value remained higher than 0.05 (no exact values were provided). Performance on a verbal reasoning test was slightly improved in the cold with response scoring better for accuracy when compared with the pre cold control. Six participants completed a total of 90 minutes and eight participants completed 120 minutes of exposure time during the studies. Skin temperatures fell during the initial phase of cold exposure but core temperatures were maintained for an initial period before dropping later in the exposure; exact timings for this were not provided in the report. A key problem with these studies were the low sample sizes which mean that changes of a magnitude that may be meaningful were not statistically significant and it is quite possible that the non-significant results are an example of a type 2 error, power and effect sizes would have been useful in allowing the reader to make this judgment.

Ellis (1982) discusses the results of the study in terms of two different cold induced effects. The first is that cold stress impacts on arousal levels and therefore can be associated with performance changes. The second is that cold stress is a distractor and this distraction effect is likely to reduce task performance. Differences in the way tasks are affected in the cold would come down to the interaction of these cold induced effects with the specific task demands. Ellis, Wilcock and Zaman (1985) reiterated the arousal and distraction hypothesis in a later study that included analgesic medications as an intervention and cooling at -5 °C and +8 °C. In the -5 °C condition they found a statistically significant difference for serial choice reaction time with 8 options. Error rate was increased in the cold condition. Participants in this study were seated during the exposure and wore shorts and socks. In their summary Ellis et al. suggest that the kind of fast cooling that occurs during exposure at -5 °C results in arousal changes that impact on performance whilst longer periods of slow cooling at +8 °C do not result in the same level of arousal changes.

Rammsayer, Bahner, & Netter (1995) studied 30 male volunteers in a protocol involving 35 minutes exposure in an environment cooling from 28 °C to 5 °C and 20 minutes exposure at 5 °C then a further 35 minutes rewarming to 28 °C. Participants were dressed in swimming trunks and seated throughout. Core temperatures were measured in the auditory canal with a thermistor placed against the tympanic membrane. Rammsayer et al. reported a 0.5 °C drop in core temperature and a slowing in response time indicative of impaired information processing. Simple reaction time was not impaired and so it was concluded that the impairment was in processing response not stimulus acquisition.

Palinkas (2001) reviewed the literature on cold and cognition. Long term effects have been noted during field studies but as Palikas has pointed out these tend to have a large number of uncontrolled factors and in any case long term effects are out of the scope of this thesis. In terms of the short term exposures that experimental studies have employed Palinkas reiterates two hypotheses for non-hypothermic studies. The first is the distraction hypothesis. The second is arousal effects where participants can become quicker but make more mistakes. Palinkas points out that it is hard to disentangle these effects in studies but also suggest s a further hypothesis that in fact both these explanations may just be to ways of viewing the same effect.

Motor performance

Enander (1989) suggests that in general cold impairs performance on physical and motor tasks suggesting a critical skin temperature for hands and fingers of 8 – 10 °C for tactile sensitivity and 12 – 15 °C for manual dexterity. Enander suggested that slow cooling is actually more detrimental to performance than rapid cooling even when the hand skin temperature was equivalent but offered no real explanation for this effect. Skin temperature has been shown to be a poor predictor of muscle temperature in the cold (Jutte, Merrick, Ingersoll & Edwards, 2001). It may be that rapid cooling results in surface tissue cooling but less deeper tissue cooling and that slower cooling produces a more consistent effect where deeper tissues are cooled to a greater degree.

Muscular cooling may be a significant inhibitor of performance in many tasks and Oksa (2002) reports that strength is impaired in human muscle for isometric contractions at temperatures of 27 °C and below. Oksa considers decreased muscle temperature to be the most important factor in determining the degree of impairment due to cold exposure. For dynamic tasks the impairment may be even earlier and Bergh and Ekblom (1979) showed decreasing jump performance with calf muscle temperatures of 31.0 °C and 29.5 °C. Bergh and Ekblom suggested that muscular strength was reduced by 2% for every degree that muscle temperature dropped. Increases in blood lactate in cooled muscle have been interpreted as impaired aerobic performance due to a slowing rate of glycolysis (Doubt, 1991). This could limit performance where heavy exercise and cold conditions are found together, however this is unlikely to provide a mechanism for postural control in the studies in this thesis. Doubt also reports that when muscles are already cooled in advance of activity then their ability to warm through exercise is reduced. This may have performance implications for participants who take part in intermittent activities in the cold or who are exposed to cold in advance of exercise.

Tactile Sensation and Temperature

A significant source of sensory information for postural control is thought to be acquired by the pressor receptors (mechanoreceptors: figure 2.2) in the glabrous (hairless) skin of the soles of the feet (Magnusson, Enbom, Johansson, & Pyykkö, 1990; Magnusson, Enbom, Johansson & Wiklund 1990; Stål, Fransson, Magnusson & Karlberg, 2003). Meissner's corpuscles are responsible for sensitivity to light touch and are more common in the skin of the hands and erogenous zones (Vega, López-Muñiz, Calavia, García-Suárez, Cobo, et al., 2012). Rapid adapting receptors (Pacinian corpuscles) are thought to contribute foot strike input and the slower adapting Merkel cells and Ruffini endings are thought most likely to contribute to postural control (Stål et al., 2003). These slow adapting cutaneous mechanoreceptors are considered an important part of the somatosensory stem that contributes to postural control (Kennedy & Inglis, 2002) providing information about the distribution of pressure through the feet.

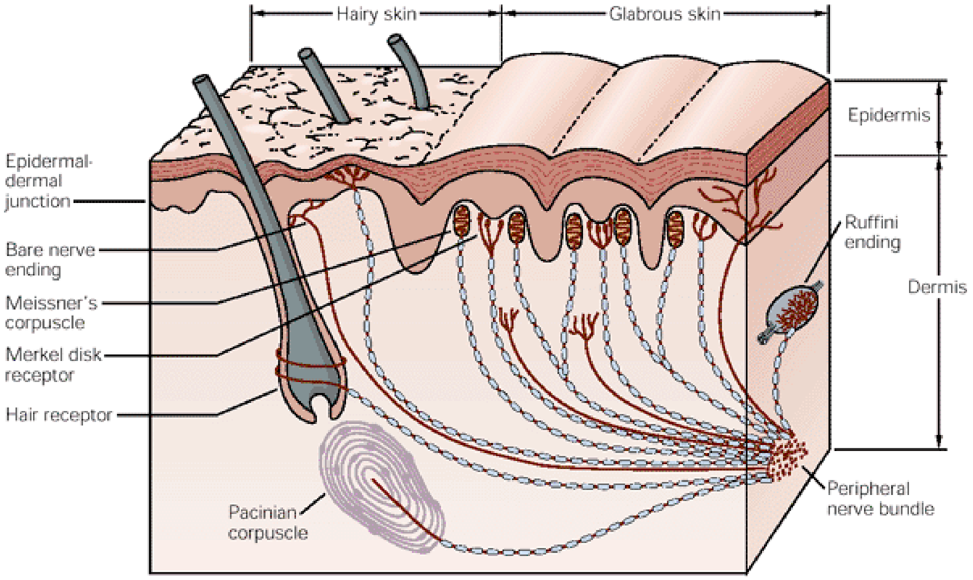


***Figure 2.2.* The location and morphology of mechanoreceptors in hairy and hairless (glabrous) skin.**

Note. From E.R. Kandel, J.H. Schwartz, T.M. Jessell, S.A. Siegelbaum, and A.J. Hudspeth, 2012, *Principles of Neural Science.* New York: McGraw-Hill Medical.

There is surprisingly little research on the effects of cold exposure on tactile sensation. Gescheider, Thorpe, Goodarz, and Bolanowski (1997) examined the effect of skin temperature on tactile sensation. They used a protocol that employed vibration at 250 Hz applied through a 3 cm^2 probe. Skin at 30 °C had the lowest detection threshold with both 20 and 40 °C requiring a greater difference between stimuli for discrimination. Clearly skin temperatures of 30 °C are significantly higher than might be expected in extremities during cold exposure but may be realistic in the room temperature conditions and so skin temperatures may be a critical factor for physical task performance in the cold.

Magnusson, Enbom, Johansson, and Pyykkö (1990) did not report measuring tactile sensitivity at all during their study of the effects of cooling the feet on postural control dynamics. In a further study Magnusson, Enbom, Johansson and Wiklund (1990) reported that participants' feet were insensitive to pain touch and temperature after immersion for 20 minutes in water at 3 °C but did not report exactly how this was established.

In their study on the effects of hypothermic anaesthesia of the feet Stål, Fransson, Magnusson & Karlberg, (2003) tested 16 participants' feet after 10 minutes of cooling in ice water they reported to be at a temperature of 0 °C at the onset of cooling. Skin temperatures were reduced to 14 °C. They tested pain susceptibility in the soles of the feet using a blunt needle. They reported that 14 of the participants showed a decrease of pain sensation after 20 minutes of cooling. Four of the participants were tested for sensation loss using vibration and a two-point touch sensation test. Vibration sensation was reduced with detection thresholds increased by between 310% and 800%. The two-point discrimination scores, however, were not significantly affected by cooling.

Tactile sensation has been of interest to a number of researchers (Magnusson, Enbom, Johansson, & Pyykkö, 1990; Magnusson, Enbom, Johansson & Wiklund 1990; Stål et al., 2003) from a postural control perspective. Assumptions have been made about sensation based on skin temperatures alone however other studies (Magnusson, Enbom, Johansson & Wiklund 1990; Stål et al, 2003) have made some attempt to quantify loss of sensation however these have tended to have limited success. It doesn't appear that any study has really been able to concretely establish the effects of cold on the slower adapting Merkel cells that are considered most likely to contribute to standing postural control (Kennedy & Inglis, 2002; Vega et al., 2012).

Adaptation and Habituation to Cold

Enander (1989) remarks that often opportunities to avoid or modify the environment are limited, and raises the question as to what degree it is possible to train human beings to withstand the effects of the cold environment. Enander remarks that physiological adaptation to heat is widely accepted but that physiological adaptation to cold exposure is more ambiguous. The main physiological compensatory mechanisms during cold exposure are cardiovascular responses; vasoconstriction in the peripheral extremities redirects blood flow and reduces heat loss (Enander & Hygge, 1990) and so blood flow responses have often been examined in adaptation studies.

Reynolds, Mekjavic, and Cheung (2007) investigated the thermal responses of the feet during repeated cold exposures in ten participants. The participant's left feet were cooled in water at 8.0 °C for 30 minutes on 15 days over three weeks. The main objective was to explore the potential for training to improve physiological responses to cold exposure; a process they refer to as acclimation. The authors reported that the toe temperatures at the end of the immersions were close to the water temperature throughout the 15 sessions at 8 – 11 °C. The authors concluded that thermal adaptation was not evident and that cold induced vasodilation is not a particularly trainable response. They also remarked that vasodilation of the feet as a protective response to the thermal stressor of cold water immersion is not actually a common response.

Daanen, Koedam, and Cheung (2012) conducted a study to examine the impact of repeated cold exposures on cold induced vasodilation of fingers and toes of sixteen participants. The rationale for the study was that humans who have to function in environments where exposing the extremities to the cold is necessary might benefit from a response that maintains dexterity. For 15 days over three weeks participants completed 30 minutes of cold water immersion of the right hand and foot in a bath of water at 8.0 °C. Data were collected on day 1 and day 15 and on those days both hands and both feet were immersed for 30 minutes. For half the group the immersion of the left hand and foot was before the right hand and foot and for the other have this was reversed in a counterbalanced design.

The temperature of the untrained hand and foot did not differ between day 1 and day 15. The temperature of the trained hand and foot did show a change over time. The fingers of the trained hand showed a significant decrease in temperature whilst three of the toes of the trained foot showed an increase in temperature of approximately 0.5 °C (middle fourth and little toe). Pain reported during cold water immersion reduced in both hands and feet for the trained and untrained side. Tactile sensitivity of the fingers did not change over the 15 days – no data for the sensitivity of the toes were presented.

Dannen et al. (2012) concluded that repeated cold exposure could result in a modest improvement in blood flow to the toes. Participants experienced less discomfort to cold when they were habituated to the cooling protocol and the authors warn that this could pose problems if people become less aware of their thermal status but do not adjust their behaviour.

Familiarity with cold exposure can produce an effect that Glaser, Hall and Whittow (1959) referred to as habituation and defined as a reduction in the intensity of pain or sensations due becoming accustomed to the stimuli. Psychological habituation may include changes in thermal sensation or increased ability to ignore the distracting thermal stimuli due to familiarity with a cold environment (Enander, 1989). Enander reports that increased performance on manual tasks can be demonstrated without any measurable physiological changes being evident when participants become familiar with cold exposure. In a comparison of ten office workers and ten workers used to a refrigerated environment whilst there were no significant physiological differences the workers occupational exposed to cold reported less cold sensation and less pain in a test where they were required to immerse their hands in cold water at 10 °C for two minutes (Enander, Skoldstrom, & Holmer, 1980). There were no task based performance measures in this study.

Carman and Knight (1992) examined cold induced pain over 9 days and 38 participants received 5 cryokinetic cold applications to the right ankle each day and on one day 5 applications to the left ankle. They found that the sensation of pain reduced over repeated days but not applications on the same day. Most changes occurred over the first 5 days and the authors concluded that a habituation effect occurs with repeated cold treatments that make them easier to tolerate. Unsurprisingly patents treated with 0 °C water reported more pain than those treated with 5 °C water. These findings indicate that there may be a small habituation effect in terms of sensation of pain that would be evident in studies with repeated bouts of cooling on different days but not if bouts of cooling were on the same day. Since attention control and distraction effects have been used to explain cognitive performance changes in the cold (Palinkas, 2001; Teichner, 1958) habituation effects where participants become less susceptible to thermal discomfort could result in improved performances.

Leppäluoto, Korhonen, and Hassi (2001) studied the effects of cold air exposure at 10 °C for two hours each day for 11 days. Six men completed the study and were dressed in shorts during the cold exposures. They found that thermal sensations became significantly less intense after the first and second exposures, an effect they referred to as habituation. There were some significant differences between days for skin temperature (chest, forearm and mean temperature) but most sites were not significantly different including the cheek, calf, instep and forefinger. The main finding was that thermal sensation became less intense with experience of the exposure protocol which the authors concluded was an improvement in thermal comfort and could lead to advantages for those who work in cold environments.

It seems that repeated exposures to cold may reduce our subjective cold sensitivity but physiological responses that improve performance are very limited. Tasks that are impaired mainly by distraction effects may benefit from the reduced attention / awareness that habituation allows but those impaired by physiological processes including reduced tactile sensitivity are unlikely to show any training effects. Anecdotally familiarity in real world environments can appear to offer performance improvements. It is highly likely that a key factor here is the behavioural changes that come with improved competence at working within a real world cold environment (Enander, 1989).

Body Temperature Assessment

Although not universally supported the most widely accepted standard for measuring core body temperature is the use of rectal thermometers (Casa, Becker, Brown, Yeargin, Roti, et al., 2007). Mazerolle, Ganio, Casa, Vingren, and Klau (2011) reviewed 16 studies and report that there are a limited number of reliable and valid methods to measure core body temperature and these are rectal, oesophageal, pulmonary and ingested devices. Whilst clinicians often prefer to take oral temperatures because they are less invasive these, along with auditory canal temperatures, have been shown to be quite inaccurate in many cases (Casa et al., 2007). Rectal temperature devices and ingestible thermometers have been shown to provide accurate core body temperatures for resting and exercising participants (Casa et al., 2007; Moran & Mendal, 2002).

Mazerolle et al. (2001) were most concerned about situations where body temperature was changing. Critically when this was the case then oral temperatures lagged an average of 0.58 °C behind the change in rectal temperatures taken as the reference standard. Most of the data on temperature measurement comes from studies examining hyperthermia inducing conditions but the few studies that consider cooling conditions as well support an even more cautious approach to the use of oral temperatures as the effect of cold air inhalation appeared to cause additional problems with the validity of oral temperature measurements (Doyle, Zehner, & Terndrup, 1992; Livingstone, Grayson, Frim, Allen, & Limmer, 1983).

Assessing peripheral body temperatures is normally achieved by making direct measurements of the appropriate body segments (Van der Struijs, et al., 2008). Thermistors or thermocouples are the most common method employed because they offer a combination of accuracy and convenience. Thermistors are taped to the skin so that multiple measurements, or even continuous monitoring, of temperature at the same site can be made during a protocol (Todnem, Knudsen, Riise & Aarli, 1989; Daanen et al., 2012). Taping thermistors or thermocouples to the skin has been used as an effective way of measuring skin temperatures in air or water (Van der Struijs, et al., 2008). Van der Struijs et al. used thermocouples to measure skin temperatures of fingers and toes during localised cooling with two conditions; 30 minutes of cold air exposure at −18 °C, and 30 minutes of water immersion cooling at 5 °C. Reynolds et al. (2007) successfully used thermistors taped to the skin of the feet to measure temperatures in their study of cold induced vasodilation responses described earlier. In practice either thermistors or thermocouples appear to be able to provide acceptable skin temperature data during exposure to environmental thermal stress.

Measurement of Thermal Sensation and Thermal Comfort

Extreme thermal environments have a great impact on human thermal comfort and behavioural responses (Parsons, 2003). That said humans differ greatly in their individual responses (Enander & Hygge, 1990) and Parsons remarks that research into the psychological effects of thermal environments is still in its infancy. Thermal sensation and thermal comfort are terms that at times are used somewhat interchangeably with researchers like Leppäluoto et al. (2001) deriving conclusions about comfort from thermal sensation scores. From this viewpoint thermal comfort is essentially the lack of uncomfortable thermal sensations (Parsons, 2003). This model can work well for participants undertaking light or sedentary activities (ASHRAE, 1997). Other researchers such as Zhang, Huizenga, Arens, and Wang (2004) have used separate scales for thermal sensation and comfort. Thermal sensation is considered to be a non-judgmental feeling of thermal status such as neutral, cold, or very cold, and can be strongly influenced by activity and other physiological phenomenon (Brager, Fountain, Benton, Arens, & Bauman, 1993). Thermal comfort is often defined as a person's degree of satisfaction with their thermal environment or condition (Fanger, 1973). Zhang et al. used a nine point scale ranging from very cold (-4) to very hot (+4) to evaluate thermal sensation and a second nine point scale ranging from comfortable (+4) to very uncomfortable (+4) to evaluate thermal comfort. Their argument is that this a better approach for changing environments or where activity levels are varied; in these circumstances thermal sensation and comfort can have a more complex relationship than in steady-state tasks and stable environments.

As comfort is related to how people think about their individual subjective experience it is difficult to calibrate an effective tool for appraising thermal comfort; Parsons (2003) comments that the search for a definite tool has continued for more than 100 years. Fanger (1970) states that three conditions must be met for a person to be in thermal comfort; the body is in heat balance, sweat rate is within a comfortable limit, and mean skin temperature is within comfortable limits. Other issues such as differences in localised thermal sensations and global sensations mean that there is no single standard measure for thermal perception instead there are a number of different scales. Hensel (1981) suggested a nine point scale ranging from painfully cold to painfully hot, 5 being a neutral condition. The Bedford (1936) and ASHRAE (1966) scales both have 7 levels of sensation with comfortable or neutral as level 4. Another approach to rating thermal comfort is the use of a ten point visual analogue scale where the limits and midpoint of the scale are defined: 0 = "the coldest you've ever been;" 5 = "neutral, neither cold nor warm;" and 10 = "the hottest you've ever been" (Frank, Raja, Bulcao, & Goldstein, 1999) but participants can roam within the continuum rather than select categories. This approach has been used by researchers who argue that participants are able to respond in a manner more akin to ratio data rather than the ordinal data typically generated by categorical scales (Price, Bush, Long, & Harkins, 1994).

Some researchers, such as Starr, Houle, and Coghill (2010), actually use pain rating scales rather than thermal sensation scales to measure the sensory impact of heat or cold on participants.

Parsons cites McIntyre (1980) in remarking that on a practical basis thermal comfort scales all seem to produce similar ratings from subjects in similar conditions. In that case it might seem that a nine point scale such as that used by Hensel (1981) or Jendritzky, Maarouf, and Staiger (2001) will offer more discrimination particularly during studies where effectively half of the scale becomes redundant as we are working in one direction from comfortable / neutral through to very cold. Unlike perception of effort scales which tend to work from no stress upwards thermal comfort scales have a neutral point in their centre and in the vast majority of thermal stress studies this means that only half of the rating scale is actually in use. McIntyre has criticised scales like the Bedford scale because in his view they confuse thermal comfort and thermal sensation, however Parsons (2003) view is that participants are actually quite able to rate comfort on these scales if it is made explicit that it is comfort that they should attend to.

Postural Control

Postural control is the ability to maintain a chosen position despite internal and external disturbances (Jáuregui-Renaud, 2013). It is important for any locomotive organism but particularly so for one that stands upright. Mancini, Salarian, Carlson-Kuhta, Zampieri, King, et al. (2012, p. 59) outline the importance of upright postural control; “Postural control is the foundation of our ability to stand and to walk independently.”

Ragnarsdóttir (1996) explains that the terms postural control, balance and equilibrium are used as synonyms for the same concept and that they all refer to the mechanism that the human body uses to prevent itself from falling or losing balance. Massion (1994) describes the functions of the postural control system to be twofold. Firstly the body has to be positioned in a manner that allows it to resist gravitational forces and ensure that balance can be maintained. The second function is to fix the orientation and position the body segments which are required to serve as a reference for perception and action in relation to the outside world. Effectively there is a strategic planned positioning process and a reactive regulation process that utilizes multisensory inputs to maintain position during disturbances and voluntary movements.

Johansson and Magnusson (1991) identify three main systems as being involved in postural control and maintenance; the skeletal, sensory and neuromuscular systems. Postural maintenance is a dynamic process involving sensory input from somatosensory, vestibular and visual subsystems. Responses are organized in the central nervous system and executed by the locomotor subsystems. All of these systems are required to continually interact for the process of postural control to be effective. As can be seen in figure 2.3 this is a continuous cyclical process. The simple act of quiet standing actually requires a surprisingly complex sensorimotor control system and the integration of multiple sources of sensory information (Peterka, 2002).

Although the term static balance is often used in describing the processes behind standing postural control in fact it is misleading because human beings are required to make constant corrective movements to maintain upright standing. Dynamic balance as a concept has also been criticized because it is used to cover a very broad range of situations (Ragnarsdóttir, 1996). Instead Berg (1989) suggests it is more useful to view balance as an umbrella concept with demands on a spectrum ranging from postural control during involuntary movements through to postural control during voluntary movements on a moving support surface. Ragnarsdóttir suggests an advantage of this approach is that it is possible to challenge the motor skills of an individual to a variable degree of our choice. Postural control whilst standing upright on a stationary base is towards the lower end of this spectrum. Narrowing the base of support (for example by standing on one foot) increases the task demand as does removing a source of sensory input (like restricting vision), on the other hand task demands can be lowered by looking at supported postures like sitting (Ragnarsdóttir, 1996).

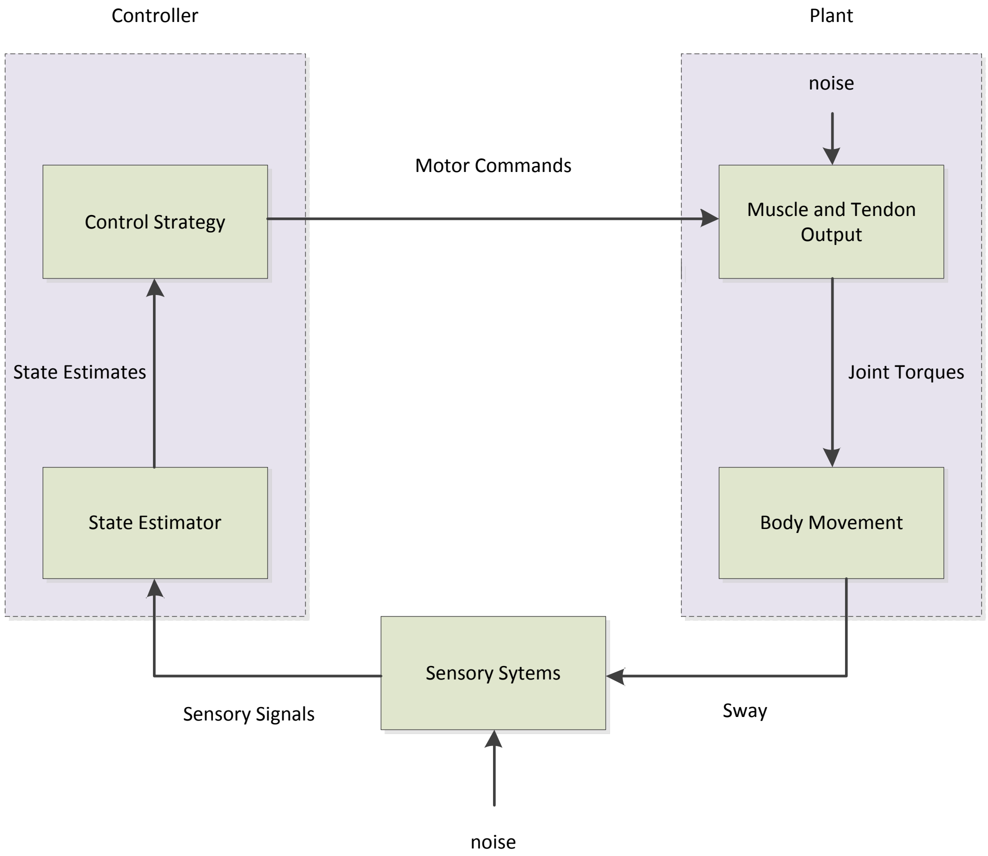


Figure 2.3. **A schematic representation of the postural control system from a control theory perspective.**

Note. From M.D. Binder, N. Hirokawa, and U. Windhorst (Eds.), 2009, *Encyclopedia of Neuroscience.* New York: Springer.

The vestibular system is particularly important in postural control and is responsible for establishing the orientation of the head relative to the earth's gravitational field and any acceleration or rotation of the head (Carpenter, Allum & Honegger, 2001). The vestibular organs of the inner ear consist of three orthogonal sets of semicircular canals that measure how the head rotates in three-dimensions. In addition are two otolith organs (the utricle and saccule) that measure linear acceleration and how the head positioned relative to gravity. Unlike most senses human beings are normally unaware of the contribution of the vestibular system because information is processed almost exclusively unconsciously (Green & Angelaki, 2010). This information is integrated with proprioceptive information and the visual feed to provide a contextualized picture of our position in space. Peterka (2002) refers to 'sensory channel reweighting' and describes how the source of sensory information contributing to postural control can be shifted to account for environmental effects a process referred to as sensory channel weighting. The independent channel model of sensory integration (figure 2.4) is an explanation of how the postural control system can prioritise sensory information based on its relevance and reliability in particular environmental, organismic and task conditions.

Swift (1984) defines physiological postural sway as the process of continuous corrective movements around the centre of gravity of a body designed to maintain postural control in the upright position whilst standing still. Horak (1987) describes the process of postural control as one of maintaining or returning the centre of body mass over the base of support. Small continuous adjustments are made mainly by ankle based movements, when larger corrections are necessary then movements at the hips are employed. This postural sway motion is viewed as a key indicator that researchers and clinicians use to evaluate the effectiveness of the postural control system in generally healthy adults who are able to maintain an upright standing position. For greater balance upsets than postural sway can accommodate stepping or hopping movements may be made to realign the base of support under the centre of mass.

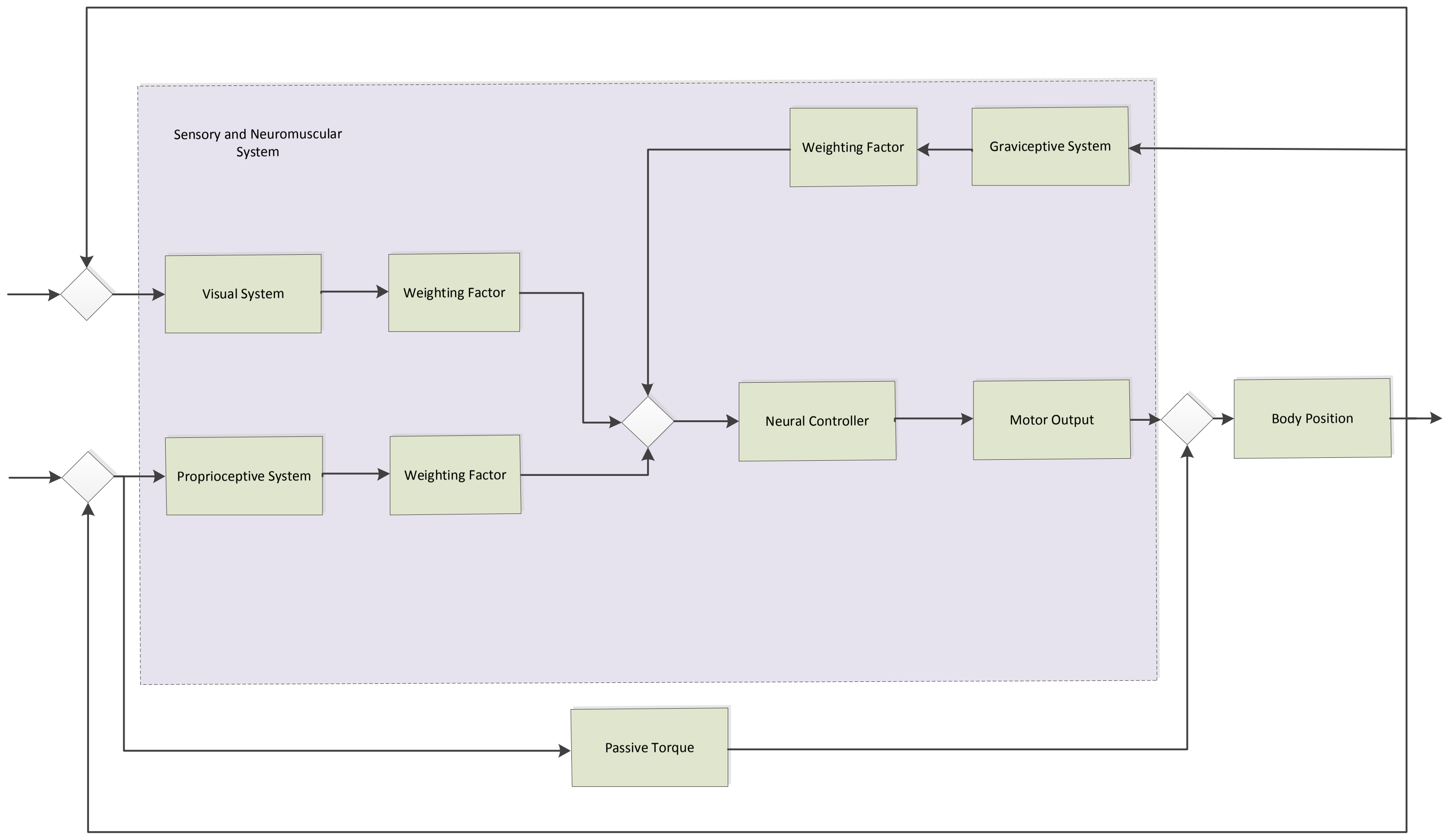


Figure 2.4. **"Independent channel" model of sensory integration in postural control showing a weighted addition of contributions from visual, proprioceptive, and graviceptive systems.**

Note. Adapted from R.J. Peterka, 2002, Sensorimotor Integration in Human Postural Control, *Journal of Neurophysiology, 88,* 1097–1118.

Postural Sway Assessment

Mancini et al. (2012) report that the most common way to evaluate postural control in the clinic is to use observation based clinical rating scales such as the Balance Evaluation Systems Test (BESTest) validated by Horak, Wrisley and Frank (2009). They criticise this approach because of limitations caused by individuals using the rating scales and on the basis of low sensitivity to mild impairments. They describe this low sensitivity problem as a ceiling effect but in fact the sensitivity problem may well exist on all points of a rating scale approach not just the top end of the scale. They go on to argue that these limitations of ratings scales along with poor reliability are serious concerns for any researchers who might want to determine intervention efficacy or treat people with mild balance deficits.

Mancini et al. (2012) suggest that the most common approach to assessing postural control in a more scientific manner is to use force plate analysis of centre of pressure (COP) displacement during static balance (quiet stance) tests. They report that experimental studies have successfully demonstrated the sensitivity of COP measures to postural disorders such as Parkinson’s disease and to the risk of falls in elderly populations. Their main criticism of the force plate centre of pressure (COP) approach is that the equipment is too expensive and impractical for clinical use.

Other approaches to postural control assessment include accelerometer based system such as those proposed by Whitney, Roche, Marchetti, Lin, Steed, et al. (2011) and Mancini et al. (2012). The main reason for using this approach is that it is relatively inexpensive in comparison to force plate based systems. Although this approach is promising and gaining evidence in terms of validity and reliability the force plate analysis of centre of pressure movement appears to remain the gold standard (Hrysomallis, 2011).

Time of day and performance

Time of day has been shown to have an effect on performance in a range of physical and mental tests. Gribble, Tucker and White (2007) examined the influence of time of day on static and dynamic postural control. Thirty participants attended six sessions over a 48 hour period. Each day testing took place at 10:00, 15:00 and 20:00. Static balance tests involve eyes open and eyes closed conditions in a unipedal stance on the participant's preferred leg. Dynamic postural control was assessed through the anterior reach in a task known as the Star Excursion Balance Test (SEBT). Centre of pressure velocity was used as the dependant variable for X and Y axes. Lower velocities were taken as indicative of better performances.

Only the static balance testing is relevant to the current study. The results of the two day protocol showed a confused picture with the best performance on day 1 being in the morning (10:00) and the worst performance in the afternoon (15:00). Performance improved through day 2 with the worst performance being recorded in the morning (10:00) and the best performance in the evening (20:00). Overall it appears that performance improved over the period of the six tests for sway in the anterior – posterior direction but not the lateral direction. Performance in the eyes closed condition was always worse than in the eyes open condition and this factor did not appear to interact with time of day or day. Despite exploring the possibility that a learning effect contributed to these results the authors were reluctant to commit themselves to this explanation. They accepted that they had not conducted any familiarisation for the static balance tests although they had included familiarisation training for the SEBT. Gribble et al. (2007) conclude that there may be a time of day effect on postural control and that this should be considered in research design. It also seems prudent to consider some familiarisation for static balance tests.

Attention

It has been established that maintaining difficult postures can impair performance on tasks such as reaction time to visual or verbal stimuli. When more attention is required to maintain posture then it seems there is less left for other tasks. By implication then we might expect that if attention is diverted away from postural control this could reduce performance of this process. Donker, Roerdink, Greven and Beek (2007) studied the influence of attention on the performance of postural control. Thirty participants completed bipedal balance tests with eyes open and closed conditions and with and without a cognitive task. Each participant completed the tasks in a randomised order. A significant difference for sway path distance was found between the eyes open and closed conditions without the cognitive task. A significant difference was also found between the eyes closed single task and the eyes closed dual task conditions. Stability variables indicated worse performances in the eyes closed conditions and that dual task effects resulting in impaired postural control were more likely in the eyes closed condition.

Donker et al. (2007) used a data analysis tool that included outputs such as entropy curves and measures of deterministic chaos. They used this information to make assumptions about the amount of attention being invested in postural control. These data suggest that when eyes are closed more attention is actively directed towards postural control but when a task acts as a distraction then this ability to direct extra attention is lost.

Donker et al. (2007) viewed eyes closed tests as a way to shift attention to an internal focus. Whilst removing sources of external sensory information may increase the proportion of internal focus employed by participants it seems highly likely that it would have other detrimental effects on performance that might overshadow the attentional focus element. Indeed other authors treat eyes closed balance conditions as a form of sensory deprivation requiring compensation (Stål et al., 2003). This would mean that drawing hard conclusions about the effects of attentional switching alone from eyes closed balance tests would be a bold step.

Cognitive performance in the cold has been of interest and a number of researchers have concluded that attentional processing can be the main component in performance degradation (Palinkas, 2001; Teichner, 1958). Studies that induce hypothermic conditions (Rammsayer, Bahner, & Netter, 1995) with reduced core temperatures show more consistent effects. Rammsayer et al. concluded in their study of 30 male volunteers that reduced core temperatures (-0.5 °C) actually impair information processing and that this is independent of attentional effects. However it appears that poor attentional control and increased distractibility (effectively the same thing) can occur with non-hypothermic core temperatures (Palinkas, 2001). Teichner (1958) was the first researcher to come to this conclusion and introduced the terms ‘distraction hypothesis’ and ‘psychological cold tolerance’ which could be increased in habituated personnel. His view was that the effect was attributable and dependent on the perceived signal strength of thermal discomfort in relation to other sensory inputs.

Postural Sway and Athletic Performance

A key aspect of this project is the intuitive link between better postural control and better athletic performance. Unfortunately it generally is not really possible to show this link within individuals so the literature in this area has typically involved a comparison of groups either comparing athletes from sports with differencing balance demands or comparing performers of different levels of achievement within the same sport. Hrysomallis (2011) reviewed the literature surrounding balance related components in order to establish links between balance ability and athletic performance. Centre of pressure (COP) motion for a fixed period of time was the most prevalent laboratory test and also considered the gold standard. Minimal COP motion was considered indicative of a good performance and studies employed both bipedal or unipedal tests and eyes open and shut conditions.

Gymnasts are the most studied group of athletes in balance research. As Hrysomallis (2011) suggests this may because there is an intuitive link between the requirements of gymnastics and balance ability. Gymnasts have typically shown the highest levels of postural control during static balance tests of all the groups that have been studied and this has been attributed to the task demands of gymnastic training.

Soccer players have been the group tested against other athletes the most. Soccer players have been found to score less well than gymnasts on dynamic balance measures but similar on static balance tests. Bressel, Yonker, Kras and Heath (2007) tested the static balance of eleven collegiate soccer players, eleven basketball players and twelve gymnasts in two footed and unipedal balance tests. They concluded the basketball players displayed inferior static balance when compared to the gymnasts but that there were no differences between soccer players and gymnasts. They argue that the sport demands of gymnastics and soccer, which both require participants to balance on one leg, resulted in a balance training effect not seen in basketball. This study relied on judgements made by observers using a Balance Error Scoring System (Riemann, Guskiewicz & Shields, 1999) rather than COP measurements so it may be that small differences between football players and gymnasts may have been present but not detected.

Hrysomallis (2011) reports that athletes from a range of sports have tested as superior to control groups on balance tests even when there is no sport specific rationale for this effect. They offer the example of swimmers, who would never practice anything that might be regarded as a balancing task. However in a comparison of swimmers, soccer players, basketball players and a non-athletic control group by Matsuda, Shinichi and Masanobu (2008) only the soccer players displayed superior balance ability to the control group (established using COP measurements). A limitation of this study was that it only examined unipedal stances which theoretical may highlight specific adaptations of the soccer players. Swimmers did perform better than the control group in Davlin's (2004) study of dynamic balance on a stabilometer platform with gymnasts performing better than swimmers and soccer players. Whilst the stabilometer offers a quite limited balance test the Davlin study did benefit from considerably larger group sizes of (58 – 70 participants per sport) than employed in many postural maintenance studies.

Despite the intuitive expectation that more proficient athletes would display higher levels of postural control if this appears to be a component of their activity there are a range of studies (Hrysomallis, 2011) that fail to show this link. Alpine skiers and judo players have shown no link between performance level attained and postural maintenance data (Noe & Paillard (2005)). Noe and Paillard found no difference in balance abilities of national and regional level ski racers when ski boots were worn for testing but actually found that regional level skiers displayed better balance when tests were carried out without ski boots. They suggested that wearing ski boots had had a detrimental effect on the unshod balance abilities of the national level racers. This explanation might seem plausible at first but the reality is that elite ski racers spend a lot of time on non-skiing conditioning activities that we might expect to condition the ankles; a point made more generally about athletic preparation by Hrysomallis. Another way of interpreting the results is that the elite skiers have learned a very sport specific form of postural control when constrained in ski boots that does not result in a generalized improvement in performance on other balance tasks; this hypothesis was employed by Chapman, Needham, Allison, Lay and Edwards (2008) to explain why surfers can perform relatively poorly on particular balance tasks but well on others. One argument made to explain the lack of differences is that the requirement for postural control has already acted as a filter on athletes in these activities during the early stages of participation (Hrysomallis, 2011). Another is that the tests used in research do not discriminate between athletes in a manner relevant enough to the sports performance characteristics of the activities (Hrysomallis, 2011). In rifle shooting, soccer and golf elite athletes have scored better in balance tests than less proficient performers. Hrysomallis neither reports nor offers any convincing explanation for the differences in research findings between sports with apparently similar balance demands.

Paillard, Margnes, Portet and Breucq (2011) studied postural sway in two groups of surfers during eyes open and eyes closed conditions. Eight surfers were local level and nine were national or international level competitors. They established that the higher ability surfers were able to maintain their posture more easily than the lower ability surfers during the eyes closed condition. The higher level surfers also displayed better postural control during the eyes open condition. The authors concluded that postural sway was connected to the sporting ability of the participants but also that higher level athletes could shift their sensorimotor dominance from vision to proprioception more effectively. Strangely Chapman et al. (2008) concluded that it was impossible to distinguish between expert and recreational surfers on static postural control tests in their study of 21 elite surfers, 20 intermediate surfers, and 19 control participants. However they did suggest that the surfers were better able to manage the demands of a simultaneous mental task and postural control task.

Postural Sway, Activity and Aging

This project examines impairment of postural control. The group studied most often in this regard has been aging populations and those with medical conditions that lead to impaired postural control. It may be that these processes give an insight that helps explain the effects that we observe during cold exposure.

Postural sway is considered to give an indication of overall muscular control and Frank, Zhou, Bezerra and Crowley (2009) examined the postural sway characteristics of a group of 11 long term surfers and an age matched group of physically active non-surfers. They found that the long term surfing group showed less postural sway than the control group when standing with eyes closed on a soft surface. Their conclusion was that recreational surfing over a long period can provide benefits in neuromuscular function that may lead to improved quality of life in older populations. The implication here is that practice can maintain or even improve postural control abilities.

Shupert and Horak (1999) question the assumption that falls in the elderly can be attributed to similar causes. They argue that postural control can fail for a number of different reasons and that this means that simple exercise based interventions aim at fall prevention may be misdirected. Shupert and Horak identify that postural control is impaired if individuals experience losses in sensory function (delaying response time), impaired central nervous system function (resulting in poor response) or in muscular strength (limiting the effectiveness of response). They reviewed two different neural pathologies on postural control loss of somatosensation in the feet (due to diabetes) and patients with Parkinson’s disease who experience problems due to muscular control issues.

Although the specific ailments of the sample in the Shupert and Horak (1999) review are quite different the mechanisms behind the impaired postural maintenance functioning reflect possible mechanisms behind decrements in performance among healthy participants in the cold environment. Impaired somatosensory function resulted in slow response onset times and poor response scaling to postural upsets. Parkinsonian subjects showed reduced ability to adapt to the situational demands of postural upsets.

Shupert and Horsak conclude that the results of poor postural control may look similar in terms of falls or injuries but that the mechanisms behind this impairment can be quite different. They go on to suggest that generalised interventions might be of very limited impact in reducing the consequences of poor postural control. The implication is that to reduce the effects of poor postural control we need to specifically target the mechanisms behind the impairment and this message seems likely to be equally valid when considering performance in cold conditions.

Postural Sway in Cold Conditions

Mäkinen, Rintamäki, Korpelainen, Kampman, Pääkkönen, et al. (2005) examined changes in postural sway at 25 °C and 10 °C. They tested 10 healthy male volunteers who had no known hypersensitivity to cold. Participants were exposed to 2 hours of cold each day for 10 consecutive days whilst clothed in shorts, socks and athletic shoes. Mäkinen et al. don't report what participants were during between tests in the cold exposure condition but there was no exercise load. Postural sway assessments were made on days 1, 5 and 10. Performance at 25 °C was measured after 90 minutes in a controlled temperature environment which was then followed by the cold exposure (10 °C). Postural sway assessment was carried out 90 minutes into the cold exposure period. Postural sway was measured for 1 minute using a mechanical mechanism to transmit movements at the sacrum to an inclinometer. Computer software was then used to convert this information into a path for this area of the body at a resolution of 0.5mm and 25 Hz.

Mäkinen et al. (2005) reported that postural sway was greater at 10 °C than at 25 °C. Path length increased 62 – 87% (eyes closed) and 51 – 65% (eyes open), total sway area increased 42–67% (eyes closed) and 10 – 49% (eyes open), and velocity increased 63 – 71% (eyes closed) and 50 – 64% (eyes open). Muscle tonus was assessed through EMG activity of m. pectoris. Muscle tonus was 140 – 260% greater in the 10 °C condition and an undisclosed number of participants displayed visible shivering. There were no significant changes to muscle tonus during the series of repeated cold exposures. Mäkinen et al. found that some postural sway elements decreased during the 10 day trial but these changes seemed greater at 25 °C than at 10 °C. Only mean side to side movement reduced in the cold condition whereas at 25 °C there were reductions in sway area, mean path length, mean forward–backward movement and mean side to side movement.

In addition to postural sway skin temperature measurements were made at forehead, upper back, chest, abdomen, upper arm, lower arm, back of hand, anterior thigh, dorsal side of foot and calf. Subjective perceptions of thermal sensation and comfort were assessed using a 9 degree judgement scale (ISO 10551). Cold related thermal sensations became less intense ($P < .05$) during the 10 day period but thermal comfort changes were not significant. Mean skin temperature at 10 °C was significantly greater on days 6 and 10 when compared to day 1.

Mäkinen et al. (2005) concluded that postural sway in their participants increased after 90 minutes of exposure to temperatures of 10 °C but that relative increases in postural sway were greater in the eyes open condition than with eyes closed. Whilst performance improved during the 10 days of acclimatisation to the cold condition it also improved at 25 °C and this was explained as an effect of motor skill learning independent of temperature. It was suggested that it may have been better to establish a plateau for performance on the balance task before starting the experimental phase. They also observed that some participants appeared to be able to temporarily suppress shivering responses in order to maintain performance on the balance task and this observation was supported by EMG amplitude data. Mäkinen et al. suggested that impairments in postural control may be due to changes in sensory functioning or neuromuscular control and that the mechanisms related to impairments were in need of further investigation.

Magnusson, Enbom, Johansson and Pyykkö (1990) examined the importance of mechanoreceptors in the soles of the feet for anterior-posterior postural control. Thirteen participants completed testing during two conditions: a control condition, with feet at room temperature, and an experimental condition in which participants' feet were cooled with ice water for 20 minutes. Pseudorandom vibration was used to stress the postural control system in both conditions and testing was completed with no vibration and with vibration at 20, 40, 60, 80 and 100 Hz. Vibration was administered through devices attached directly to the gastrocnemius muscles of both legs by elastic straps and amplitude was 0.4 mm for all frequencies.

Magnusson, Enbom, Johansson and Pyykkö (1990) reported that body sway velocity, measured on a force platform, was greater in the feet anaesthetized by cold condition both during eyes open and eyes closed testing. Significant differences were found in all the eyes closed conditions and in eyes open no vibration and 20 Hz vibration. Magnusson, Enbom, Johansson and Pyykkö tested for differences between eyes open and eyes closed conditions for change in body sway velocity and concluded that there were significant differences between conditions and that the increase in body sway velocity was greater for the eyes closed condition. This finding initially appears contrary to that of Mäkinen et al. (2005) however closer examination of the statistics reveal that significant differences only occurred with vibration at, or above, 40 Hz. Also, whilst Mäkinen et al. discussed relative increases Magnusson, Enbom, Johansson and Pyykkö compared absolute change values. This makes it difficult to confidently conclude that the two studies had conflicting results.

Magnusson, Enbom, Johansson and Wiklund (1990) completed a second study that examined cold effects on lateral postural control. Body sway values were larger in the hypothermic feet condition and participants' ability to adapt to the induced disturbance was reduced. They reported that the increases in sway were greater in the lateral aspect than they had measured in the anterior-posterior plane of the first study. It was concluded in both studies that the mechanoreceptors of the feet make a significant contribution to human postural control. The implication is that impairment of the mechanoreceptors of the feet, through medical disorders or environmental factors, could lead to relatively poor postural control performances in a range of settings.

Stål et al. (2003) examined the effects of ice bath cooling on adaptive postural control. Sixteen participants completed quiet standing postural control tests where their equilibrium was disrupted through vibration. They found increased torque variance in the initial period after vibration was applied during the ice bath cooled condition. Increases in torque were greater in eyes closed postural control tests. Stål et al. reported that skin temperatures of the feet were reduced to 14.0 °C during the cooled condition but rose to 17.8 °C by the end of the postural control tests. No attempt was made to maintain the temperature of the water in the foot bath which was reported as 0 °C at the beginning of the protocol. The researchers explained that they felt that adding ice or fresh cooled water during the protocol would result in further drops in skin temperature. Although there was a clear decline in balance abilities when vibration was initially applied the authors remarked that they expected the changes to be larger than those exhibited in the study. It was concluded that cold induced anaesthesia of the feet and the corresponding reduced sensitivity of mechanoreceptors in the skin of the feet can lead to increased risk of balance disturbance and even falling when a person is subjected to an unpredictable postural upset.

Muscle Temperature and Postural Sway

Dewhurst, Riches and De Vito (2007) examined the impact of changes in muscle temperature on postural sway. They tested nine young (22 ± 3 years) and nine old (73 ± 3 years) women in three different temperature conditions. The participants in this study completed all testing during a single laboratory session. Control trials were performed first then warm and cool trials were performed in a counterbalanced manner.

Cooling was achieved through the use of an ‘ice blanket’ consisting of large plastic sacks filled with crushed ice. Warming was achieved through the use of an electrically heated blanket. Both blankets covered the whole of both legs from the gluteal furrow to the foot. A 3 °C temperature change from the control condition was achieved in both cold and warm conditions and muscle temperature was monitored throughout testing to ensure that this temperature change was maintained. Muscle temperatures were 31.3 ± 0.3 °C in the cold condition, 37 ± 0.1 °C in the warm condition, and 34.2 ± 0.2 °C in the control condition.

Postural sway was measured during quiet standing in the Romberg position and a modified Tandem position. Trials were conducted with eyes open and eyes closed and the visual conditions were administered in a randomised order. Spectacles were worn if required and a visual target was placed 2 m in front of the participant’s eye level. Data were collected using a piezo-electric force platform at a sampling frequency of 100 Hz. Centre of pressure was then used to calculate root mean square (RMS), mean velocity (MV), sway area (SA) and mean power frequency (MPF). Data were analysed using a temperature condition x eye condition x age repeated measures ANOVA for Romberg and Tandem stances.

Significant differences were reported for age and eye condition. There were significant effects for age for RMS, MV, SA and MPF for both stance conditions with the older group scoring greater values. There were also significant differences for eye condition with greater RMS, MV and SA values in the eyes closed condition during both stance conditions. The MPF values were also greater ($P < 0.05$) during the Romberg stance trials. Dewhurst et al. (2007) found no temperature related differences in postural stability for either group during their study. It seems that a muscle temperature of 31 °C (a drop of

3 °C from room temperature) is insufficient to provoke a change in the balance abilities of participants. In fact Oksa (2002) reports that muscle performance during isometric exercise is stable or even mildly enhanced until a critical muscle temperature of 27 °C is reached after which maximum voluntary contraction is impaired. Oksa, Ducharme and Rintama (2002) found that coordination losses with sub-normal muscle temperatures result in increased rate of fatigue (in forearm muscles) even with low level work loads of 10% of maximal voluntary contraction. It may be that reduced muscle temperatures could result in impaired postural control when muscle temperatures in the lower limbs drop below 27 °C.

Stress and Stress Response

Selye (1956) was the first writer to use the term in a psychological context and described stress as a non-specific response to external stimuli, or stressors, that results in physiological changes in the body of an organism. Selye was most concerned with how an external event affects the internal state and his breakthrough was that different stressors can produce very similar responses. He referred to this response as General Adaptation Syndrome. Selye identified that stress could be positive or negative and introduced the terms eustress (positive) and distress (negative) to discriminate between the two. Selye viewed stress as a direct response to external events and so the actual intensity of the stressful stimuli was very important in determining the magnitude of the response. Mason (1975a, 1975b) challenged this cause and effect view and claimed that stress occurs as a result of a perceptual process. Mason’s view was that it is not so much the actual intensity of the external stressor but more the intensity of the perceptions that this stressor invokes that results in the stress response. An individual who perceives a situation or task as being novel or unpredictable, or one that they are unable to control will become stressed. Selye and Mason both viewed stress as being on a continuum from no stress to high stress, however in everyday language stress has come to mean high levels of distress.

McGrath (1976) proposed a process based model (figure 2.5) that includes three aspects; the perceived demands, the perceived ability of the individual to cope with the demands, and the perceived consequences of failing to cope with the demand. McGrath suggests that subjective stress is a result of a mismatch between the individual's perception of the situational demands and perception of their ability to cope with those demands accompanied by a perception that coping is important by the individual concerned. The model is often viewed as a cycle because the behavioural outcomes are likely to impact on the environmental situation and therefore the perceived environmental demands. Behavioural outcomes are also a key source of information (feedback) about the individual's capacity to cope with the on-going task demands. Many researchers approach stress as a linear cause - effect relationship (Stokes & Kite, 2001). A key element of McGrath's process based model is that human stress responses involve choice (Jex, 2002). Individuals in similar situations may see different possibilities for action and make different choices. In a cold climate someone may choose to initially respond by increasing exercise levels, whilst another may improve the arrangement of their clothing, or even try to escape by finding shelter. Each of these choices would lead to different behaviours which in turn changes the outcome. Each possible outcome creates a slightly different situation which feeds back into the perceived situation, through the cognitive appraisal process, and further response selections. Decision making and associated behaviours can be seen as a result of a continuous interaction between individuals, the environmental constraints, and their goals (Araujo, Davids, & Hristovski, 2006).

Stokes and Kite (2001) have proposed that in reality we need to view stress as a transactional effect. The transactional model views stress an interaction between external stimuli and individual differences and responses. The characteristics of the stressor and the characteristics of the individual will combine to create a, to some extent, unique set of responses. Stress can be a response to a psychological challenge, a physiological load or threat, or a combination of the two. In fact Stokes and Kite indicate that there are not really any pure psychological or physiological stressors and that, in terms of human beings, the response is always to a lesser or greater extent a combination of the two. In turn the outcomes of stress inducing situations can be both psychological and physiological. Stokes and Kite argue that we should be careful not to define stress in terms of the responses it provokes as these will to some extent be individualised. They list behavioural, cognitive and affective changes as key outcomes of the stress process.

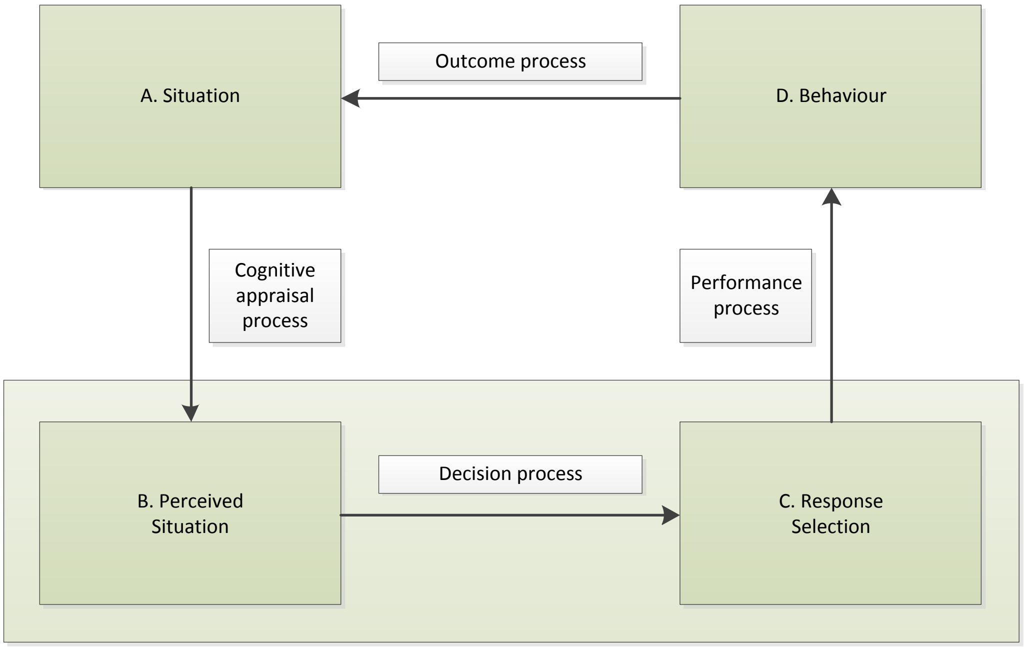


Figure 2.5. **McGrath's process model of occupational stress.**

Note. From J.B. McGrath, 1976, Stress and Behavior in Organizations, In M.D. Dunnette (Ed.) *Handbook of Industrial and Organizational Psychology* (pp. 1351-1396) Chicago: Rand McNally.

Researchers and clinicians normally break the umbrella term of stress into acute stress and chronic stress (Miller & Smith, 2013). Acute stress is a response to a short term situation in the recent past present or anticipated in the close future, for example an immediate physical threat (Contrada & Baum, 2011). Acute stress can be thrilling and exciting or performance debilitating but it is a short term experience and in itself is not a health risk (although the stressors that cause it can present physical dangers). Chronic stress is a prolonged experience due to long term or lifestyle pressures. Contrada and Baum point out that acute stressors can lead to chronic stress if exposure recurs on a regular basis. This can result in a semi-permanent change in psychological and physiological functioning. Chronic stress can have a profound effect on physical health but it is outside the scope of this project.

Physical Stress Reponses and Assessment

Typical physiological responses to acute stress include measurable and repeatable changes to cardiac, autonomic and neuroendocrine functioning (Chida & Hamer, 2008). Childa and Hamer reviewed 729 papers for a meta-analysis on stress responses. A key conclusion of the analysis was that different stressors are likely to have different levels of effect on different stress markers and that a much stronger response can be shown if the 'right' outcome measure is selected. The methodology of data collection and its interaction with other protocol constraints should also be considered; the example cited is Heart Rate Variability (HRV) measurements would be compromised by the breathing requirements of a public speaking task. Another example of this may be the impact of taking blood samples on the level of stress that a participant perceives during a protocol.

Neuroendocrine responses of the Hypothalamic-Pituitary-Adrenal (HPA) axis such as cortisol or adrenocorticotropic hormone (ACTH) were used as a marker in 5.2% of the studies. Biochemical stress markers can be effective in providing support for acute stress responses but these tend to be either invasive in the case of blood plasma samples (Pollard, 1995) or if urine samples are taken are more effective for longer term stress responses (Fröberg, Karlsson, Levi & Lidberg, 1972). Salivary cortisol sampling overcomes some of these problems (Kirschbaum & Hellhammer, 1989) but is still relatively expensive in a study where it is not a primary component given the requirement for processing multiple samples for each point of analysis.

Skin conductance level was used as a marker in 5.5% of studies (Chida & Hamer, 2008). A key advantage of this technique is that it is non-invasive. However it seem highly unlikely that it would be a valid measure during a stress study involving temperature manipulations as stress responses are likely to be masked by thermoregulation responses and so it fails one of the key tests suggested by Chida and Hamer: that the measure needs to be unaffected by the other aspects of the protocol.

Cardiovascular system responses were used as a marker in 77.3% of the studies and HRV in 3.7% of the studies. Although Childa and Hamer (2008) treat these as separate outcomes data acquisition for heart rates (the most commonly used cardiovascular measure) can also result in data that allows variability analysis with little increase in complexity and no real changes to experimental protocols. It is also a non-invasive technique that doesn't suffer from the expense of biochemical analysis.

Heart Rate Variability

HRV is a collection of measures that examine the variance in the beat-to-beat cycle (also known as RR intervals as seen in figure 2.6) of the cardiac cycle; RR intervals are the times between two successive R-wave events (Barbieri, Matten, Alabi, & Brown, 2004). A key aspect of the analysis is assumptions about the balance between the cardiac sympathetic and vagal efferent activity (Crawford et al., 1999). Cardiac rhythm is controlled through internal mechanisms within the heart but variations of the heart rate are as a result of autonomic nervous system control (Lopes & White, 2005).

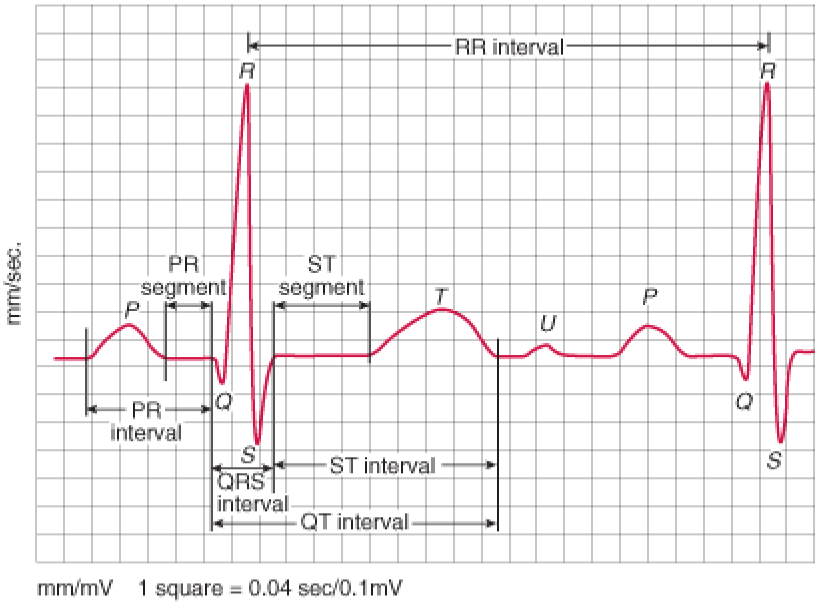


***Figure 2.6.* The ECG tracing of the RR interval divided into the P wave, PR interval, QRS complex, QT interval, ST segment, T wave, and U wave.**

Note. From *The Merke Manual*, By R.S. Porter and J.L. Kaplan, 2010, USA: Merck Sharp & Dohme Corp. Copyright 2010 by Merck Sharp & Dohme Corp.

Measurement of Heart Rate Variability

RR interval recording can range from 30 RR intervals to 24 or even 48 hours. Short term recording is viewed as records from 2 minutes to a few hours. The minimum period of recording recommended by the European Society of Cardiology is 5 minutes. The sampling rate for RR recording is usually 1000 Hz (Lopes & White, 2005). Some filtering of the digitized data is often required because of errors in recording or noise. Problems can occur due to technical artefacts that can include missing or additional QRS complex detections or errors in R-wave occurrence times (Tarvainen & Niskanen, 2012). Typically a visual inspection of data and bandpass filter (a filter with a high and loss pass component) might be used to eliminate anomalous recordings outside of the 0.5 to 50 Hz cycle range (Blascovich, Vanman, Berry Mendes, & Dickerson, 2011). This process can eliminate noise from power sources, muscular activity, or movement (Tarvainen & Niskanen, 2012).

Analysis of Heart Rate Variability

Analysis of HRV has often been performed using a time domain analysis approach (Malliani, Lombardi, & Pagani, 1994). This means examining the Mean RR interval and the Standard deviation of the RR interval (SDNN). Calculating these measures is straightforward and the level of assumptions about the meaningfulness of the output is low. Generally lower variation (lower SDNN values) are associated with a system under higher levels of stress (Delaney & Brodie, 2000).

Frequency domain analysis breaks up the interval spectrum into classes in order to examine the contribution of sympathetic and parasympathetic function to overall cardiac control (Lopes & White, 2005). The very low frequency (VLF) component (< 0.04 Hz) is considered to represent fluctuations that occur very slowly such as circadian rhythms. The low frequency (LF) component is thought to represent sympathetic activity (known informally as the fight-or-flight system) and is the frequency band between 0.04 Hz and 0.15 Hz. However, there is some controversy over how well it can be used as an index because this component may also include a small element of parasympathetic activity (Malliani et al., 1994; Lopes & White, 2005). Malliani et al. (1994) report that despite this controversy in their studies the LF component of heart rate does increase as a result of mental stress.

The high frequency (HF) component (between 0.15 Hz and 0.4 Hz) is considered an indicator of parasympathetic innervation of the sinoatrial node of the heart (figure 2.7) through activation of the vagal nerve. This activity generally results in a reduction in heart rate and there is strong support for its use as a marker for this effect (Malliani et al., 1994; Lopes & White, 2005). This element is the least controversial of the frequency domain analysis components. It is informally known as the rest-and-digest system.

The LF/HF ratio has also often been viewed as an index of sympathovagal modulation of the sinoatrial node. Again this has sometimes been questioned because of the potential problem with parasympathetic activity contributing to the LF component that is supposed to represent sympathetic activity (Lopes & White, 2005).

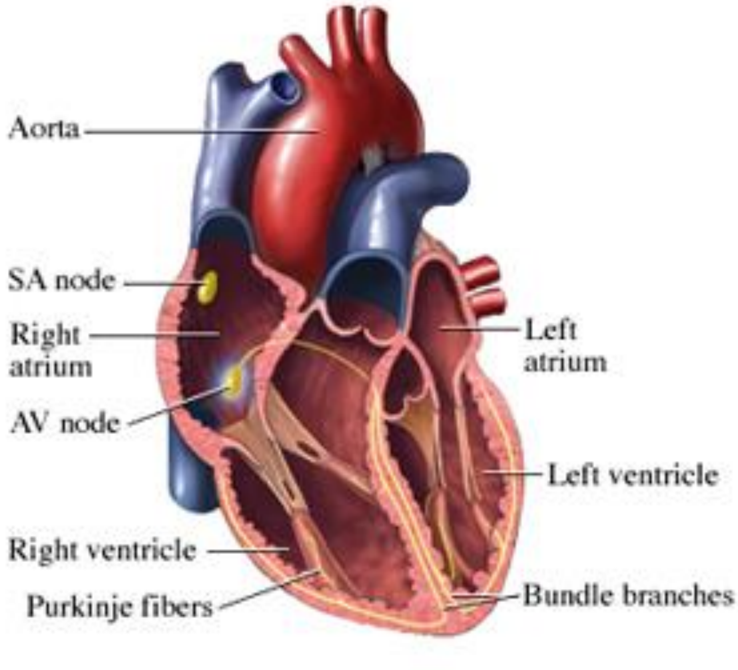


Figure 2.7. **Functional architecture of the human heart.**

Note. Copyright © Nucleus Medical Media, Inc.

Heart Rate Variability and Cold Stress

Matsumoto, Miyawaki, Ue, Kanda, C Zenji, et al. (1999) examined the effects of 10 °C cold air exposure on 12 obese and 12 non-obese women. The women complete 15 minute exposure at 25 °C then 10 °C whilst dressed in T-shirts and shorts. Participants were seated quietly throughout their exposures. Heart rate decreased significantly (approx. 8 beats·min^{-1}) during the cold exposure in both groups. HRV measures included LF and HF power. There was a significant increase in LF power for the non-obese group and a significant increase in HF power for both groups (exact values not provided). Matsumoto et al.'s conclusions were mainly regarding the differences in response between obese and non-obese groups but their study did demonstrate HRV response to cold air exposure.

Yamazaki and Sone (2000) examined the effects of thermal stress on cardiac control. They heated and cooled 15 participants using a specially constructed suit that incorporated tubes through which water could be flushed at a controlled temperature. Participants completed both conditions on different days and each stress phase was preceded by a control phase (normothermic condition) with water at approximately 35 °C. The order of the conditions was randomised. In the hot condition the water introduced to the suit during the stress phase was at 45 °C and in the cold condition the water was at 10 °C.

A number of cardiac measures were used in the study including heart rate and the frequency domain variability measures of LF power, HF power and LF/HF ratio. Heart rate was reduced ($P < .05$) from 61.2 ± 2.5 beats·min^{-1} in the control condition to 56.5 ± 2.1 beats·min^{-1} in the cold condition. During the cooling condition LF and HF power was increased ($P < .05$) which could indicate increased sympathetic and parasympathetic activity, but there was no change in the LF/HF ratio. Exact values for the frequency domain variables were not provided in the paper.

Huang et al. (2011) examined the changes in HRV during heat and cold stress. They had 60 participants complete two conditions. In one condition participants immersed their left hands into water at 45 °C and in the other they immersed their left hands in water at 7 °C. Participants rested for 20 minutes prior to the immersion and the last part of the 20 minutes was used to collect 'control' data. Huang et al. report that the tests were conducted with a 10 minute rest period in between the two conditions and all participants appear to have been tested in the heat condition first. HRV variables including RR intervals, LF, HF and LF/HF ratio were calculated. Both LF and HF were seen to increase in the cold test condition. LF/HF ratio decreased after the cold stress was applied. Huang et al. found no actual significant differences, probably because of the large standard deviations associated with HRV measures. LF increased from 785.04 ± 793.48 ms^2 to 883.84 ± 1003.82 ms^2 and HF from 1081.99 ± 1394.05 ms^2 to 1383.35 ± 2329.98 ms^2 ($P = .066$). LF/HF ratio reduced from 1.79 ± 2.27 to 1.42 ± 1.94 ($P = .076$). Huang et al. suggest that skin cooling can augment both the cardiac sympathetic activity and vagal nervous activity.

Although some of the measures in the Huang et al. (2011) study had not quite reached significance in should be remembered that only one limb was exposed to the thermal stress in this protocol. As a result it might be thought that a greater level of stress would elicit changes that would breach the threshold for statistical significance at the 5% level.

It seems that although the research is limited there is some evidence that cold stress can elicit HRV responses in human participants. The magnitude of the changes may depend on the extent of the cold stressor itself as full body cooling seems more likely to elicit a statistically significant result than partial cooling of the body.

It is also possible that repeated exposure to cold can result in changes in the HRV response to subsequent stressors and Lunt, Barwood, Corbett and Tipton (2010) examined that effect for cold water exposures at 12 °C. Participants (32 males) completed 10 minutes of exercise in normal and hypoxic conditions and then repeated this protocol after six 5 minute immersions at 12 °C or 35 °C dressed in swim shorts. There was a significant increase in HF Power in the post immersion hypoxic condition for participants described as hypoxic sensitive in the cold water group. In any experiment involving repeated cold exposures it should be remembered that participants with higher sensitivity to the primary stressor may have modified HRV responses after cold exposure.

Conclusion

In conclusion, generally the research suggests that performance in cold and sub-zero conditions is impaired on a number of cognitive and motor tasks whilst others are affected relatively little (Ellis, 1982). Typically tasks requiring manual dexterity are impaired if skin temperatures of the hands fall below around 15 °C (Enander, 1989). Studies on cognitive tasks indicate that cold stress can result in an additional attentional load that can reduce performance on the primary task (Palinkas, 2001). Research on dual task activities has highlighted disrupted attention as a factor that can impact on performance during even straightforward postural control.

Thermoregulatory responses to cold have been well researched but generalised stress responses to cold have not. There are a small number of studies that have examined HRV as a biological stress indicator during cold conditions (Huang et al., 2011; Matsumoto et al., 1999; Yamazaki & Sone, 2000) but these conditions have been very limited in scope and cooling protocols have been somewhat contrived. No studies have examined physiological stress indicators during acute sub-zero exposure.

There is a very limited amount of published research on the effects of whole body exposure to cold conditions on postural control and in the only study where this does exist (Mäkinen et al., 2005) researchers have examined conditions down to 10 °C which represent the kind of external climate we might often expect much of the time in winter in moderate climatic zones like western Europe. Even in parts of the UK winter temperatures can often fall substantially below this. There is no published research on postural control during exposure to sub-zero air temperatures such as may be found in mountaineering, arctic or industrial conditions. There are a small number of papers on postural maintenance when feet are cooled in isolation to impair tactile sensation although these studies tend to have either methodological or dependant variable based limitations such as uncontrolled foot bath temperatures (Stål et al., 2003), or the omission of sway rates (Magnusson, Enbom, Johansson and Pyykkö, 1990), that leave a somewhat incomplete picture.

The hypotheses for this project are:

Acute whole body cooling in sub-zero conditions will result in a generalised physiological stress response that can be measured through HRV.

Postural control will be impaired as a result of the physical stress associated with the sub-zero environment.

Targeting the main component responsible for performance changes with a focused intervention will allow us to maintain performance in a sub-zero environment.

CHAPTER 3

RELIABILITY OF CENTRE OF PRESSURE MEASUREMENTS WITH THE RS SCAN INTERNATIONAL FOOTSCAN® PLATE SYSTEM DURING QUIET STANDING

Introduction

Centre of pressure measurements are often considered to be the gold standard for postural control assessment but these are normally carried out on rigid force platform systems and this limits the use of this technique to laboratory work with fixed apparatus installation sites (Mancini, Salarian, Carlson-Kuhta, Zampieri, King, et al., 2012). The ability to measure centre of pressure in the University of Chichester Controlled Environmental Chamber (T.I.S. Services UK, Hampshire, UK) during cold conditions was an essential element of this project and it was therefore necessary to adopt a centre of pressure measuring system that could fulfil this requirement. The RSscan International Footscan® Plate System (RSscan International, Olen, Belgium) is designed as a portable system requiring no specialist physical installation. It consists of a flat mat that can be positioned on any hard floor (The RS Footscan® plate) and connected to a computer running Microsoft Windows using a flexible cable and an RSscan International Footscan® 3D Box.

It was relatively easy to establish that the Footscan® system could operate in the conditions within the environmental chamber. A key feature of the system is that unlike a rigid force platform the Footscan® plate itself does not have moving parts making it more likely to tolerate extremely low temperatures. The chamber is capable of maintaining a temperature of approximately -20 °C and it was chosen to test the system at -20 °C on the grounds that if it could function effectively in these conditions it would cope with all likely conditions in the study. The system was set up with the plate positioned within the chamber and the flexible cable fed out through one of the ports in the chamber wall to the Footscan® 3D box and a laptop running Microsoft

Windows and the Footscan® 7 balance software package. This approach meant the laptop and Footscan®3D box were at normal room temperature and could be operated by a researcher dressed in normal clothing.

The system was set up prior to the chamber being drawn down to temperature; a process that takes approximately 7 hours to complete. Previous experience with the chamber at low temperatures (< 0 °C) had indicated that electrical equipment operates most effectively if it is allowed to cool at the same rate as the chamber and where necessary 'powered up' (lighting, treadmills, etc. must be running throughout the cooling protocols and kept running until all testing protocols are completed). As the powered aspects of the Footscan® system were outside of the environmental chamber this last step wasn't necessary and so only the interior lighting needed to be ran during 'draw down'. During initial testing at -20 °C the Footscan® system ran effectively and throughout all of the later studies there were no problems operating at this temperature, however, on a small number of occasions when the 'draw down' was completed overnight with very cold winter weather conditions the environmental chamber cooled to temperatures of around -22 to -23 °C and at these temperatures function of the Footscan® plate was intermittent and slow until the temperature was brought back up to -20 °C. As a result -20 °C should be considered the effective limit of consistent operation for the Footscan® system.

Balance Tests

A key aspect of this project was the comparison of postural control performances through centre of pressure (COP) analysis during quiet standing balance tasks. Three balance tests were chosen for the study. The three tests were all quiet standing balance tests and the three tests were selected because they each had a different level of task demand. The easiest test was to maintain an upright posture in a two footed stance with both eyes open. The second test was a repeat of the first test but with both eyes closed. Depriving participants of vision for postural control test is a common way to make the test harder (Donker et al., 2007; Gribble et al., 2007). It also moves the source of sensory information to an entirely internal focus reliant on the vestibular apparatus and soma-sensation (Donker et al., 2007; Paillard et al., 2011).

The final, and most difficult test, was a single footed quiet standing balance test where participants were required to maintain an upright posture on one foot but with both eyes open. To eliminate any lateral dominance effects participants completed this task on each foot and the results were a mean of the two performances.

Reliability

The problem of consistency and repeatability of measurements within research is generally referred to as that of reliability (Thomas & Nelson, 2001). Since fundamentally all measurements must be approximate then there will always be a degree of variation between repeated measurements. Some of this variation will be as a result of the physical limits involved in making the measurement itself. In this study there is a finite resolution for sway data as a fixed limitation of equipment. Centre of pressure data were acquired at 50 Hz meaning movements reserved less than 20 milliseconds were effectively invisible during the study. The excel (Microsoft® Office 2010) output available from the software consists of calculated centre of pressure information to 0.001mm intervals along the X and Y axes however a 0.5 meter RSscan footscan® plate consists of 64 lines of pressure sensors so this information is derived from combining pressure measurements from larger 'pixels' under the surface contact area of the feet rather than being a direct measurement.

A more likely threat to reliability was the inherent problem involved in testing human beings that repeated performances will result in a spread of scores even within one individual. Thomas and Nelson (2001) refer to the concepts of observed score, true score and error score. The true score is an idealised value that a participant should score but in reality the observed score will differ from this value because it will include an error score which is an unknown amount of variance as result of the process of measuring the variable (Ley, 1972). A goal for any researcher is to minimise possible sources of error.

Learning and Familiarisation Effects

A key aspect of the project was to be able to compare postural control performances in different environmental conditions and change over time during different conditions. In any study involving repeated measurements of tasks carried out by human beings it is important to consider the possibility that the process of testing a participant could elicit changes on any subsequent measurements (Glaister, Howatson, Abraham, Lockey, Goodwin, et al., 2008). Clearly if this were to occur then it would be very difficult to draw any conclusion from a comparison of measurements made at different time points.

Learning effect is a term which describes a trend towards better performance due to the increasing skill of a participant as they effectively practice an evaluated task during testing. Learning effects are likely when a task has a high skill element underlying performance and participants have little prior experience of the task. Familiarisation effect is similar in that performance on a measured task may improve as a participant becomes more comfortable with the test. Familiarisation effects may be possible even when skill is not a large factor in the performance of a test if a participant performs more confidently as a result of an increased understanding of test protocols.

When learning or familiarisation effects are possible then a common way to manage these effects is to ensure that participants have practised the protocols to a point where any further increases in performance will be non-existent or at least very small prior to experimental testing using a familiarisation trials protocol (Glaister et al., 2008; Tzelgov, Henik & Berger, 1992). For this approach to be effective it is essential to know how performance could be expected to change during repeated measurements under identical conditions. This knowledge can allow a judgement to be made on the number of practice, or familiarisation, trials that will be necessary to reduce learning and familiarisation effects to acceptable levels (Thomas & Nelson, 2001).

Rationale

The purpose of this study was to ascertain the magnitude of performance variation for postural sway measurements during quiet standing and establish if any habituation training would be necessary for subsequent studies. A test-retest method to establish reliability was adopted. This is a common method of establishing stability in tests that involve fitness or motor performance

(Thomas & Nelson, 2001). Participants completed identical balance tests five times on separate days. Performance on four quiet standing balance tests was measured once on each of five days in order to allow a judgement to be made on the number of practice tests required for a stable level of performance to be reached. This information was vital in planning inductions for participants for the subsequent studies planned for the project.

An intraclass correlation approach was used to establish variance. This is a versatile and commonly used technique that provides information regarding systematic and error variance (Bland & Altman, 1990; Thomas & Nelson, 2001). An advantage of the technique is that it avoids a linear relationship being mistaken for agreement. In this approach a repeated measures ANOVA is used to determine if there are significant differences between trials. A significant difference results in the earlier trials being discarded and the ANOVA recalculated with the remaining trials, this process is repeated until a non-significant result is achieved. The intraclass correlation coefficient then provides a measure of the within group consistency of performance.

Method

Participants

A mixed sex group of 19 academic and professional Higher Education staff (12 men; 7 women) participated in the study. Participants were screened for pre-existing musculoskeletal injuries that may have impacted on their performance during testing. The mean age of participants was 39.3 years (range: 25 - 60). Anthropometric variables measured were height (176.9 ± 9.1 cm) and weight (75.2 ± 11.8 kg). All participants were volunteers and gave consent to participate in the study after being fully informed about the purpose of the investigation (appendix 2, page 202). Ethical approval for the study was obtained from the University ethics committee (appendix 1, page 193).

Equipment

The equipment for the study was a 0.5m RS Scan International footscan® plate system running through a footscan® 3D box into a windows laptop PC. Footscan® 7 balance software was used to record the sway dynamics. This was positioned two metres from a bank wall equipped with a visual target at eye height. The plate was orientated so that the Y axis would correspond to fore / aft movements. The laptop was positioned so that it could not be seen by the participant during testing.

Experimental Design

Participants attended an initial induction, familiarisation and testing session during which all tests were explained and performed. This visit to the laboratory took approximately 20 minutes. Participants then attended the laboratory at the same time of day on each of the next four days for repeat testing. During the four follow up visits participants were asked to report if there were any factors that might impact on their performances and completed the postural control tests. Each of these visits took approximately 10 minutes. Tests were always completed in the same order.

Data Acquisition

Balance performance data were collected in four balance conditions;

1. Two feet placed hip width; eyes open.
2. Two feet placed hip width; eyes closed.
3. Left foot only; eyes open.
4. Right only foot; eyes open.

As can be seen in figure 3.1 for each trial participants stood barefoot, centrally aligned on the footscan® plate. Participants stood with their arms by their sides and were asked to look at a target at eye height on the wall two metres in front of them. Participants held each position for approximately 30 seconds. The experimenter would initiate measurements when the participant appeared to be ready and the force plate began recording data after a pre-programmed delay of 5 seconds. This delay was to avoid any attempt by the researcher to pick a specific moment to begin the measurements and to avoid any response to the experimenter's movements impacting on participants' behaviours / performance. Although there was no evidence that participants were affected by the experimenter's movements it was considered sensible to retain this delay setting for all subsequent testing. Balance data were recorded for 20 seconds at 50 Hz. Spectacles were worn, if required by participants, for all trials irrespective of whether eyes would be open or closed during the test.

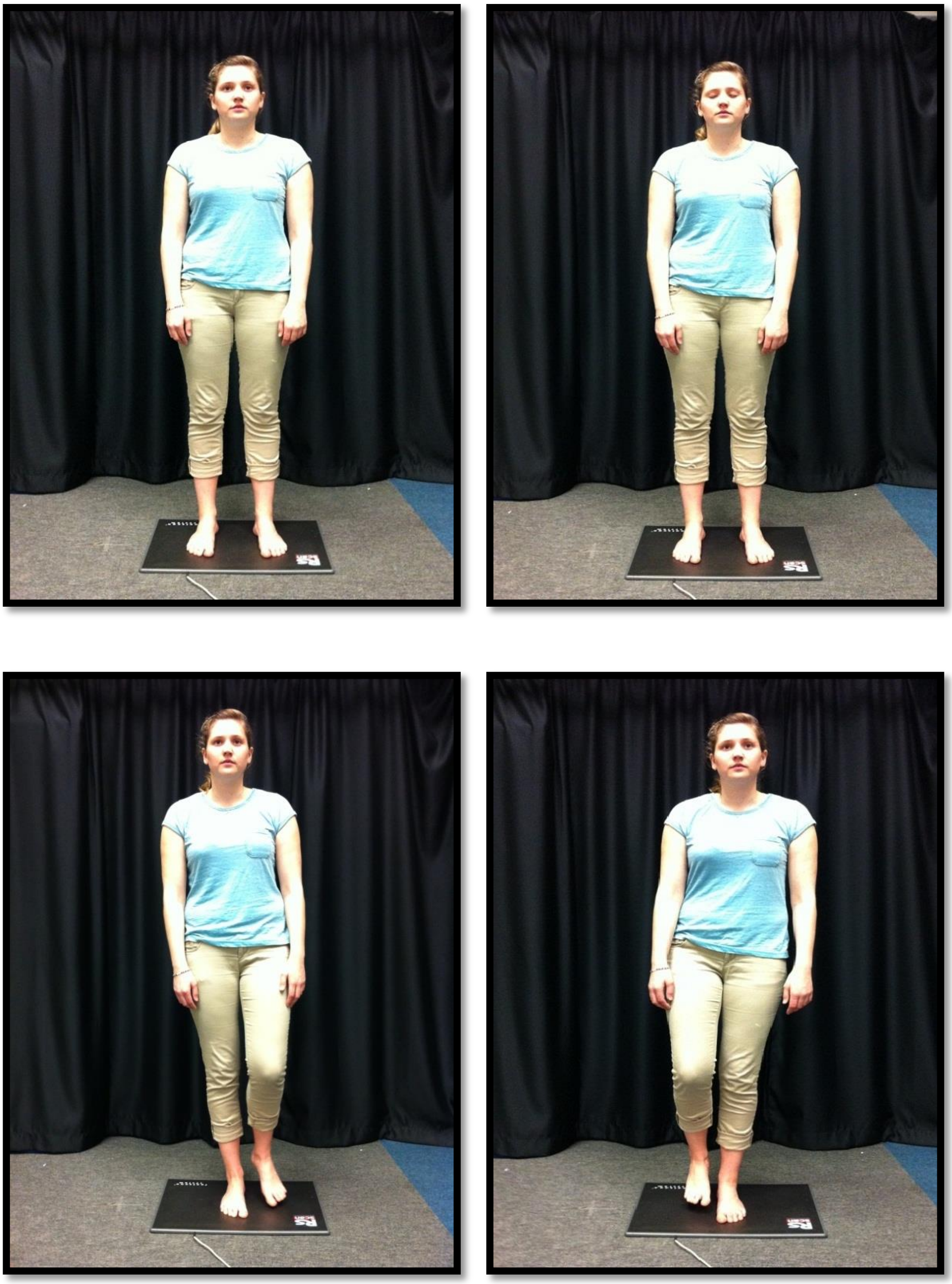


Figure 3.1. Quiet standing balance tests: top right – two feet eyes open; top left – two feet eyes closed; bottom left – right foot eyes open; bottom right – left foot eyes open.

Data Analysis

Sway data were exported from the Footscan® 7 balance software package into Microsoft Excel (Microsoft® Office 2010). Centre of pressure location in each frame was used to calculate total distances moved on X (lateral) and Y (fore / aft) axes and sway rates for both X and Y axes using two clustered logic functions written in Excel (appendix 3, page 206). Scores for each dependent variable were calculated for each of the four balance tests. Data for the single footed tests were combined as means to create a single foot score for each participant for each dependent variable.

The three different balance tests were then analysed independently: Two feet eyes open quiet standing balance test; two feet eyes closed quiet standing balance test; single foot quiet standing balance test. An intraclass correlation coefficient reliability analysis (IBM SPSS Statistics 20) was used to examine the stability of the four dependent variables of total lateral distance travelled of COP, lateral sway rate of COP, total fore / aft distance travelled of COP and fore /aft sway rate of COP for each of the balance tests. This analysis included a repeated measures ANOVA with 5 levels of day and an intraclass correlation coefficient (appendix 4, page 210). An alpha level of 5% was considered significant for statistical tests. In line with Bland and Altman (1997) reliability coefficients of .70 or higher were considered satisfactory.

Results

Two Feet Eyes Open Quiet Standing Balance Test

The repeated measures ANOVA components of the analysis showed no significance for the distance Centre of pressure (COP) travelled during the two feet eyes open quiet standing balance test. COP distances in the two feet eyes open quite standing balance test was very consistent over the 5 days of testing as can be seen in figure 3.2.

The mean lateral distance of the COP was 124.2 ± 19.8 mm and ranged from 119.3 mm to 129.3mm ($F_{17, 68} = 1.59$, $P = .19$). The intraclass correlation coefficient was strong ($r_{IC} = .847$). The mean for fore / aft distance was 85.1 ± 11.8 mm and ranged from 82.6 mm to 86.5 mm ($F_{17, 68} = 0.48$, $P = .752$) The intraclass correlation for fore / aft distance was also strong ($r_{IC} = .816$).

Sway rates over the 5 days were also consistent and this can be seen in figure 3.3. The repeated measures ANOVA components of the analysis for sway rates showed no significant differences.

Lateral sway rate was 26.2 ± 1.3 Hz and ranged from 26.6 Hz to 26.7 Hz ($F_{17, 68} = 1.32$, $P = .271$). The intraclass correlation coefficient was weak ($r_{IC} = .311$) this seems likely to be a result of the low variance within the group on the sway rate variables. Fore / aft sway rate was 23.0 ± 3.4 Hz and ranged from 22.2 Hz to 24.3 Hz ($F_{17, 68} = .99$, $P = .419$) and again the intraclass correlation coefficient was low ($r_{IC} = .434$) due to the small variance in the sway rates of participants in the two feet eyes open tests.

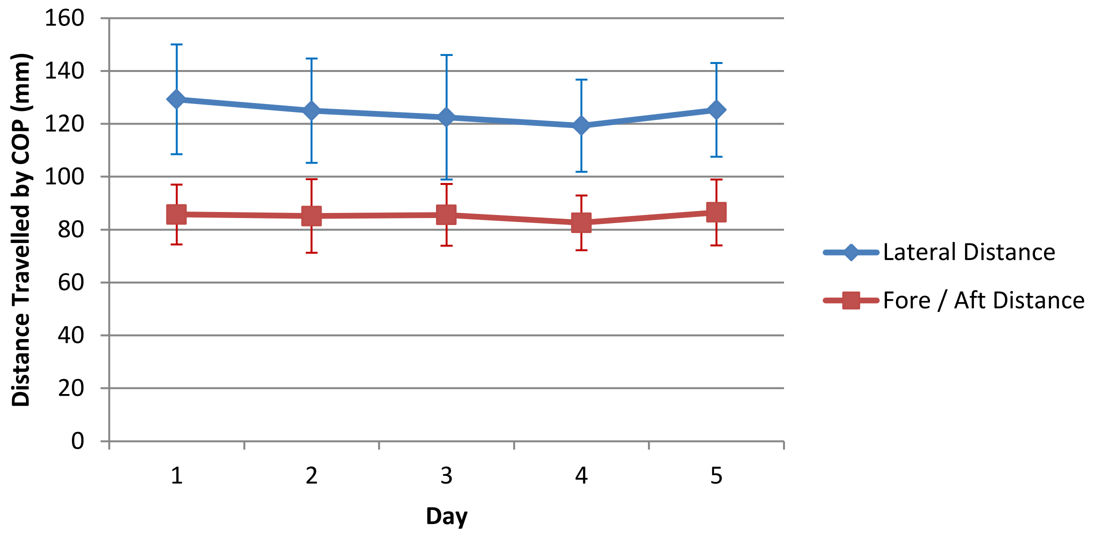


Figure 3.2. **Mean (SD) distance travelled (mm) by the Centre of Pressure (COP) over five trials for the two feet eyes open balance task (*N* = 19).**

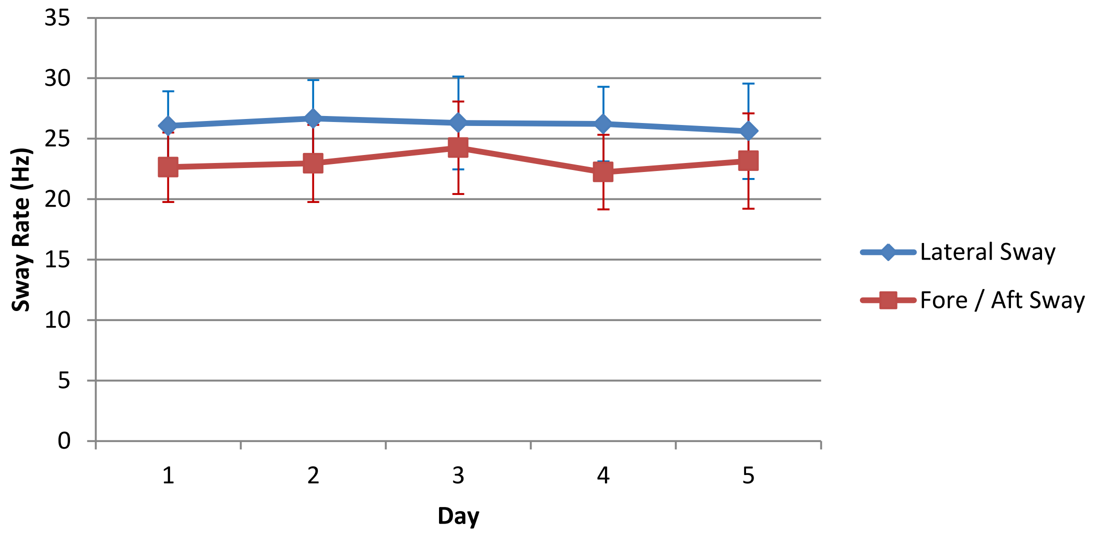


Figure 3.3. **Sway rate over five trials for the two feet eyes open balance task (*N* = 19).**

Two Feet Eyes Closed Quiet Standing Balance Test

Centre of pressure (COP) distances in the two feet eyes open quiet standing balance test were consistent over the 5 days of testing as can be seen in figure 3.4. The repeated measures ANOVA components of the analysis showed no significance for the lateral and fore /aft distance Centre of Pressure (COP) travelled during the two feet eyes closed quiet standing balance test.

The mean lateral distance travelled of the COP was 124.4 ± 18.3 mm and ranged from 122.2 mm to 127.50 mm ($F_{17,\ 68}$ = 0.48, P = .754). The intraclass correlation coefficient was strong (r_{IC} = .855). The mean for fore / aft distance was 98.6 ± 21.8 mm and ranged from 96.04 mm to 102.25 mm ($F_{4,\ 68}$ = 0.76, P = .555). The intraclass correlation for fore / aft distance was also strong (r_{IC} = .916).

Lateral and fore / aft sway rates over the 5 days were also consistent and this can be seen in figure 3.5. The repeated measures ANOVA components of the analysis for sway rates showed no significant differences.

Lateral sway rate was 25.8 ± 1.6 Hz and ranged from 25.40 Hz to 26.25 Hz ($F_{17,\ 68}$ = 1.16, P = .338). The intraclass correlation coefficient was moderate to strong (r_{IC} = .731). Fore / aft sway rate was 20.4 ± 4.1 Hz and ranged from 20.04 Hz to 20.83 Hz ($F_{17,\ 68}$ = 0.25, P = .911) and again the intraclass correlation coefficient was moderate to strong (r_{IC} = .762).

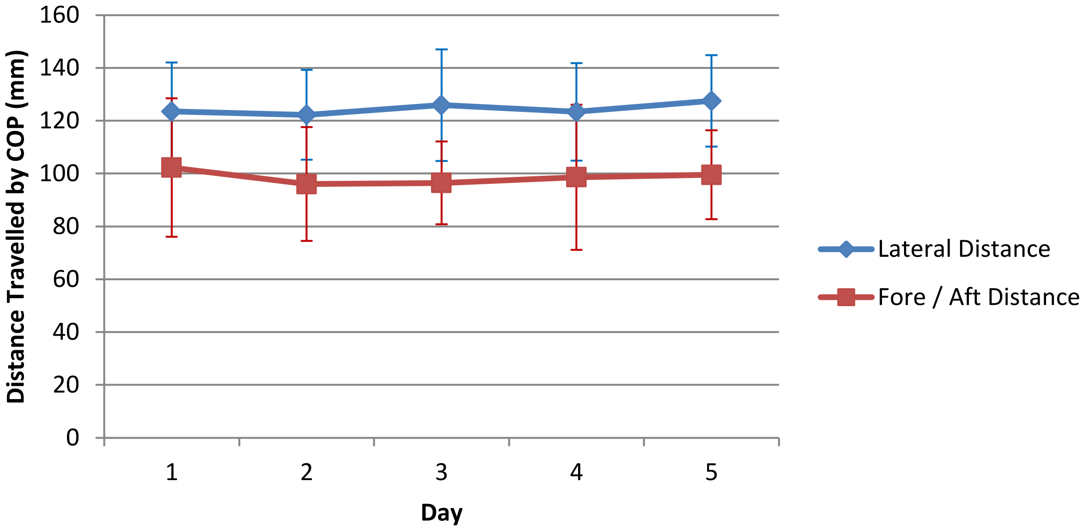


Figure 3.4. **Distance travelled by the Centre of Pressure over five trials for the two feet eyes closed balance task (*N* = 19).**

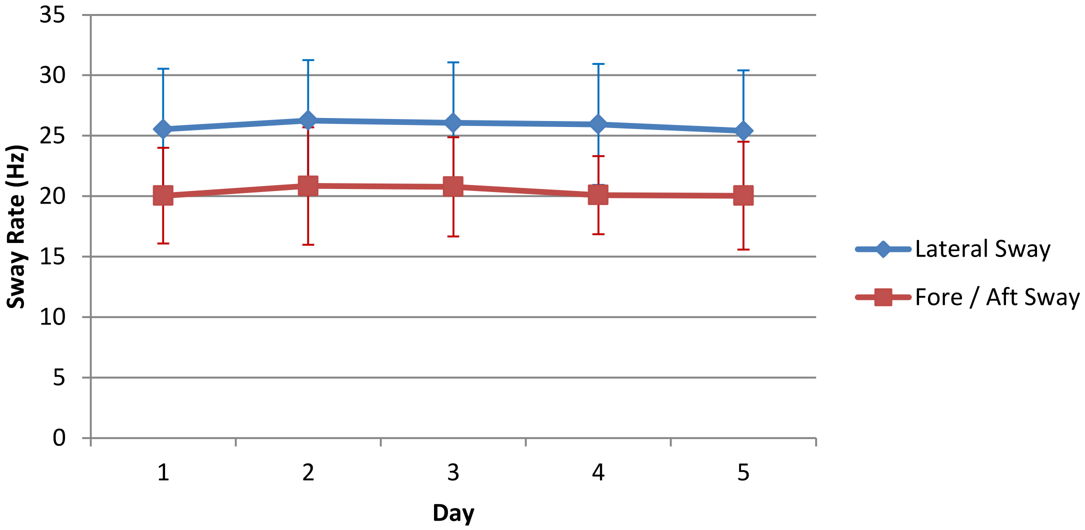


Figure 3.5. **Sway rate over five trials for the two feet eyes closed balance task (*N* = 19).**

Single Footed Quiet Standing Balance Test

Centre of pressure (COP) distances in the single footed eyes open quiet standing balance test were significantly different over the 5 days of testing. As can be seen in figure 3.6 total distance travelled was higher in the first test than on subsequent trials. The repeated measures ANOVA components of the analysis showed a significant difference for the lateral distance of the COP movements ($F_{17, 68} = 3.31$, $P = .016$). Fore /aft distance of the COP movements were also significantly different ($F_{17, 68} = 5.08$, $P = .001$).

Intraclass correlation coefficients were recalculated with data for the first day omitted (as described in the data analysis section) which resulted a non-significant result for lateral distance ($F_{17, 51} = 1.29$, $P = .289$). The intraclass correlation coefficient was strong ($r_{IC} = .922$). The mean lateral distance travelled of the COP on days 2 through to 5 was 223.38 ± 59.31 mm and ranged from 215.10 mm to 233.50 mm.

It was necessary to omit the first two days' data in order to produce a non-significant difference for fore / aft distance travelled of the COP ($F_{17, 34} = 0.27$, $P = .763$). The intraclass correlation coefficient was strong ($r_{IC} = .877$). These results indicate that scores for distance travelled by the COP improve after the trials on the first and second days but then become stable. The mean for fore / aft distance on days 3, 4 and 5 was 243.51 ± 54.77 mm and ranged from 240.70 mm to 247.34 mm.

Figure 3.7 shows lateral sway rates consistent over the five days with no significant difference for the ANOVA component of the analysis ($F_{17, 68} = 0.94$, $P = .446$). The intraclass correlation coefficient was strong ($r_{IC} = .821$). Lateral sway rate was 6.99 ± 0.81 Hz and ranged from 6.83 Hz to 7.14 Hz

Fore aft sway rates were significantly different ($F_{17, 68} = 3.53$, $P = .011$) with a lower sway rate on day 1 (figure 3.7). Recalculated intraclass correlations omitting day one were non-significant ($F_{17, 68} = 2.33$, $P = .085$). The intraclass correlation coefficient was strong ($r_{IC} = .872$). Fore / aft sway rate for days 2 through to 5 was 12.91 ± 1.76 Hz and ranged from 12.47 Hz to 13.40 Hz.

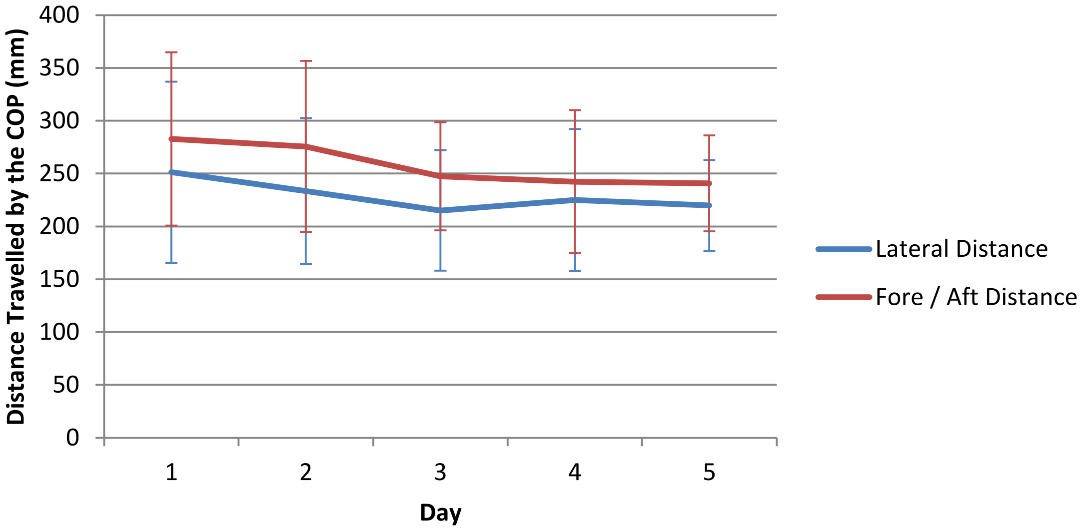


Figure 3.6. **Distance travelled by the Centre of Pressure over five trials for the single footed eyes open quiet standing balance test (*N* = 19).**

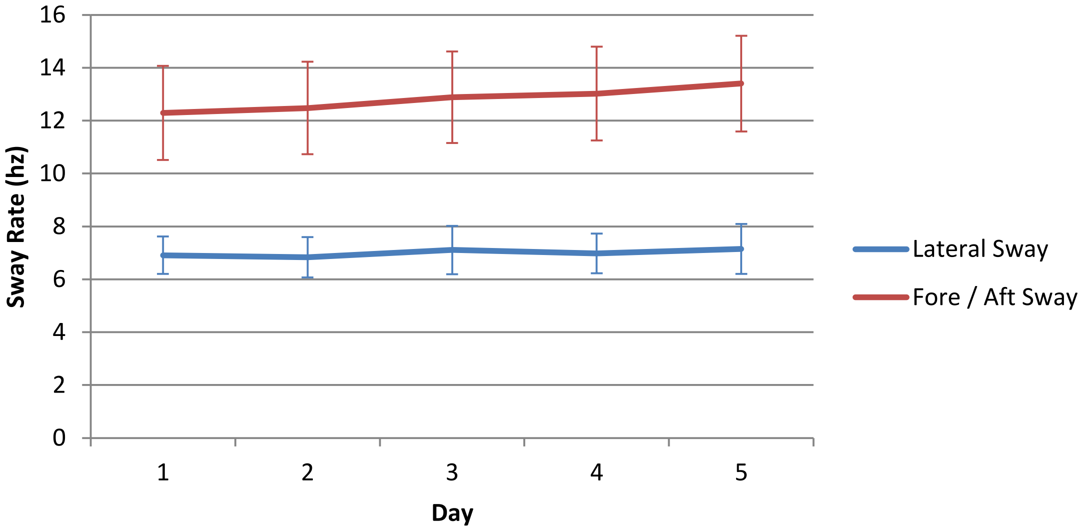


Figure 3.7. **Sway rate over five trials for the single footed eyes open quiet standing balance test (*N* = 19).**

Discussion

To summarise the above findings, intraclass correlation coefficient analysis showed no significant differences during either of the two footed tests irrespective of the eyes open or eyes closed condition. From these findings it could be assumed that no significant familiarisation, or learning, effects took place during repeated two footed balance tests. The correlation coefficients for the eyes open condition were strong ($r_{IC} > .8$) for the total distance travelled of the COP for both lateral and fore / aft components. The correlation coefficient for the sway components, however, were much weaker ($r_{IC} = .311$ and $r_{IC} = .434$). This may be due to the small variation in performance that the eyes open balance test elicited. Because the performances of participants were very similar (standard deviations for this measure were 1.3 Hz for lateral sway rate and 3.4 Hz for fore / aft sway) and the performances on each day were very similar both the between participants variance and the within participants variance is small producing a low coefficient.

The two footed eyes closed balance tests produced strong coefficients for the total distance travelled of the COP components ($r_{IC} > .8$). Coefficients for the COP sway rates were moderately strong ($r_{IC} > .7$). Bland and Altman (1997) suggest that for non-clinical research then reliability coefficients of .70 or higher are satisfactory. It seems reasonable then to be quite confident in the reliability of the two footed eyes closed quiet standing balance test.

The single footed test presented a different pattern and the first trial and in one case the second trial elicited a significant difference ($P < .05$). This indicates that some familiarisation can result in improved performance for a new participant. Once the early trials were discarded from the analysis then the remaining trials were not significantly different and produced strong reliability coefficients ($r_{IC} > .8$) for both total distances travelled components and the COP sway rate components. This indicates that post familiarisation performances on the single footed tests can be considered reliable. Two familiarisation trials appear to be sufficient to reduce learning effects to a tolerable level for subsequent research even for the variable most prone to improvement during early trials.

Of the 12 variables considered 10 have moderately strong reliability coefficients ($r_{IC} > .7$) and ten score as strong ($r_{IC} > .8$). Bland and Altman (1997) report that when a comparison of eight variables is made that it can be reasonable to accept some values lower than .70 when five or more variables score higher than .70. Given that it seems low variation between subjects is responsible for the two poor r_{IC} scores then it seems reasonable to conclude that the tests are in the main reliable after familiarisation but that significant difference on the sway components of the two feet eyes open condition should be considered with caution unless they are corroborated by other postural component changes or of a relatively large absolute change.

Conclusion

In conclusion the results of this study indicate that participants who have completed two familiarisation trials on the footscan® plate should exhibit stable performance on the four balance tasks on any subsequent testing. It was decided for all future studies a cautious approach should be adopted and that that the protocol should include a familiarisation phase of three trials of each test and that these should be performed in a manner as consistent with the protocol in this study as possible. Although it appears from the results that a familiarisation is not strictly necessary for the two footed tests it seems prudent to include all four balance tests in the familiarisation protocol. Tests should be performed in a predictable predetermined sequence and with a consistent timing so that participants are not only habituated to the test but familiar and cooperative with the test pattern. This was deemed to be particularly important because both the participants and researcher would be under increased stress in the environmental chamber.

Future research with the footscan® plate that relies on the stability of participants' performance during the balance tasks should adopt a rigorous familiarisation protocol. This familiarisation protocol should ensure that any changes in performance are as a result of the conditions that participants encounter during the study rather than being due to an underlying change in the way participants are able to complete the task.

CHAPTER 4

THE EFFECTS OF ACUTE COLD EXPOSURE ON BODY TEMPERATURE, POSTURAL SWAY DYNAMICS DURING QUIET STANDING, AND HEART RATE VARIABILITY

Introduction

A small number of previous studies had referred to postural control in cold environmental conditions however these studies had either included elements of compound stress or else had employed higher temperatures than were the key focus of this project. Cymerman, Young, Francis, Wray, Ditzler et al. (2002) had exposed participants to a prolonged temperature of 4 °C during an exercise that replicated the conditions aboard a disabled submarine over five days. However the cold element had been part of a compound stress study and so it was impossible to establish what effect cold alone had had. Mäkinen, Rintamäki, Korpelainen, Kampman, Pääkkönen et al. (2005) had isolated cold effects but had utilised relatively conservative temperatures of 10 °C and two hour exposure times. Participants in this study were dressed in shorts socks and athletic shoes.

As no studies had examined performance in below freezing conditions it was decided to examine performance in a sub-zero environment. Because one purpose of the project was to provide information for participants in activities such as mountaineering, winter sports and participation in expeditions in arctic conditions then colder temperatures were of particular interest. Ellis (1982) had studied the effects of sub-zero (-12 °C) temperatures on cognition and participants dressed in shorts had completed 90 minute and 120 minute trials and this was taken as a starting point for the investigation. As most of the previous research in the cold included elements of exercise or other factors producing compound stressors then it was important to establish a protocol that participants could complete but that would be demanding enough to elicit performance changes. It had been established that the equipment for the study could operate down to -20 °C in the environmental chamber. The use of cold weather clothing was considered but it seemed that this would just mean participants would spend longer in the chamber to achieve a similar outcome once the thermal properties of their clothing was overcome. It was decided that exercise protocols should be avoided, particularly in light of the Ellis study where sedentary participants had completed exposures of up to 120 minutes, but also because this would potentially introduce a fatigue effect and a key aim was to isolate cold effects.

A pilot study involving two participants and the experimenters indicated that participants could tolerate 35 minutes of exposure in a -20 °C environment, in light clothing, before becoming unjustifiably distressed. However, after this pilot, completion of 60 minute exposures seemed unlikely and to be unjustifiably stressful both for participants and the experimental team. Skin temperatures of 6 to 8 °C had been cited as a lower limit for research in previous studies on safety grounds (Enander, 1989). At 30 - 35 minutes exposure the skin temperatures of the pilot participants' feet were around 10 °C and so this was considered a practical limit for the study.

The primary aim of this study was to establish the level of performance decrement to postural control (as measured using COP analysis) that would occur as a result of 30 minutes of cold exposure at -20 °C. Secondary aims included establishing the degree of cooling that participants would experience through core and skin temperature measurements and the level of stress they would experience through thermal comfort and HRV measures. Each round of postural control and temperature testing took approximately 5 minutes to complete so this meant that participants were finished in the cold condition at 35 minutes.

Method

Participants

For this study twelve participants were recruited from the undergraduate population. Eight were male and four female. All were unpaid volunteers. The mean age of participants was 21.9 years (range: 21- 24). Anthropometric variables measured were height (172.9 ± 8.0 cm), weight (72.8 ± 11.4 kg), and body fat (14.0 ± 3.9%). Body Mass Index was calculated as 23.0 ± 3.3 $kg{\cdot}m^{-2}$.

Participants were vetted for history of cold injuries including hypothermia, frostbite and non-freezing cold injuries, or other circulatory disorders. Individuals with a history of frost bite can be predisposed to recurrence of these injuries (Wilkerson, 1992) and the increased risk was seen as avoidable and therefore unjustifiable. Wilkerson explains that these participants would have had physiological changes in their extremities, for example impaired circulation. This may have resulted in functional differences such as quicker cooling, that would have been atypical and therefore their inclusion within the study could have made data less representative of most of the comparable population. Accounting for previous cold injury in a small subset of participants would have make data analysis much more complex and provided little additional benefit in terms of understanding.

Overall Experimental Design

A repeated measures design was employed with participants completing two phases of testing: one in the cold condition (-20 °C) and the other at room temperature (defined as between 20 and 25 °C the laboratories were maintained at a temperature of 21 ± 1 °C). This was a counterbalanced crossover design with 6 participants completing the cold condition first and 6 participants completing the room temperature condition first. This design was intended to prevent any order effect from impacting on the overall results of the study. Participants were assigned their sequence on a randomised basis. Since a placebo cold condition was impossible and participants would know which condition they were arriving for on the second visit participants were informed of the order of testing prior to their first visit to the laboratory. This ensured participants had maximum consistency in their knowledge of the protocols they were going to complete.

Participants attended an orientation session in the laboratory prior to the two visits for data collection. In the first (reliability and familiarisation) study it was established that there was a familiarity effect for the balance tests which meant that participants were likely to have improved performances on the second and third trials after which performance on the tests would be acceptably consistent. During this orientation visit participants completed three cycles of balance tests in order to ensure that this familiarisation effect did not impact on actual data collection during the study. Particular attention was paid to ensure that the tests were carried out accurately and consistently in order that this would be replicated during data collection. Balance tests were always carried in the order of two feet eyes open, two feet eyes closed, right foot and finally left foot. The intention was to have participants well drilled so that they would find it as easy as possible to cooperate during the testing that was to follow.

During this session participants completed health questionnaires (see appendix 2, page 202) and were briefed in detail about what the two data collection sessions would entail. They were screened for previous cold injuries or muscular skeletal injuries that could have impacted on their abilities to complete the balance tests. It was made clear to participants that they were free to leave the study at any time including during testing. They were also reassured that they would be monitored continuously throughout the cold testing procedure and that if they were considered to be at risk of physical harm they would be removed from the cold chamber. Since it was obvious that testing in the cold chamber would be physically uncomfortable it was considered important that participants felt included and valued within the study. The rationale behind this was that participants would be more likely to persist despite discomfort if they felt their contribution to the study was individually valued and also that it would increase their confidence that if they became too distressed they would be taken seriously and removed from the cold chamber promptly, reducing the chance that they would ask to leave prematurely.

Measurement

Body temperature.

Each participant arrived at the laboratory dressed, as instructed, in a single layer of light clothing that included long sleeves and trousers. Participants were required to wear the same clothing on each occasion. The head, hands and feet were left bare. Bare feet are a standard protocol for most postural control studies (Deschamps, Magnard & Cornu, 2013; Magnusson, Enbom, Johansson & Pyykkö 1990) and participants in Ellis (1982) study had completed up to 120 minutes at -12 °C with bare feet. Participants were prepared for the protocol in a warm room close to the environmental chamber. Participants inserted a rectal thermistor (Edale Instruments (Cambridge) LTD, Cambridge, UK) 10 cm beyond the anus in order to measure core body temperature (Ellis, 1982; Ellis et al., 1985). Edale Instruments thermistors were attached to the participant's skin using self-adhesive hypoallergenic surgical tape. Thermistors were attached to the right hand side of the body at the temple, calf and the top of the foot. Calf thermistors were placed on the visual centre of mass of the calf muscle (between the lateral and medial heads of the gastrocnemius) and foot thermistors were placed on the joint of the intermediate cuneiform and the second metatarsal of the right limb. These locations were selected because they would not interfere with balance testing but the skin temperatures in those areas were considered important in terms of postural control.

Temperatures were displayed on a multi-channel Edale box model CD (Edale Instruments (Cambridge) LTD, Cambridge, UK). The Edale box has an effective range of -40 to 140 °C, a resolution of 0.1 °C and an accuracy of ± 0.1 °C. Edale standard thermistors have an accuracy of ± 0.2 °C when used to measure temperatures between zero and 70 °C. In between data collection points the Edale box was set to read core body temperature so this could be monitored continuously. Temperatures were recorded on hand written notes at the predetermined time points. Permanent felt markers were used to make notes as ballpoint pens were found to be prone to failure after even short exposures in the -20 °C condition as the ink became too viscous.

Thermal comfort scale.

A nine point perception of thermal comfort scale (Jendritzky, Maarouf & Staiger 2001) was used to gauge the participants' experience of the effect of the cold exposure. This scale and the descriptive terms for each rating can be seen in table 4.1. Participants were specifically instructed to use the scale to rate their personal comfort and not the environment. Parsons (2003) has argued that participants are quite able to rate comfort on a scales of this nature by comparing their state with the desirable 'comfortable' condition.

Table 4.1. ***Perception of Thermal Comfort Rating Scale***

Thermal Comfort Rating	Descriptor
9	Very hot
8	Hot
7	Warm
6	Slightly warm
5	Comfortable
4	Slightly cool
3	Cool
2	Cold
1	Very cold

Heart rate and variability.

A Polar RS810 (Polar Electro Inc., Lake Success, NY) with beat by beat recording capability was fitted. This includes a watch which acts as the recorder and coded chest strap and transmitter. This was activated prior to entering the environmental chamber and recorded beat by beat data continuously throughout the protocol to be downloaded and analysed later.

Postural control.

Postural control tests were conducted as described in chapter 3 (pages 47-63). The equipment was set up so that the RS Footscan® plate inside the chamber and the Footscan® 3D Box and laptop running Microsoft Windows and the Footscan® 7 balance software package was immediately outside on a desk at the window of the environmental chamber so that the experimenter outside would have a clear view of the participants and the experimenter inside the chamber.

Protocol

Participants were given a short briefing to remind them of what to expect during the testing. The stance for each of the balance tests was described and demonstrated once again.

Participants entered the cold chamber and immediately completed the first cycle of testing. Thermal comfort ratings were recorded followed by body temperatures and then sway dynamics during the four balance tests in the rehearsed sequence; two feet eyes open, two feet eyes closed, right foot then left foot. This testing was repeated after 15 minutes and after 30 minutes in the environmental chamber. Participants left the environmental chamber immediately after this final round of testing; participants spent approximately 35 minutes inside the chamber in total. Between bouts of testing participants were asked to remain standing and refrain from any form of physical activity.

Body temperatures were monitored continually throughout the study for participants' safety and participants were required to be removed from the chamber if their core temperature fell by 1.0 °C; in practice this was not necessary. Participants were accompanied throughout their stay in the chamber by a researcher dressed in appropriate cold weather clothing who could continuously monitor their condition, record measures inside the environmental chamber such as participants thermal comfort and temperatures, and generally ensure that participants adhered to the experimental protocol. Parsons (2003) makes the very good point that although participants in a study of this nature should have the right to withdraw from a thermally challenging environment they should not have an overriding right to remain in it and that the investigator must be prepared to exercise their judgment in removing a participant (based on their physiological responses) even if they are committed to remaining in it. As well as the 1.0 °C core temperature drop criteria participants extremities were monitored for signs of the onset of cold injury. This judgement was made on a visual assessment of the condition of the feet together with a skin temperature cut off point of 5 °C (Heus, Schols, & Kistemaker, 2005).

A second researcher remained outside of the environmental chamber in order to operate the computer based balance data recording software (Footscan® 7) and oversee the experimental protocol. It was also their responsibility to monitor both the researcher and participant inside the environmental chamber for signs that either were not coping. This was important as even though the researcher inside the chamber was fully prepared with appropriate extreme environment protective clothing they were exposed to the cold environment for significantly longer than any single participant (approximately 45 – 50 minutes). They were also exposed to repeated bouts of cold exposure in the same day which none of the participants had to endure.

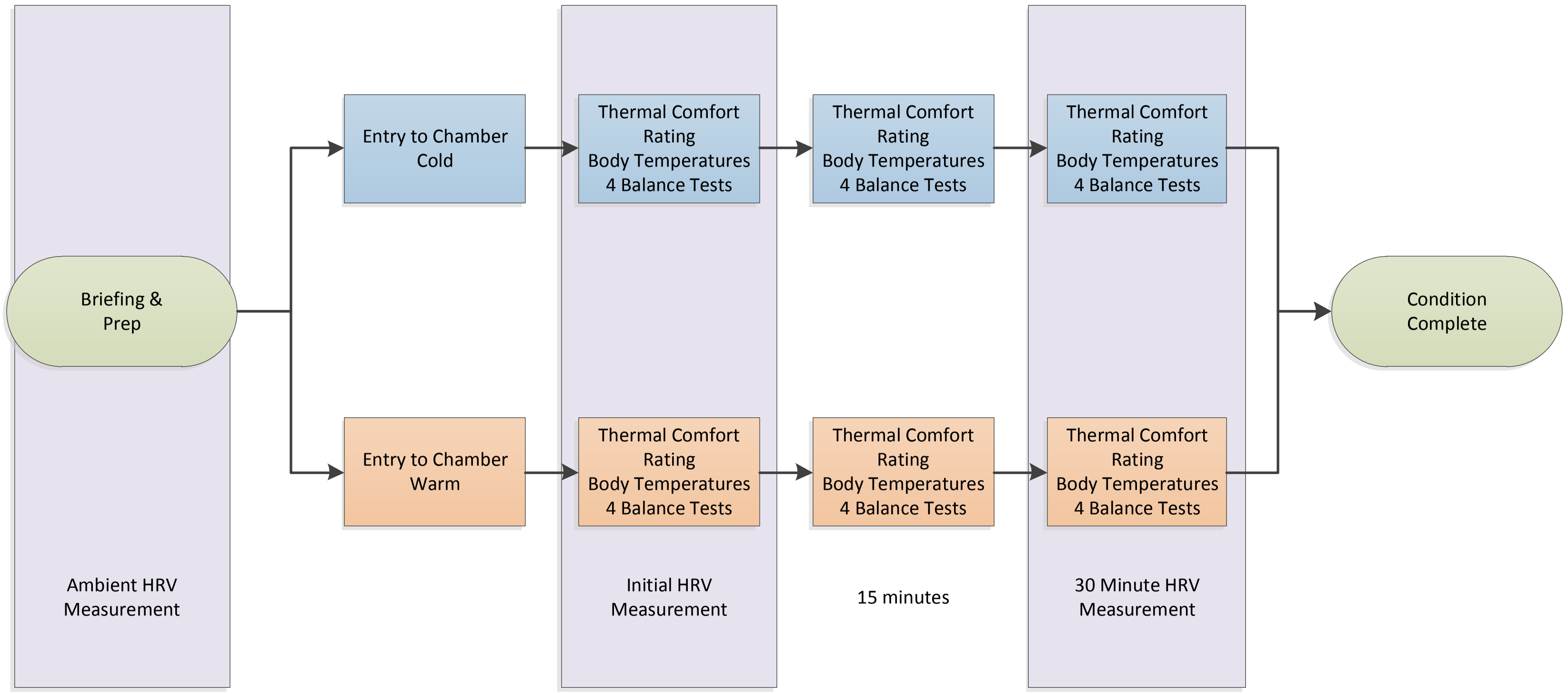


Figure 4.1. **Overview of the experimental protocol: room temperature and −20 °C condition.**

Statistical Analysis

Body Temperatures (core, head calf and foot) and thermal comfort rating were analysed for differences with one way ANOVAs that included temperatures recorded at room temperature prior to cold condition exposure, on initial exposure and after prolonged exposure. Power and effect sizes (η^2_p) were calculated using IBM SPSS Statistics 20 (appendix 6, page 241).

RR heart rate data were uploaded as text files to a PC running Microsoft® Windows and then imported to MATLAB® Kubios HRV 2.0 for analysis. Heart rate variability was calculated from the beat by beat data for the room temperature condition, the first five minutes in the chamber, and the final five minutes using MATLAB® Kubios HRV 2.0. Mean RR, STD RR (SDNN), LF (0.04 – 0.15 Hz), HF (0.15 – 0.4 Hz) and LF/HF ratio were calculated and these were tested for significant differences using one way ANOVAs. Power and effect sizes (η^2_p) were calculated using IBM SPSS Statistics 20 (appendix 5, page 233).

Sway data were exported from Footscan® 7 into Microsoft® Excel and the variables sway rate X (lateral) and Y (fore / aft) and distance travelled by centre of pressure X and Y were calculated using the programme described in study 1 (appendix 3, page 206). Sway data were analysed for differences between condition, time and interaction using two way ANOVAs for the variables within each stance (IBM SPSS Statistics 20). Polynomial contrast analysis was used (including linear and quadratic effects) for pre-planned comparisons of data where there were more than two levels within a factor (in this case time); the analysis is provided in appendix 7 (page 248). Clark-Carter (1997) suggests that contrast analysis can be present for pre-planned (a priori) comparisons even when the ANOVA falls short of significance and so these are presented where P scores indicate either variables on the borderline of significance or variables approaching significance ($P < .10$). Viewing significance scores up to $P = .10$ as potentially worthy of discussion is a Bayesian statistical stance recommended by Sterne and Smith (2001).

Results

Body Temperature

Core body temperature remained very consistent throughout both the room temperature and cold conditions ($F_{3, 30}$ = 0.56, P = .643, η^2_p = .053, Power = 0.152). However the head ($F_{3, 30}$ = 68.23, P < .0005, η^2_p = .872, Power > .9995), calf ($F_{3, 30}$ = 68.75, P < .0005, η^2_p = .873, Power > .9995) and foot temperatures ($F_{3, 30}$ = 57.84, P < .0005, η^2_p = .853, Power > .9995) dropped significantly during the cold condition. The temperature of the foot dropped to 10.1 ± 3.5 °C after 30 minutes of cold exposure.

Polynomial contrast analysis showed all of these changes to be linear effects. Head ($F_{1, 10}$ = 182.11, P < .0005), calf ($F_{1, 10}$ = 76.14, P < .0005) and foot ($F_{1, 10}$ = 100.81, P < .0005) and figure 4.2 shows that temperatures dropped in an even and consistent manner over time once in the environmental chamber. The skin temperature of the foot was around 5-7 degrees colder than the head and calf.

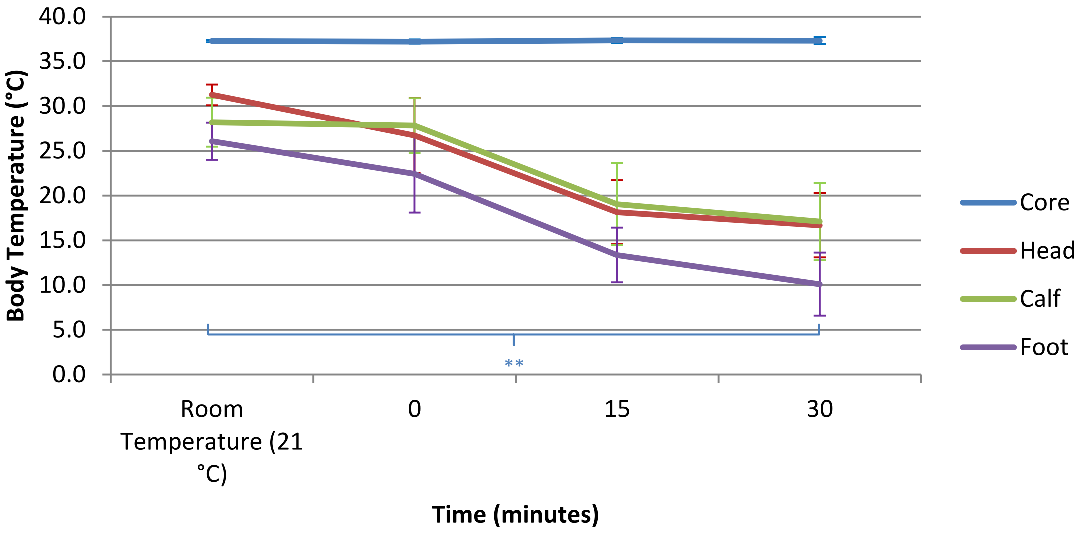


Figure 4.2. **Mean and standard deviation (*N* = 12) body temperature (°C) during the room temperature condition (21 °C) and during 30 minutes cold condition exposure (-20 °C).**

** P < .01 linear effect (Head, Calf & Foot)

Thermal Comfort Rating

Thermal comfort ratings were also significantly different ($F_{3,\ 30}$ = 66.78, P < .0005, η^2_p = .870, Power > .9995) participants reported a drop in perceived comfort from 4.8 ± 0.6 (comfortable) in the room temperature condition and 3.9 ± 0.7 (slightly cool) on initial exposure to −20 °C to 1.5 ± 1.0 (cold to very cold) after 30 minutes at −20 °C. Unsurprisingly participants all reported being comfortable at room temperature but became colder the longer they were exposed to the cold condition (−20 °C). Polynomial contrast analysis showed a linear effect ($F_{1,\ 10}$ = 120.35, P < .0005) as comfort ratings steadily declined over time (figure 4.3).

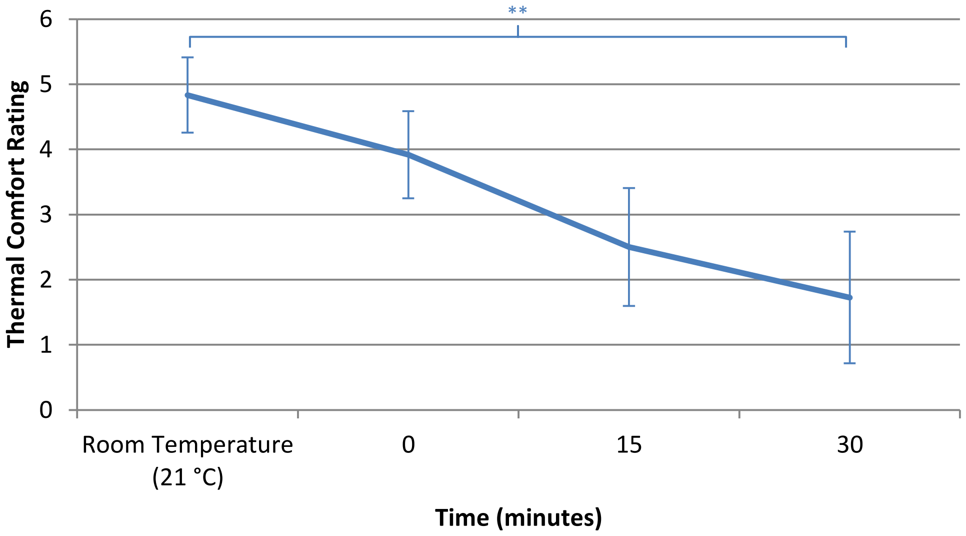


Figure 4.3. **Thermal comfort rating (N = 12) in the room temperature condition (21 °C) and during 30 minutes cold condition exposure (−20 °C).**

** P < .01 linear effect

Heart Rate and Heart Rate Variability

The change in absolute values for all variables were towards reduced variability which is normally interpreted as a stress response. However there were no actual statistically significant differences for any of the heart rate variability measures between room temperature conditions and initial exposure to the –20 °C cold condition, or after 30 minutes of cold exposure.

Time Domain Analysis

Mean RR interval.

Figure 4.4 shows the decline in heart rate from 761 milliseconds in room temperature conditions to 667 milliseconds after 30 minutes of exposure at –20 °C. However, no significant difference was found for heart rate (mean RR interval) despite the reduced absolute scores ($F_{2,\,8} = 2.41$, $P = .152$, $\eta^2_p = .376$, Power = .351). The .376 effect size (η^2_p) indicates that there might actually be a trend here that would be significant in a larger study.

SDNN.

The variation in RR beat interval (SDNN) reduced from 162 milliseconds 101 milliseconds however this difference was not statistically different ($F_{2,\,8} = 2.57$, $P = .137$, $\eta^2_p = .391$, power = .372). Figure 4.5 appears to show a steady decline in variability and the medium effect size ($\eta^2_p = .391$) indicates that there may actually be a trend here that would be significant in a larger study.

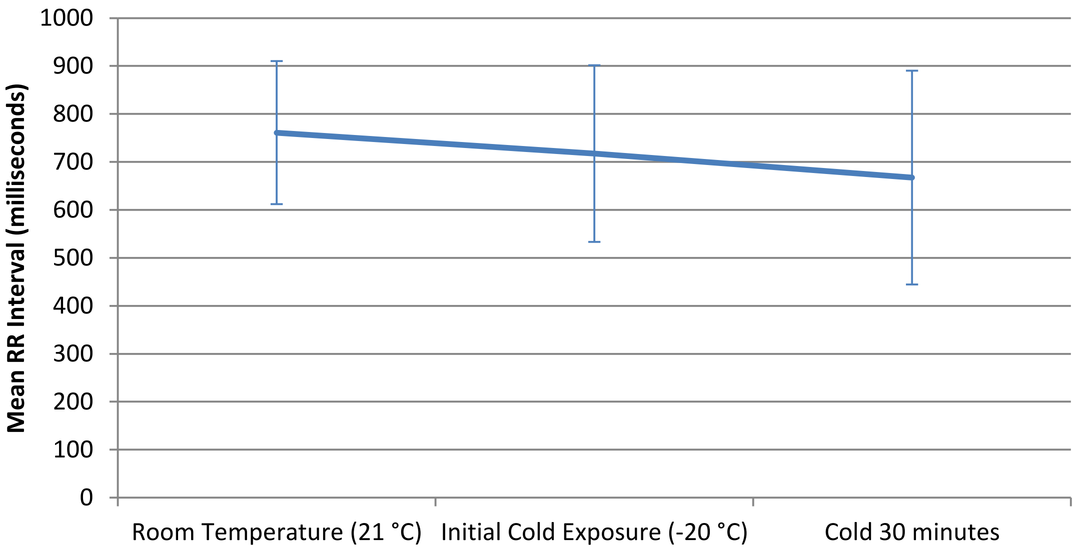


Figure 4.4. **Mean (SD) of the Mean RR Interval during room temperature conditions, on initial cold exposure and after 30 minutes cold exposure at −20 °C (*N* = 8).**

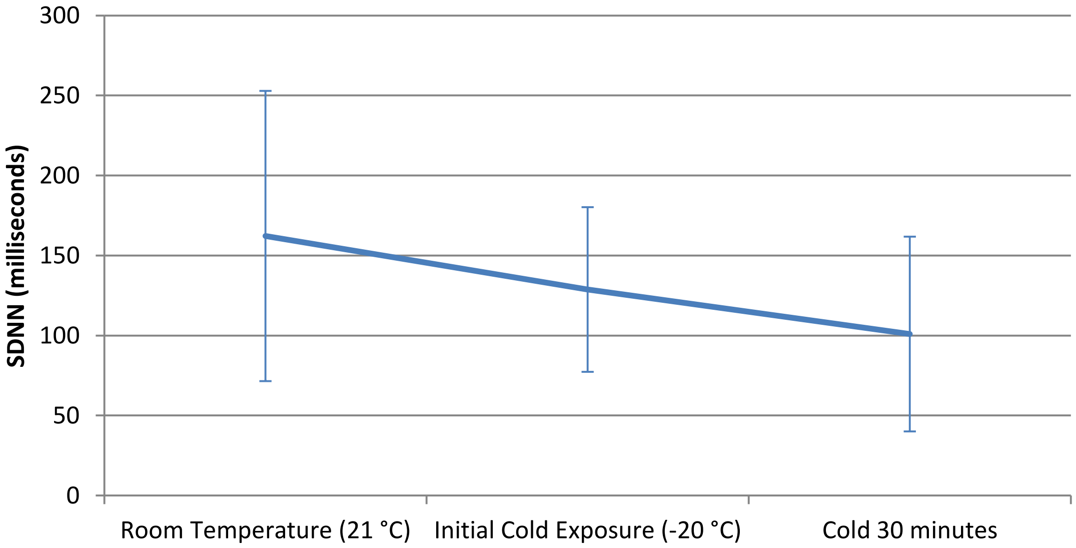


Figure 4.5. **Mean (SD) of the Mean RR SD (SDNN) during room temperature conditions, on initial cold exposure and after 30 minutes cold exposure at −20 °C (*N* = 8).**

Frequency Domain Analysis

LF and HF power.

Figure 4.6 shows decreased absolute values for LF and HF power but these were not significantly different ($F_{2,8} = 1.63$, $P = .271$, $\eta^2_p = .289$, Power = .168 and $F_{2,8} = 1.73$, $P = .238$, $\eta^2_p = .302$, Power = .263 respectively). The HF power value does reach the level required for a medium effect size with an eta squared statistic ($\eta^2_p > .3$).

LF/HF ratio.

The LF/HF ratio, as can be seen in figure 4.7, was also moving in the direction of greater LF dominance which is indicative of increased sympathetic nervous system control over cardiac function. Again this was not a statistically significant result ($F_{2,8} = 1.73$, $P = .237$, $\eta^2_p = .302$, Power = .263) but the effect size reaches the $\eta^2_p > .3$ value of a medium effect indicating this trend well be a real effect that would reach significance in a larger study.

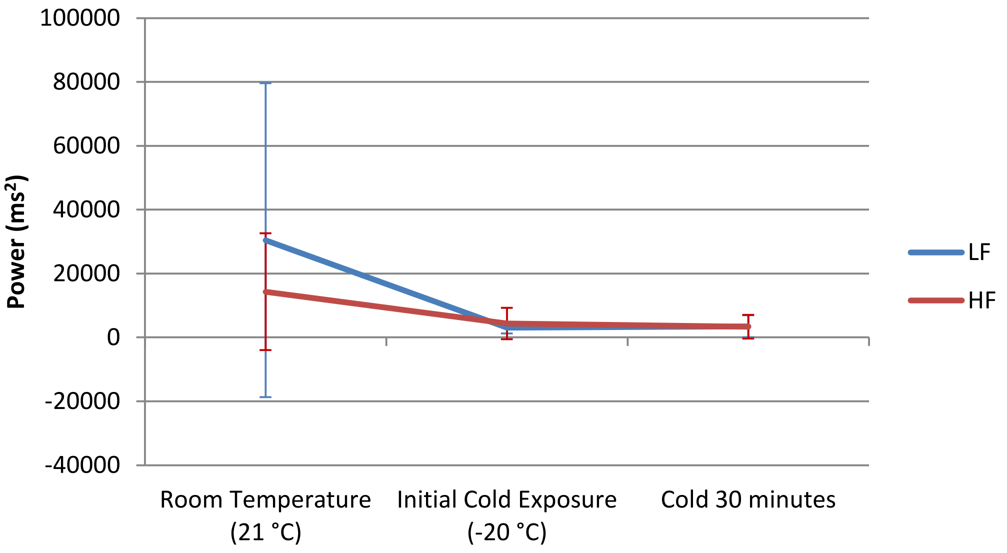


Figure 4.6. **Mean (SD) of the LF (0.04 – 0.15 Hz) and HF (0.15 – 0.4 Hz) power during room temperature conditions, on initial cold exposure and after 30 minutes cold exposure at −20 °C (*N* = 8).**

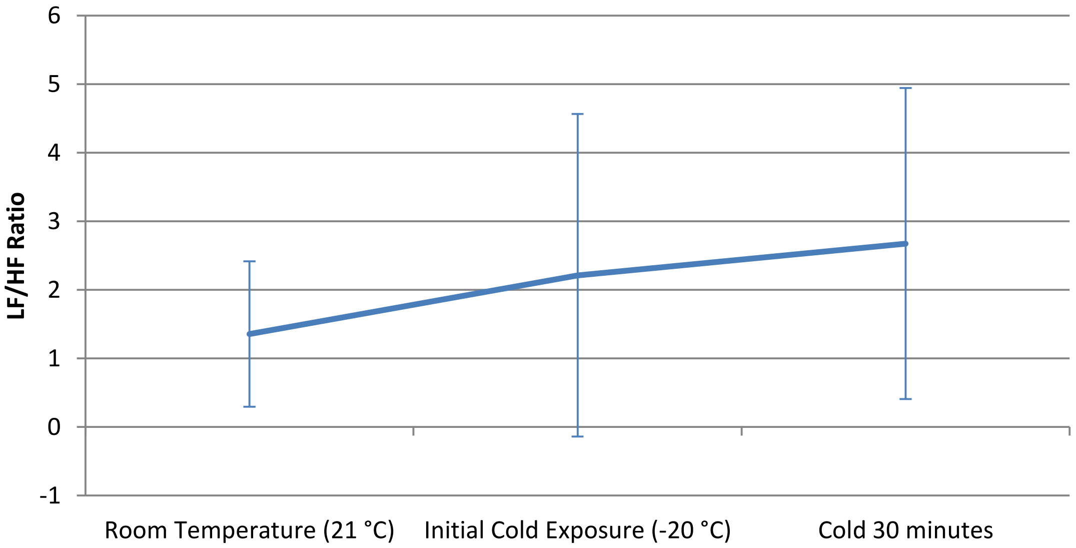


Figure 4.7. **Mean (SD) of the LF/HF Ratio during room temperature conditions, on initial cold exposure and after 30 minutes cold exposure at −20 °C (*N* = 8).**

Postural Control

Two Feet Eyes Open Quiet Standing Balance Test

COP sway rate.

The ANOVA for lateral sway showed significant differences for Time ($F_{2,\ 18}$ = 7.02, P = .006, η^2_p = .438, Power = .878), Condition ($F_{1,\ 9}$ = 13.98, P = .005, η^2_p = .608, Power = .913) and the interaction Time x Condition ($F_{2,\ 18}$ = 6.30, P = .008, η^2_p = .412, Power = .839). In figure 4.8 it can be seen that the lateral sway rate in the cold condition was lower for the initial test and that the sway rate reduced during the cold exposure. The polynomial contrast analysis identified a linear effect for Time ($F_{1,\ 9}$ = 13.74, P = .005) and a linear effect for interaction ($F_{1,\ 9}$ = 10.66, P = .010) which indicates a linear between conditions effect with the difference between conditions increasing in a consistent manner over time.

The ANOVA for Fore / aft sway also showed significant differences for Time ($F_{2,\ 18}$ = 6.87, P = .006, η^2_p = .433, Power = .870), Condition ($F_{1,\ 9}$ = 11.98, P = .007, η^2_p = .517, Power = .868) and the interaction Time x Condition ($F_{2,\ 18}$ = 3.93, P = .038, η^2_p = .304, Power = .630). Figure 4.9 shows that although the fore / aft sway rate was no lower for the initial test the rate of sway reduced during the cold exposure. Polynomial contrast analysis identified linear effects for Time ($F_{1,\ 9}$ = 19.84, P = .002) and for interaction ($F_{1,\ 9}$ = 7.02, P = .026). The between conditions change appears to exhibit a consistent magnitude of change over time.

As participants were exposed to the prolonged cold condition their ability to change the direction of travel appears to have been impaired.

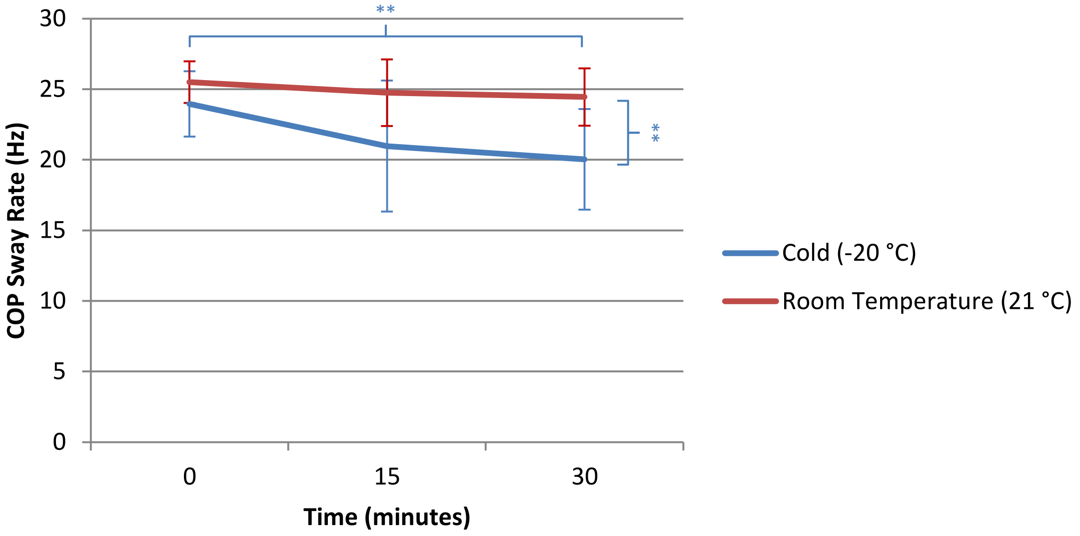


Figure 4.8. **Mean (SD) lateral sway rate in cold and room temperature conditions for both eyes open balance test (*N* = 12).**

**$P < .01$ linear effects

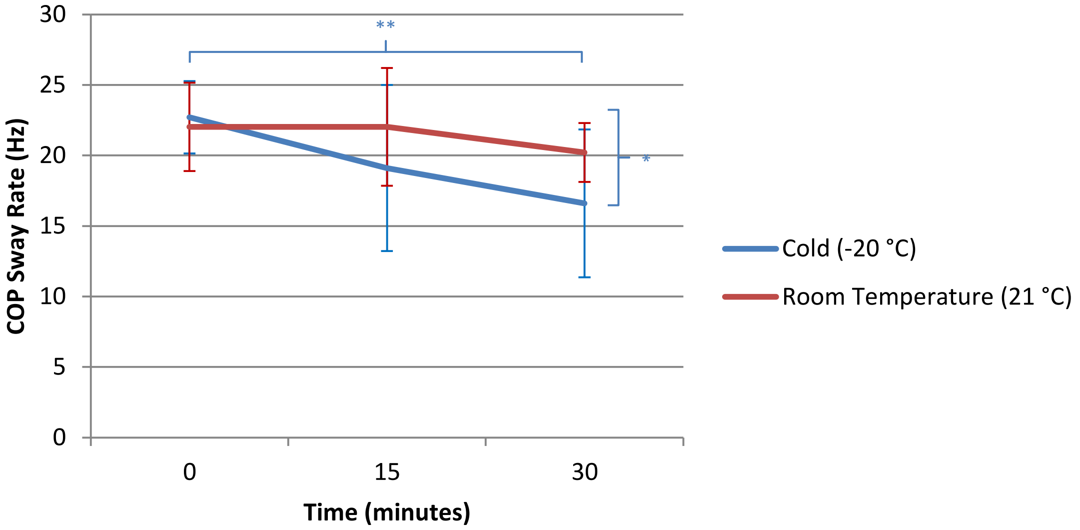


Figure 4.9. **Mean (SD) fore / aft sway rate in cold and room temperature conditions for both eyes open balance test (*N* = 12).**

**$P < .01$ linear effect; *$P < .05$ linear effect

Total distance travelled by the COP.

The ANOVA for total lateral distance travelled by the COP showed significant differences for the main effects of Time ($F_{2,18}$ = 4.55, P = .025, η^2_p = .336, Power = .698) and Condition ($F_{1,9}$ = 12.25, P = .007, η^2_p = .576, Power = .875). The interaction time x condition ($F_{2,18}$ = 3.44, P = .054, η^2_p = .276, Power = .569) was at the borderline for significance. Figure 4.10 shows that the lateral distance travelled during postural maintenance was greater during all of the cold exposure but there was a marked increase in distance travelled between the initial exposure and the 15 minutes test. The interaction contrast has been included as Cark-Carter (1997) suggests that for pre-planned comparisons contrast analysis is still a valid statistical measure even when the ANOVA was not statistically significant. Polynomial contrast analysis identified linear effects for Time ($F_{1,9}$ = 4.99, P = .052) and for Interaction the linear contrast was approaching significance ($F_{1,9}$ = 4.64, P = .060); between conditions differences appear to increase in a consistent manner over time.

The ANOVA for total fore / aft distance travelled by the COP showed significant differences for the main effects of Time ($F_{2,18}$ = 4.19, P = .032, η^2_p = .318, Power = .661) and Condition ($F_{1,9}$ = 15.72, P = .003, η^2_p = .636, Power = .940). The interaction Time x Condition ($F_{2,18}$ = 3.04, P = .073, η^2_p = .253, Power = .516) was approaching statistical significance. Figure 4.11 shows that the fore / aft distance travelled during postural maintenance was greater in the cold condition even on initial exposure and that there was a steady increase in distance travelled during the continued cold exposure. The polynomial contrast analysis confirmed this was a linear effect for Time ($F_{1,9}$ = 6.26, P = .034) and for Interaction the linear contrast was on the borderline of significance ($F_{1,9}$ = 4.76, P = .057). It appears that the between conditions difference increases consistently over time.

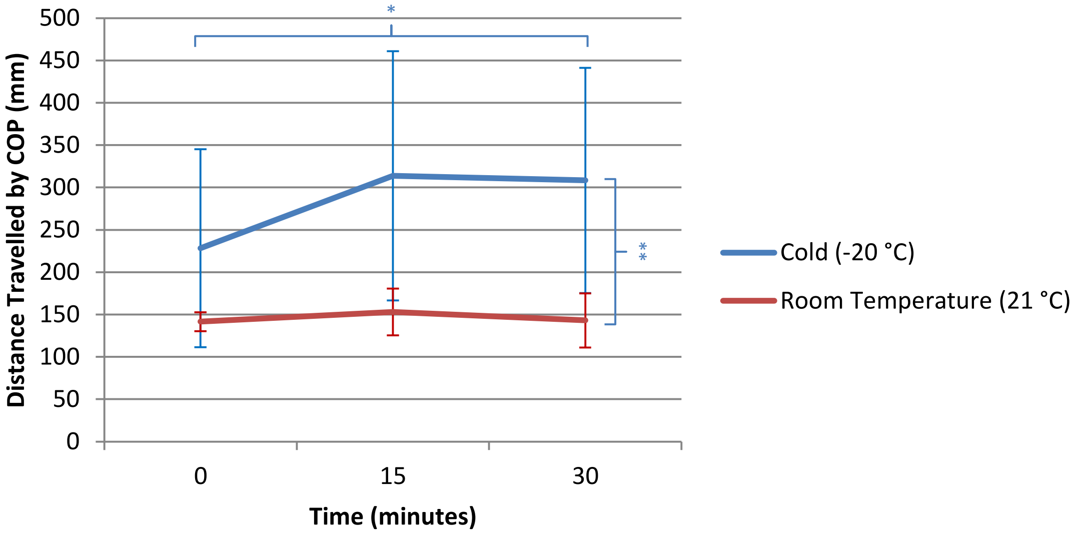


Figure 4.10. **Mean (SD) total lateral distance travelled by the COP in cold and room temperature conditions for both eyes open balance test (*N* = 12).**

***P* < .01 linear effect; **P* < .05 linear effect

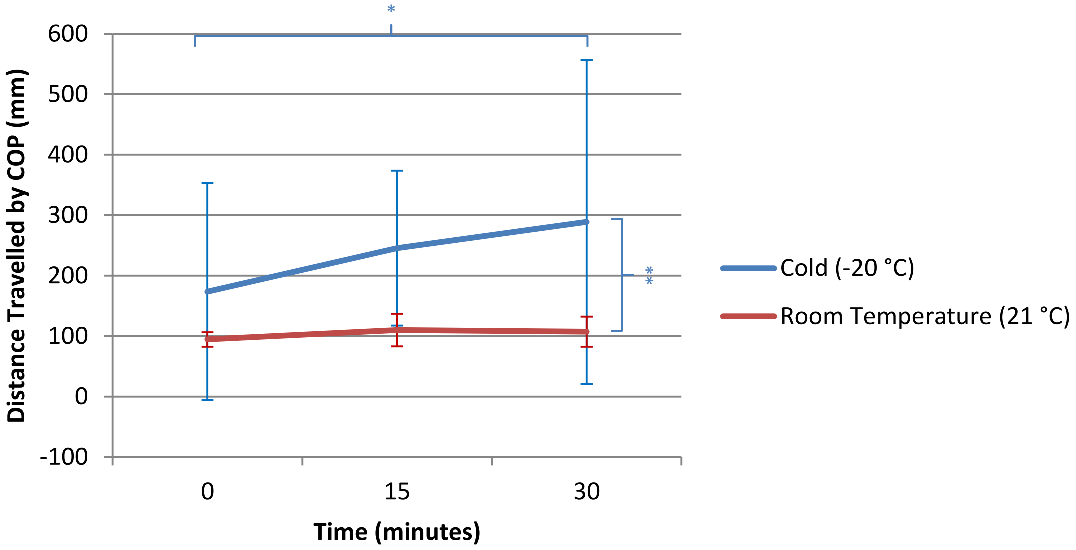


Figure 4.11. **Mean (SD) total fore / aft distance travelled by the COP in cold and room temperature conditions for both eyes open balance test (*N* = 12).**

***P* < .01 linear effect; **P* < .05 linear effect

Two Feet Eyes Closed Quiet Standing Balance Test

COP sway rate.

In the eyes closed condition the ANOVA for lateral sway showed significant differences for Time ($F_{2,\ 18} = 6.06$, $P = .010$, $\eta^2_p = .402$, Power = .824), Condition ($F_{1,\ 9} = 34.33$, $P < .0005$, $\eta^2_p = .792$, Power = .999) and the interaction Time x Condition ($F_{2,\ 18} = 3.63$, $P = .047$, $\eta^2_p = .288$, Power = .594). Figure 4.12 shows similar starting COP sway rates followed by a steady decrease in lateral sway rate during cold exposure. Polynomial contrast analysis showed linear effects for Time ($F_{1,\ 9} = 16.11$, $P = .003$) and for Interaction ($F_{1,\ 9} = 6.22$, $P = .034$) indicating a consistent between conditions change over time.

The ANOVA for fore / aft sway showed a significant difference for the main effect Time ($F_{2,\ 18} = 5.24$, $P = .016$, $\eta^2_p = .368$, Power = .482). The main effect Condition ($F_{1,\ 9} = 4.60$, $P = .061$, $\eta^2_p = .338$, Power = .824) and the interaction Time x Condition ($F_{2,\ 18} = 2.89$, $P = .082$, $\eta^2_p = .243$, Power = .494) were both approaching significance with small to medium and medium effect sizes. Figure 4.13 shows the decline in fore / aft sway rate during the cold exposure. Pre-planned polynomial contrast analysis (Clark-Carter, 1997) showed linear effects for Time ($F_{1,\ 9} = 17.20$, $P = .002$) and a borderline linear contrast for Interaction ($F_{1,\ 9} = 4.74$, $P = .057$) indicating consistent between condition changes over time. Figures 4.12 and 4.13 do seem to indicate a steady decline in sway rate for the two feet eyes closed quiet standing balance test compared to relatively stable room temperature performances. The reduction in sway rates are around 25% of the starting values after 30 minutes of cold exposure at -20 °C.

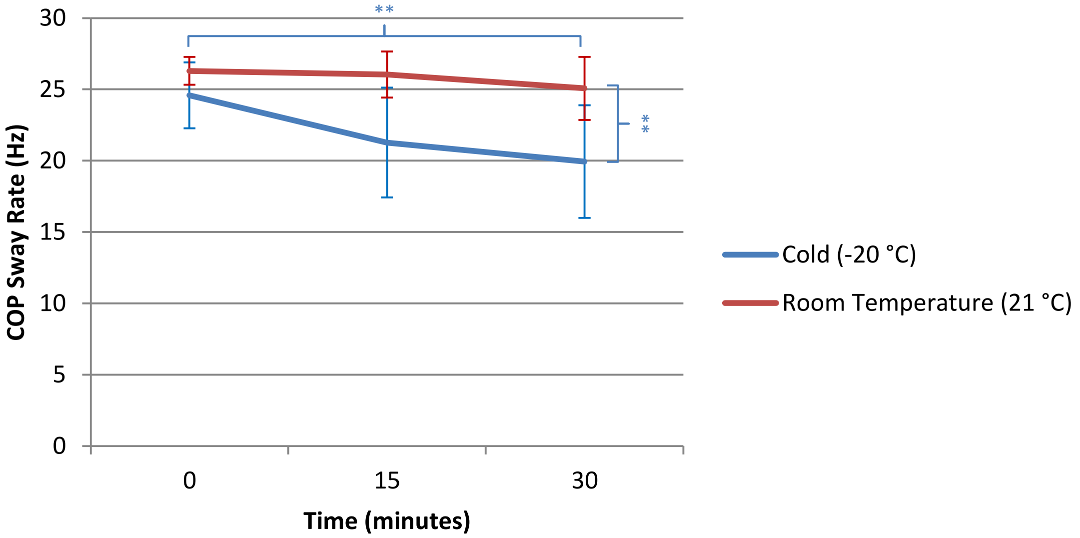


Figure 4.12. **Mean (SD) lateral sway rate in cold and room temperature conditions for both eyes closed balance test (*N* = 12).**

**$P < .01$ linear effects

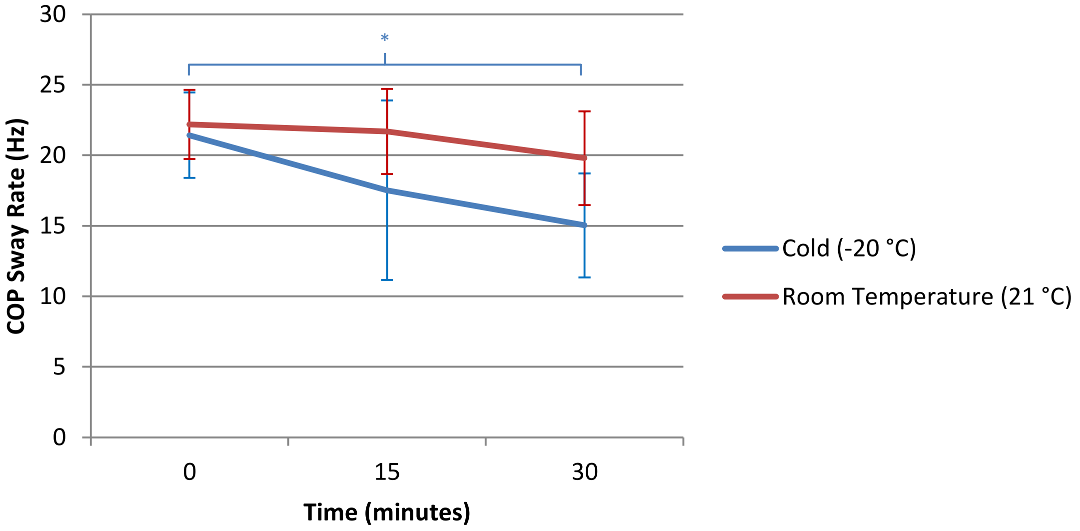


Figure 4.13. **Mean (SD) fore / aft sway rate in cold and room temperature conditions for both eyes closed balance test (*N* = 12).**

*$P < .05$ linear effect

Total distance travelled by the COP.

The ANOVA for total lateral distance travelled by the COP showed significant differences for both main effects Time ($F_{2, 18} = 4.62$, $P = .024$, $\eta^2_p = .339$, Power = .705) and Condition ($F_{1, 9} = 31.11$, $P < .0005$, $\eta^2_p = .776$, Power = .998), and also for the interaction Time x Condition ($F_{2, 18} = 4.95$, $P = .019$, $\eta^2_p = .355$, Power = .737). After 15 minutes of cold exposure the distance travelled by the COP during the two feet eyes closed quiet standing balance test had more than doubled from the room temperature values (figure 4.14). Although the mean distances in figures 4.14 and 4.15 suggest more increase in the first 15 minutes polynomial contrasts showed these were statistically linear effects for Time ($F_{1, 9} = 7.51$, $P = .023$) and Interaction ($F_{1, 9} = 8.35$, $P = .018$) indicating a consistent increase in between conditions differences over time.

The ANOVA for total fore / aft distance travelled by the COP showed a significant difference for the main effect Condition ($F_{1, 9} = 17.65$, $P = .002$, $\eta^2_p = .662$, Power = .961). The main effect Time ($F_{2, 18} = 2.81$, $P = .087$, $\eta^2_p = .238$, Power = .483) was approaching significance and the interaction Time x Condition ($F_{2, 18} = 2.21$, $P = .139$, $\eta^2_p = .197$, Power = .391) was not significantly different. Figure 4.15 shows that the fore /aft distance travelled during the cold exposure was greater than in the room temperature condition. Cohen (1988) defines eta squared (η^2_p) effect sizes between .2 and .3 as a small to medium effect. A small effect is probably a real difference but one that could only be seen in a well-designed study rather than with the naked eye. Figure 4.15 does appear to support the view that the fore / aft distance travelled by the COP increases during the cold condition but the large standard deviation may explain why this isn't significantly different. The polynomial contrast analysis did indicate a linear effect for Time ($F_{1, 9} = 5.13$, $P = .050$) and a linear contrast for Interaction approaching significance ($F_{1, 9} = 4.17$, $P = .072$) which would be indicative of a consistent between conditions change over time.

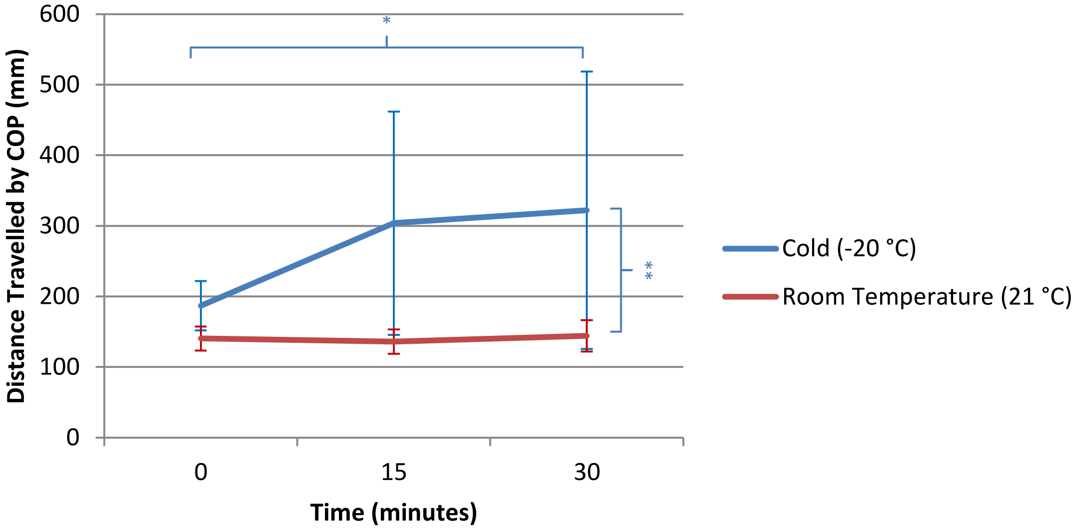


Figure 4.14. **Mean (SD) total lateral distance travelled by the COP in cold and room temperature conditions for both eyes closed balance test (*N* = 12).**

**P < .01 linear effect; *P < .05 linear effect

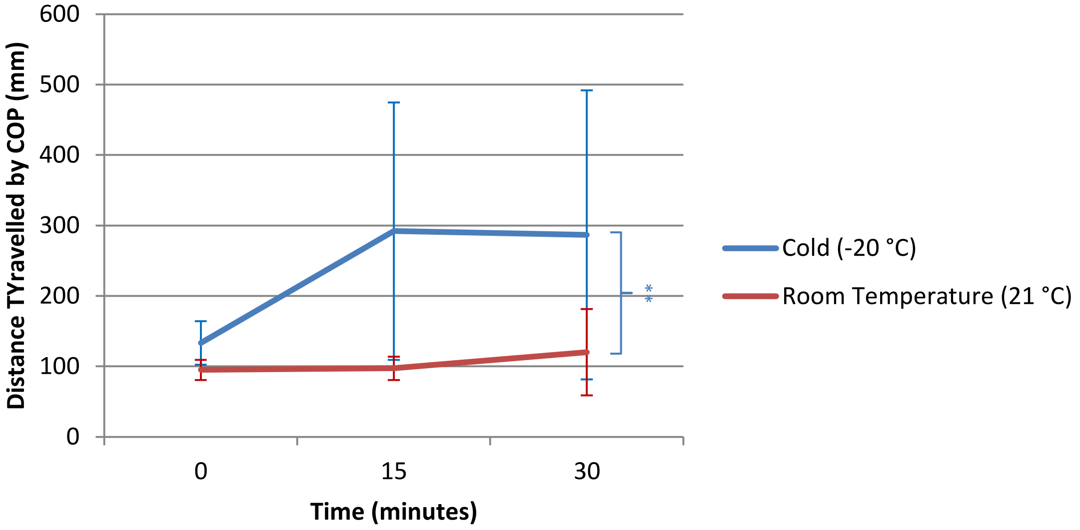


Figure 4.15. **Mean (SD) total fore / aft distance travelled by the COP in cold and room temperature conditions for both eyes closed balance test (*N* = 12).**

**P < .01 linear effect

Single Footed Quiet Standing Balance Test

COP sway rate.

The ANOVA for lateral sway showed no significant differences for the main effects Time ($F_{2, 18}$ = 0.22, P = .809, η^2_p = .023, Power = .079) and Condition ($F_{1, 9}$ = 1.51, P = .251, η^2_p = .143, Power = .196) or the interaction Time x Condition ($F_{2, 18}$ = 0.54, P = .592, η^2_p = .057, Power = .125). The effects sizes (η^2_p) are also very small indicating that there is no real trend for lateral sway rate.

Likewise the ANOVA for fore / aft sway showed no significant differences for the main effects Time ($F_{2, 18}$ = 0.94, P = .409, η^2_p = .094, Power = .187) and Condition ($F_{1, 9}$ = 0.76, P = .406, η^2_p = .078, Power = .123) and very small effect sizes. However the interaction Time x Condition ($F_{2, 18}$ = 2.91, P = .081, η^2_p = .244, Power = .496) was approaching significance with a small to medium effect size. The polynomial contrast for Interaction did show a statistically significant linear effect ($F_{1, 9}$ = 5.35, P = .046) which would be indicative of a consistent between conditions change over time.

Figures 4.16 and 4.17 show there is actually very little difference between the conditions and during the cold exposure. It appears that sway rates on single footed quiet standing tests are not really affected by the cold condition or prolonged exposure.

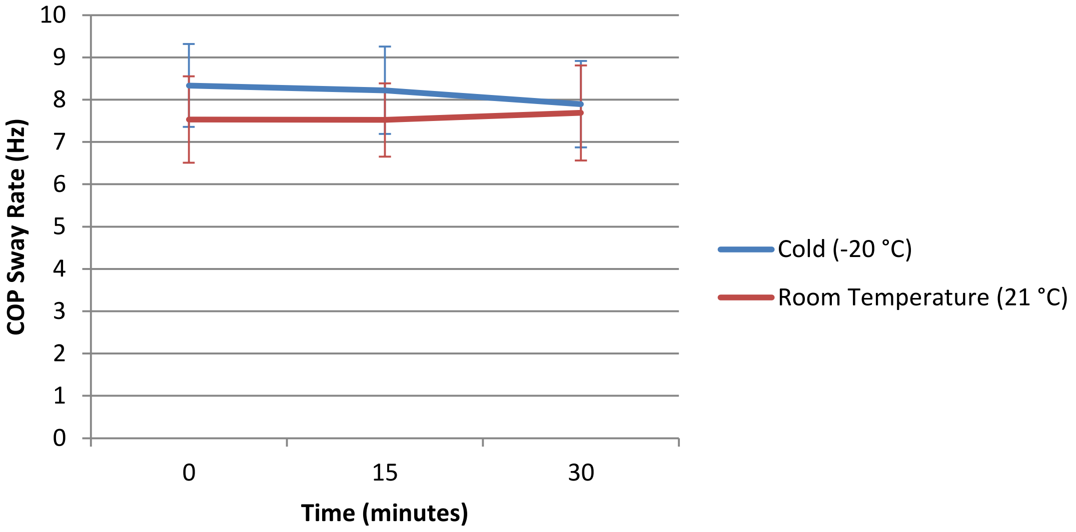


Figure 4.16. Mean (SD) Lateral sway rate in cold and room temperature conditions for single footed quiet standing balance test (N = 12).

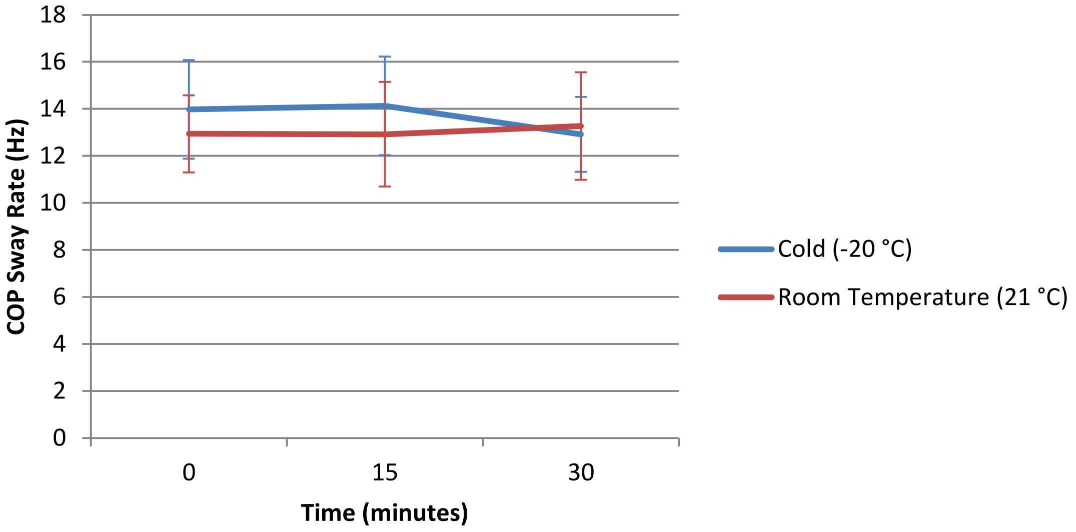


Figure 4.17. Mean (SD) fore / aft sway rate in cold and room temperature conditions for single footed quiet standing balance test (N = 12).

Total distance travelled by the COP.

The ANOVA for total lateral distance travelled by the COP showed no significant difference for the main effect Time ($F_{2,\,18} = 1.72$, $P = .208$, $\eta^2_p = .160$, Power = .313) but the main effect Condition ($F_{1,\,9} = 8.56$, $P = .017$, $\eta^2_p = .488$, Power = .741) and the interaction Time x Condition ($F_{2,\,18} = 10.40$, $P = .001$, $\eta^2_p = .536$, Power = .970) were both significantly different. Figure 4.18 shows that distance travelled by the COP is very similar on initial exposure but increases during the prolonged cold exposure condition. Polynomial contrast analysis for Interaction showed this was a linear effect ($F_{1,\,9} = 19.51$, $P = .002$) with the distance travelled by the COP in the cold condition increasing at an even rate from 0 to 15 minutes and 15 to 30 minutes against a stable performance in the room temperature condition.

The ANOVA for total fore / aft distance travelled by the COP showed no significant difference for the main effect Time ($F_{2,\,18} = 1.46$, $P = .260$, $\eta^2_p = .139$, Power = .270) but the main effect Condition ($F_{1,\,9} = 9.39$, $P = .013$, $\eta^2_p = .511$, Power = .778) and interaction Time x Condition ($F_{2,\,18} = 9.32$, $P = .002$, $\eta^2_p = .509$, Power = .953) were significantly different. Figure 4.19 shows a consistent increases in fore / aft distance during the cold exposure condition and polynomial contrast analysis for Interaction confirmed that this was a linear effect ($F_{1,\,9} = 11.51$, $P = .008$) indicating a consistent change of between condition differences over time.

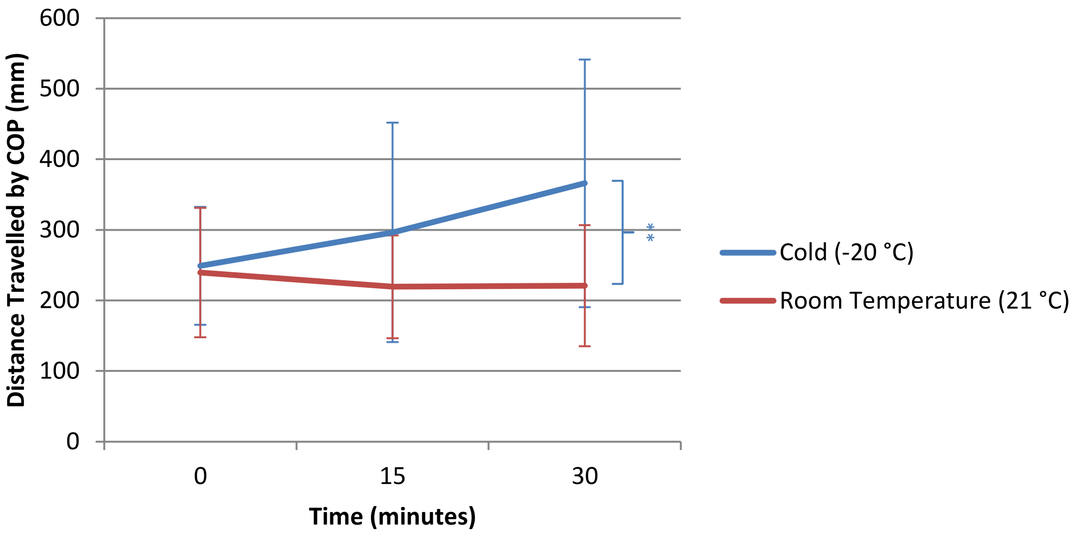


Figure 4.18. **Mean (SD) total lateral distance travelled by the COP in cold and room temperature conditions for single footed quiet standing balance test (*N* = 12).**

**P < .01 linear effect

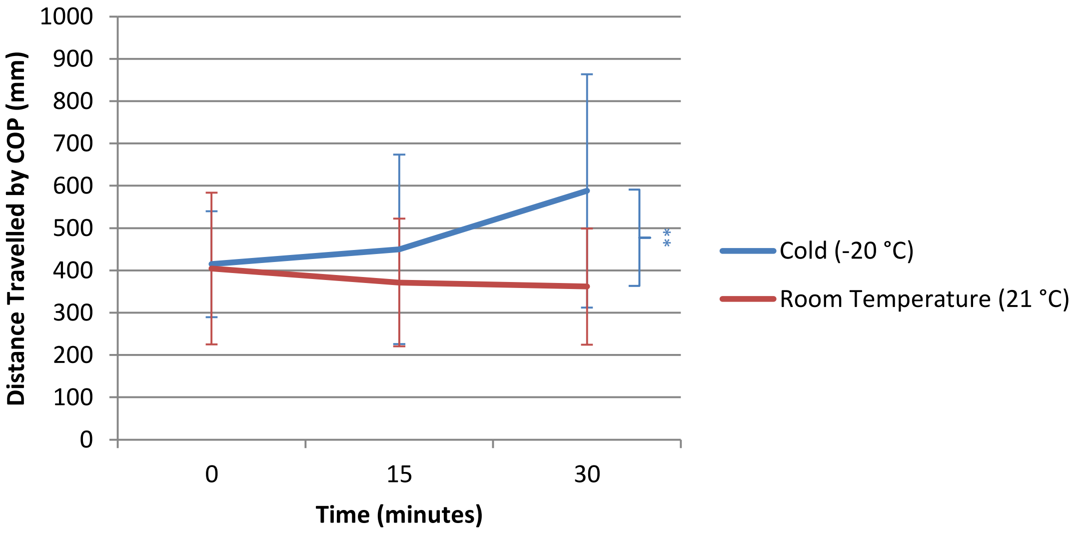


Figure 4.19. **Mean (SD) total fore / aft distance travelled by the COP in cold and room temperature conditions for single footed quiet standing balance test (*N* = 12).**

**P < .01 linear effect

Discussion

The aims of this study were to establish the level of performance decrement to postural control that would occur as a result of acute cold exposure, establish the degree of cooling that participants would experience and the level of stress they would experience during acute cold exposure at -20 °C.

Body Temperature and Thermal Comfort

The main findings were that core body temperatures were not compromised by 30 minutes exposure to -20 °C in light clothing. Not only was there no significant difference for core temperature there were no trends towards lower core temperatures or increases in variability within the group. This finding supports Ellis' (1982) reports that participants exposed to -12 °C for 90 and 120 minutes wearing light athletic clothing (shorts and bare feet) maintained steady core temperatures during the initial exposure (Ellis failed to provide exact times for the onset of core temperature changes).

Skin temperatures at the head, calf and foot showed significant change over time with temperatures at the foot reaching the lowest recorded values of 10.1 ± 3.5 °C a drop of 16 °C from a starting temperature of 26.1 ± 3.5 °C in the room temperature (21 °C) environment. Head and calf temperatures showed a decrease of around the same magnitude but started at higher values and so didn't reach the same low terminal temperature after 30 minutes cold exposure.

The drop in skin temperatures alongside the effective maintenance of core body temperatures suggest that the vasoconstriction responses prioritising the core body temperature described by Charkoudian (2010) and Parsons (2003) are sufficient to protect core body temperature during 30 minutes of continuous exposure at -20 °C. The problem with this response is that the extremities, particularly the feet of participants, became very cold during the cold exposure condition. Enander (1989) suggested a critical temperature of 8 - 10 °C for hands below which the tactile sensitivity of skin is impaired and in the current study participants' feet reached this critical temperature by 30 minutes in the cold exposure condition.

Unsurprisingly thermal comfort (nine point perception of thermal comfort scale: Jendritzky et al., 2001) was affected with thermal comfort scores reducing with increasing exposure time at -20 °C. After thirty minutes of exposure half the participants rated thermal comfort as low as the scale allowed (very cold). There was a surprising amount of variation in thermal comfort ratings amongst a minority of participants who still rated their comfort above the bottom two ratings on the scale. One participant rated thermal comfort after 30 minutes cold exposure at -20 °C at 4 on the rating scale (slightly cool), this might be viewed simply as a participant boasting but interestingly this participant had maintained the highest foot temperature rating after 30 minutes of anyone in the study (15.0 °C). However, their head and calf temperatures were relatively low compared with others. Perhaps this individual experienced less vasoconstriction than others leading to warmer feet but cooler muscles. There was no evidence that their core temperature had dropped during the -20 °C condition. A question here might be as to what extent participants in acute cold relate their thermal comfort to the coldest part of their bodies and to what extent it is a global measure of their status In fact Arens, Zhang and Huizenga (2006) reported that in their study of 27 participants who took part in a series of tests at different ambient and localised temperatures overall thermal comfort followed the sensation in the most uncomfortable body part and that in the cold this was very often the feet.

The majority of thermal comfort ratings towards the end of the cold exposure protocol, and observations of participants from the team in the laboratory, suggested that participants were close to or at the end of the limits of their ability to withstand the conditions within the environmental chamber. All of the participants, with one exception, reported painfully cold feet and had clearly visible impairment in the circulation of their toes. One participant had to be removed from the chamber after 20 minutes because of the condition of her feet and realistically only one participant was likely to have made it to 45 minutes (final testing began with temperature readings at the 30 minute mark but participants remained in the chamber to complete tests for approximately five minutes meaning total exposure time was 35 minutes). Anecdotally the experience of working with fit and healthy participants in the environmental chamber during this study at -20 °C leads to unanswered questions regarding how Ellis (1982) was able to have participants complete the long exposure times of 90 minutes and 120 minutes at -12 °C during his studies given that his participants wore only shorts.

Heart Rate and Heart Rate Variability

Acquisition of beat-by-beat heart rate data proved to be difficult in the cold condition and as a result only eight participants provided viable data for heart rate and heart rate variability measures. As a result caution needs to be adopted with adopting *P* scores as definitive indicators of the meaningfulness of HRV changes. There were no significant differences for heart rate variability measures but changes in the absolute values for these variables generally indicated movement towards higher stress levels during the cold exposure condition and effect sizes showed promise with a number of these being greater than the $\eta^2_p = .3$ value that Cohen (1988) describes as medium.

Mean RR interval reduced by 94 milliseconds, a change of 12%. This reduction of the beat-to-beat interval represents an increase in heart rate rather than a variability component. As participants completed the cold exposure their heart rate increased despite a very controlled environment with no increased exercise load; participants were required to stand on the spot during the cold exposure condition and were prevented from actively exercising to increase their metabolic rates. These results a similar to those of Huang et al. (2011) who reported non-significant changes in the RR interval, LF, HF and LF / HF ratio when participants experienced localised cold stress from having their arms immersed in water at 7 °C. In fact the Huang et al. study found no significant changes but did report non-significant changes for measures where these were apparent; HF and LF / HF ratio had *P* scores less that 0.1. Yamazaki and Sone (2000) who used whole body cooling did report differences for heart rate but unlike the present study they found heart rate was actually reduced. Once difference was that they used a protocol for cooling involving a water filled body suit at 10 °C rather than a cold air environment at -20 °C. Because of the increased thermal conductivity of water (Somers, 2014) this is still a considerable thermal stressor but arguably the level of psychological stress involved may be different.

Standard deviation of an individual’s RR interval (SDNN) is the most basic measure of variability of the RR interval. During the current study SDNN reduced by 61 milliseconds during cold exposure, a change of 38% but not a statistically significant result. The effect size (η^2_p) for this measure of .391 would be classified as a medium size effect (Cohen, 1988) and could be indicative of a meaningful trend which would be significant in a larger study. Lower SDNN scores are normally viewed as indicative of higher stress (Lopes & White, 2005).

Frequency domain analysis is thought to provide information about sympathetic and parasympathetic functioning (Crawford et al., 1999). There was a trend toward reduced LF and HF power spectrum components during the exposure in the cold chamber but these were not significant although the effect size (η^2_p) for HF power was .302 which would be viewed as a medium effect (Cohen, 1988). This finding is the opposite of the results in the Huang et al. (2011) study who reported non-significant increases in LF and HF power, Yamazaki and Sone (2000) who reported significant increases in LF and HF power and Matsumoto, et al. (1999) who reported significant increases in HF power. The LF power component is often viewed as a sympathetic nervous system activity indicator (the fight-or-flight system) but there is some evidence that it can include a small element of parasympathetic activity (Malliani et al., 1994; Lopes & White, 2005).

The HF power component is less controversially interpreted as a parasympathetic nervous system indicator (Lopes & White, 2005). Higher levels of parasympathetic activity are normally viewed as more restful and relaxed. Higher levels of HF activity would be expected to depress the heart rate and so the lower values found in the cold condition (non-significant but high effect size) make sense alongside the shorter RR intervals recorded. Participants were less relaxed during the cold condition and this finding is exactly what could be expected from the thermal comfort ratings and observed behaviours.

During the present study LF / HF ratio was numerically higher but not significantly different in the cold condition and during prolonged exposure. The changes were not statistically significant but the medium effect size (η^2_p = .302) could be indicative of a meaningful trend (Cohen, 1988). The increasing ratio would indicate increasing LF dominance: a move towards the sympathetic (fight-or-flight) system becoming dominant and a classic stress response. Interestingly, Huang et al. (2011) and Yamazaki and Sone (2000) reported non-significant decreases in the LF / HF ratio in their studies which would normally indicate increasing parasympathetic dominance. This difference in the current study may relate to the higher levels of thermal stress elicited from full body cooling at -20 °C than in the previous cold and HRV research.

These effect sizes indicate that HRV may be worth considering as a variable in a larger study designed to specifically examine HRV during cold air exposure. However a possibility is that HRV responses to cold exposure may just be to variable and prone to individual differences to provide statistically significant results. A study with a larger sample size may be able to identify different types of responder within the main group.

Postural Control

Postural control in all three balance tasks was affected by exposure in the cold condition. In the two footed balance tasks both sway rates and distances travelled by the COP showed changes. Lateral and fore / aft sway rates reduced during the cold condition to a level showing statistical significance or approaching it (fore / aft sway rate in the eyes closed test was approaching a statistical difference for main effect condition and interaction). Lower sway rates indicate that the ability to respond quickly to postural control information from the sensory system has deteriorated (Shupert & Horak, 1999). Lateral sway rates were around 25 Hz in the room temperature condition and reduced to 20 Hz after 30 minutes at -20 °C, a 20% reduction. The decline in fore / aft sway rate was slightly greater as a proportion of the starting values with room temperature sway rate around 21 Hz and sway rates after 30 minutes of cold exposure around 15 to 16 Hz, a change of around 25%.

Distances travelled by the COP increased during the cold exposure condition and at the end of the 30 minute period the values for these variables had increased in comparison to the room temperature performances by approximately 100%. This held true for both the eyes open and closed quiet standing balance tests. Distances travelled by the COP are a measure of how much movement an individual makes whilst maintaining their upright position. Generally in quiet standing balance tests increased distances indicate a poorer performance as it is a sign the system is unable to respond quickly enough with appropriately scaled responses (Hrysomallis, 2011). Distance travelled in room temperature conditions was between 100 and 150 mm and increased to around 300 mm. These increases in distance travelled by the COP seem reasonable when compared to those of Mäkinen et al. (2005) who reported increases in path length (a synonym for distance travelled used by some postural control writers) of between 51% and 87% after 90 minutes of exposure at 10 °C. Mäkinen et al. found that eyes closed sway rate increased more than eyes open rates but this wasn't the case in the current study. Eyes closed balance tasks are generally viewed as testing the ability of participants to switch attentional systems from visual to internal cues (Donker et al., 2007). Paillard et al. (2011) showed that higher level surfers were more able to maintain their posture during eyes closed conditions than less trained surfers and they attributed this difference to the increased ability of the higher level surfers to use proprioceptive information. The results of the current study might be explained by the difference in cold temperatures that other studies have used. In the current study the very low skin temperatures elicited by the -20 °C may limit the usefulness of some proprioceptive information, particularly tactile sensations from the soles of the feet that would otherwise be used to compensate when the eyes are closed.

Changes in postural control during single footed tests seem to follow a slightly different pattern to the two footed tests with the sway rates being relatively unaffected but the distances travelled by the COP still showing changes with differences between conditions and interaction effects for lateral and fore / aft measures. Intuitively we might expect to see more change in the performance of the more difficult test of balancing on one foot and less obvious changes in the two footed tests but this does not seem to be the case in terms of sway rate. The best explanation for this seems to be that the sway rates in single foot tests are already much lower at room temperature than in the two footed tests and that therefore any changes in postural control tend to be reflected in the distances travelled by the COP. Lateral sway rates were consistently around 8 Hz and fore / aft sway rates were around 13.5 Hz. These sway rates were also consistent with the results of the reliability study where participants had lateral COP sway rates of 7 Hz and fore / aft COP sway rates of 13 Hz (Figure 3.7, page 61).

The distances travelled by the COP increased from around 250 mm and 400 mm in the room temperature condition to 350 mm and 600 mm after 30 minutes of cold exposure. This represents a 40% and 50% relative increase in these measures. Although relative increases are smaller than the increases seen in the two footed tests the absolute increase of 200 mm in fore / aft distance travelled by the COP scores is larger than the increase for two footed tests in the cold condition and in fact is actually greater than the starting values for the two footed tests in the room temperature condition.

Shupert and Horak (1999) identified a number of problems with different postural control mechanisms in their study on aging participants. They identified slow response onsets and poor response scaling as characteristics of impaired somatosensory functioning. Similar findings in the current study during cold exposure suggest that the impact of cold on somatosensory information may be a significant part of the explanation for reduced postural control during acute cold exposure. A promising approach to this problem was made by Magnusson, Enbom, Johansson and Pyykkö (1990) who carried out a study to examine the impact of mechanoreceptors by cooling the feet in in an ice-water mix. Participants showed increased fore / aft sway velocities when feet were cooled, however this study did not examine sway rates so it is not completely comparable. Particularly in terms of participants' ability to initiate changes of direction which sway rate addresses.

Muscular functioning is an aspect of performance that should really be considered during full body cold exposure. In the current study skin temperatures of the calf were around 17.1 °C after 30 minutes of cold exposure. In a study designed to reduce muscle temperatures in isolation Dewhurst et al. (2007) cooled the legs of participants with 'ice blankets' but no significant differences were found for postural control variables. Enander (1989) suggests that the critical temperature for manual dexterity in the hands is 12 – 15 °C and so it may be that with skin temperatures of 17.1 °C the muscle temperatures in larger muscle mass areas like the legs are simply not reduced to a level where motor function becomes a problem.

Conclusion

In conclusion, core body temperatures were unaffected by 30 minutes of cold exposure at -20 °C but skin temperatures at the head, calf and foot dropped significantly. Thermal comfort was reduced significantly and many participants rated this at the limit of the scale after 30 minutes. Overall postural control became worse in the two feet eyes open quiet standing balance test, two feet eyes open quiet standing balance test and single footed eyes open quiet standing balance tests during cold exposure. Distances travelled by the COP were greater after cold exposure in every case but sway rates were unaffected for single footed tests. Heart rate variability indices showed non-significant movement towards reduced variability and sympathetic dominance (the fight-or flight response) but no significant differences. Medium effect sizes indicate that HRV shows some promise as a physiological marker for stress during full body cold exposure.

Impaired postural control during acute cold exposure may be a result of limited somatosensory information when skin temperatures of the feet drop to critical levels. Isolated cooling of the feet may provide an opportunity to explore this effect and try to replicate the impact of loss of somatosensory information on postural control whilst avoiding any whole body effects such as attentional deficits or deep tissue cooling in the muscles of the feet.

CHAPTER 5

THE EFFECTS OF ISOLATED COOLING OF THE FEET ON POSTURAL CONTROL DYNAMICS

Introduction

It was clear from the results of the study in chapter 4 (the effects of acute cold exposure on body temperature, postural sway dynamics during quiet standing, and heart rate variability) that the temperature of participants' feet dropped considerably during whole body exposure to acute cold at -20 °C. As it seemed probable that this cooling of the feet contributed significantly to the impaired performance on the postural control tasks during the cold condition cooling the feet of participants alone seemed an appropriate way to examine the contribution of this element whilst eliminating other effects.

During the cold condition of study 2 skin temperatures of the foot had reduced to 10.1 ± 3.5 °C after 30 minutes of exposure at -20 °C (chapter 4, page 75) and so a skin temperature for the feet of 10.0 °C was taken as an initial target temperature for this study. An ice bath protocol where both feet were immersed in a mixture of ice and water was chosen as a basic method to reduce the skin temperature of the feet as this was expected to provide both localised, and relatively quick, cooling of the feet (Cross, Wilson & Perrin, 1996; Kernozek, Greany, Anderson, Van Heel, Youngdahl, Benesh & Durall, 2008). The increased rate of cooling in water is due to the thermal conductivity differential of water of water being around 24 times that of air (0.024 $W \cdot m^{-1} \cdot K^{-1}$ for air; 0.58 $W \cdot m^{-1} \cdot K^{-1}$ for water: Somers, 2014). Magnusson, Enbom, Johansson and Pyykkö (1990) had shown some postural sway changes in a study using ice bath cooling but these weren't directly comparable because of their limited choice of dependent variables and balance tasks. For example Magnusson, Enbom, Johansson and Pyykkö did not consider sway rates or single footed balance tests. Sway rates are a key indicator of the postural control systems ability to respond to sensory information quickly.

The aim of this study was to investigate the impact on performance that would occur due to the cooling of the feet in isolation. The hypothesis for this study was that similar changes to postural control dynamics would be seen when participants' feet were cooled without the extra effects of whole body cooling that occurred in the environmental chamber, for example reduced temperatures at the head and calf.

Method

Participants

For this study twelve participants (12) were recruited from the undergraduate population at the University of Chichester. Ten were male and two were female. All were unpaid volunteers. The mean age of participants was 22.2 ± 0.8 years and weight was 79.7 ± 8.5 kg. As in the previous study (the effects of acute cold exposure on body temperature, postural sway dynamics during quiet standing, and heart rate variability) participants were screened for history of cold injuries (chapter 4, page 67).

Overall Experimental Design

The basic experimental design for this study followed that of study 2 (The Effects of Acute Cold Exposure on Body Temperature, Postural Sway Dynamics during Quiet Standing, and Heart Rate Variability) where practical. A repeated measures counterbalanced crossover design was employed with participants completing two phases of testing: one in the cold condition involving ice bath cooling and the other at room temperature.

Ice Bath and Cooling Protocol

During initial pilot testing cooling participants' feet enough to reach skin temperatures of 10.0 °C in standard laboratory conditions (room temperature at 21 °C) proved unexpectedly difficult. Initially adjustments to the ice bath were necessary to achieve consistent cooling. When participants sat with their feet placed on the bottom of the ice bath it seemed that a boundary layer of water built up under the soles of the feet that impeded further cooling. A cooling protocol was then piloted where participants were asked to maintain their feet in a fixed position in the ice bath without contact with the bottom. The ice-water mix was also stirred regularly to prevent the formation of a boundary layer. Although the cooling process was more effective with these changes maintaining the fixed position proved very difficult for participants and it seemed likely that this would result in inconsistent bathing of the feet as participants inevitably moved their feet up or down in the ice bath.

The foot position problem was eventually solved by placing a metal grill in the ice bath at a height of 10 cm from the bottom to create a false floor that water could pass freely through but would support the feet. This meant that the feet were effectively suspended above the bottom of the bath at a fixed height and without any need for the participant to control this process or muscular tension. Ice-water could also be circulated under the soles of the feet achieving cooling of all the foot surfaces. The false floor grill allowed complete control and consistency of the depth of immersion that each participant’s feet underwent.

It was found that water temperatures in the ice bath could be effectively reduced to approximately 1.0 °C by mixing ice into cold tap water at around a 1:5 ratio but once participants feet were immersed then the ice would begin to melt and after approximately 3 – 4 minutes the temperature of the water would increase to 5 – 6 °C. Whilst having higher ice to water ratios didn’t produce colder water temperatures it did buffer the warming effect of the feet. In practice it was found necessary to have a high ice ratio to begin with (close to 1:1) and as soon as the ice was seen to be visibly reduced then more ice was added and water was removed as necessary to maintain a consistent immersion level. Using this method of replacing water with ice at regular intervals it was possible to maintain a foot bath temperature of 0.9 °C during cooling.

An immersion time of 10 minutes in water at 0.9 °C proved to be effective at producing the required skin temperatures. However, maintaining the reduced foot temperature long enough for participants to complete four balance tests (approximately 4 minutes) was another problem. It became clear that once the feet were removed from the ice bath they tended to warm up quite quickly and after 3 minutes they could no longer be considered representative of the 10 °C skin temperature that the study was intended to replicate. With no other thermal stressor than the residual cold effect of the participants’ feet then vasodilation of the feet would set in with visible flushing and a corresponding increase in skin temperature. Longer exposure times had no effect on skin temperature or the speed of rewarming and the problem was eventually resolved by creating a protocol that consisted of completing two balance tests then a period of ‘top up’ re-cooling before completing the last two tests. It was established that after 2 minutes of balance tests at room temperature a simple 2 minute period of further cooling was very effective in reducing the skin temperature of feet back to the 10.0 °C target.

Familiarisation

Prior to the experimental sessions participants attended an orientation and familiarisation session. Body mass was measured in normal clothing and participants ages and shoe sizes were recorded. Participants were taught the positions for the quiet standing balance tests and completed 3 trials of each test to eliminate familiarisation effects (for a full explanation refer back to chapter 3, pages 47-63). Standard UoC laboratory health history questionnaires were completed and the purpose of the study was explained (appendix 2, pages 202).

Participants were randomly assigned to a cold first or room temperature first sequence and were given this schedule in advance. As it would be clear to participants before the final visit to the laboratory which protocol to expect it was decided to make this explicit before both sessions in the laboratory and maintain consistency.

Protocol

At the beginning of the testing sessions participants were given a short briefing to remind them of what to expect during the testing. Each participant arrived at the laboratory dressed in shorts so as to leave the lower legs and feet bare for cooling and easier attachment of thermistors. Participants were seated in the laboratory so that they could be prepped for ice bath foot cooling or simply quiet sitting depending on which condition they were participating in. The stance for each of the balance tests was described and demonstrated once again.

Thermistors (Edale Instruments (Cambridge) LTD, Cambridge, UK) were fitted to the skin on top of the cuboid bone of both feet with self-adhesive tape and the leads were taped to the skin of the lower leg so as not to interfere with the cooling or subsequent balance tasks. During piloting it had been clear that the thermistors reported unrealistically low temperatures that did not represent skin temperature if they had been ‘wetted out’ during immersion. Alternatively thermistors fitted ‘dry’ post immersion reported higher temperatures than those that had been immersed even after 2 minutes. The final protocol employed thin waterproof bags during cooling to eliminate the problems of cold water getting between the thermistors and the skin and of the adhesive tape becoming waterlogged. This allowed a more accurate skin temperature to be measured. A further benefit of using the waterproof bags was that it also eliminated the need to dry the feet prior to the balance tests which in turn reduced the delay between cooling the feet and the performance of the balance tests. This was important as, has already been explained, the feet recovered their temperatures quite quickly once removed from the ice bath so faster cooling / testing transitions were a nice side effect. The thin bags proved no real resistance to cooling and the weight of the water in the ice bath eliminated air pockets very effectively allowing unimpaired heat transfer. The temperature data during piloting had indicated no problems with the temperature of the feet obtained at the end of 10 minutes when the bags were used.

For both conditions participants were seated in the laboratory. In the cold condition the participants’ feet were placed in the thin waterproof polyethylene bags and immersed in an ice bath up to the bottom of the ankle bone. Participants were asked to keep their feet on the false floor of the ice bath and the water was maintained at a temperature of 0.9 ± 0.1 °C. Participants were required to complete 10 minutes of immersion or 10 minutes of quiet sitting. Figure 5.1 shows the sequence of cooling / resting and testing that participants completed on each visit to the laboratory. For the room temperature condition participants remained seated for 10 minutes with their feet resting on an insulating foam mat to replicate the period required for cooling the feet in the cold condition.

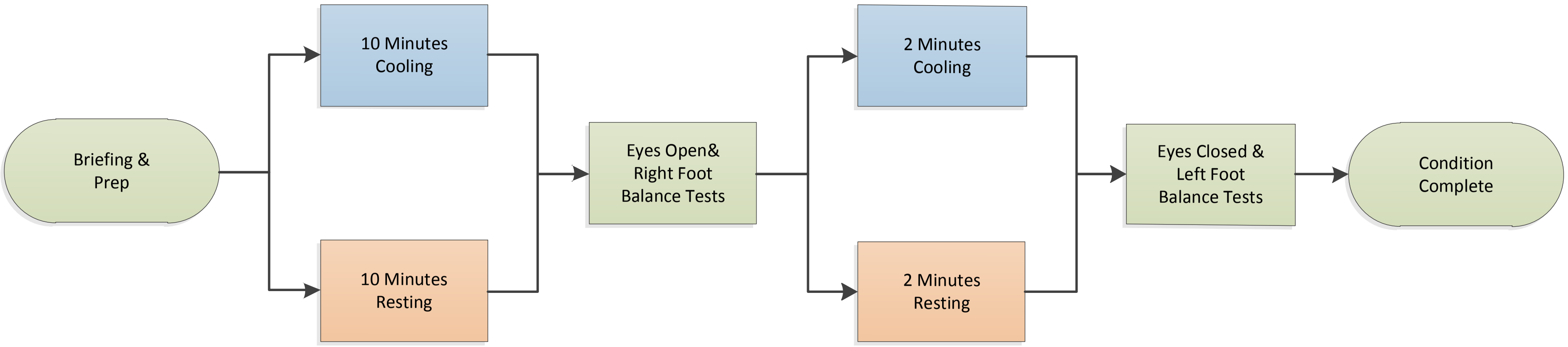


Figure 5.1. **Basic laboratory sequence for both room temperature and cold conditions.**

After the 10 minute cooling or sitting period participants removed their feet from the ice bath and bags (in the cold condition) and moved across to the RS Footscan® plate. They completed the first two balance tests then went back to their seated position. If they were in the cold condition then their feet were placed back in the waterproof bags and into the ice bath. After two minutes of re-cooling or quiet sitting they went back to the RS Footscan® plate and completed the remaining two balance tests.

Measurement

Sway.

In the two previous studies participants had completed the quiet standing balance tests in a set order where both the two footed tests were completed first and then right and left one footed tests. In the environmental chamber the thermal status of participants changed relatively slowly but having identified that the rewarming of participants' ice bath cooled feet was a problem it was decided that this approach needed to be reconsidered for the current study. As the tests would be conducted in batches of two with the re-cooling period in between the choice was between completing one two footed test then the second before re-cooling and completing the one footed tests in turn or reordering the tests to try and maintain more consistency between the more similar tests. It was concluded that it was better to have both the two footed tests completed immediately after the ice bath cooling sessions and the one footed balance tests completed at a consistent one minute after cooling. Tests were conducted in the following sequence; 10 minutes cooling, eyes open two feet eyes open, right foot, 2 minutes cooling, eyes closed two feet, left foot (figure 1). This meant the feet were at a more consistent temperature for the pair two footed tests having just completed cooling (approximately 1 minute) and both of the one footed tests were conducted after a two footed test and approximately 2 minutes after the cooling was completed.

The balance test themselves were set up and carried out as in the validation study (chapter 3, pages 47-63).

Temperature.

Skin temperature was monitored with thermistors and a multi-channel Edale box (model cd). Temperatures were recorded at room temperature, after 5 and 10 minutes of cooling and then prior to re-cooling, at the end of 2 minutes re-cooling at after the final balance tests.

Statistical Analysis

Sway data were exported from the Footscan® 7 balance software package into Microsoft Excel (Microsoft® Office 2010) and the variables sway rate X (lateral) and Y (fore / aft) and distance travelled by centre of pressure X (lateral) and Y (fore / aft) were calculated using the programme described in study 1 (appendix 3, pages 206). Scores for each dependent variable were calculated for each of the four balance tests. Data for the single footed tests were combined as means to create a single foot score for each participant.

Sway data were analysed for differences between conditions using one way ANOVAs for the variables within each stance (appendix 8, pages 288). Power and effect sizes (η^2_p) were calculated using IBM SPSS Statistics 20.

Results

Foot Temperature

Foot skin temperatures at room temperature were approximately 26 °C which is consistent with the results of study 2 (chapter 4, page 75). After 10 minutes of ice bath cooling the foot temperatures were reduced to 9.3 °C and after re-cooling 10.5 °C which compares favourably to the target temperature of 10 °C. Two minutes post cooling foot temperatures had risen to 16.3 °C and 17.3 °C respectively. This temperature profile can be seen in figure 5.2.

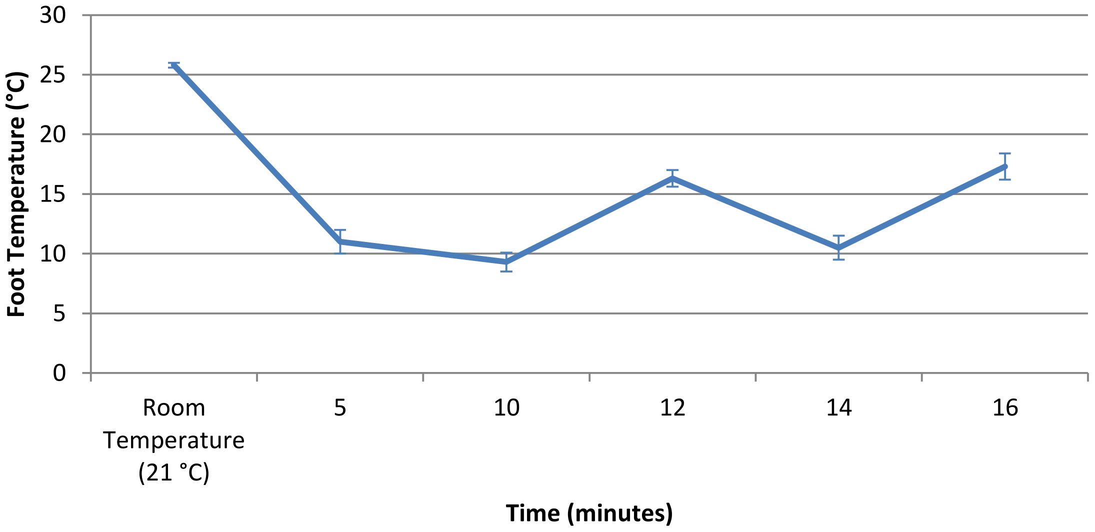


Figure 5.2. **Mean (SD) foot temperature (°C) at room temperature (21 °C) and during the ice bath cooling cold condition (*N* = 12).**

Postural Control

Two Feet Eyes Open Quiet Standing Balance Test

Sway rates.

The ANOVA for lateral sway rate showed no significant difference between cold and room temperature conditions ($F_{1, 11}$ = 2.36, P = .153, η^2_p = .176, Power = .289). The ANOVA for fore / aft sway rate showed no significant difference between conditions ($F_{1, 11}$ = 2.81, P = .122, η^2_p = .203, Power = .334). In figure 5.3 it can be seen that both lateral and fore / aft sway rates are within 2 Hz.

Distances travelled by the COP.

The ANOVA for lateral distance travelled by the COP showed no significant difference between cold and room temperature conditions ($F_{1, 11}$ = 2.46, P = .145, η^2_p = .183, Power = .299).

The ANOVA for fore / aft distance travelled by the COP showed no significant difference between conditions ($F_{1, 11}$ = 2.64, P = .132, η^2_p = .194, Power = .318). Figure 5.4 shows that the trend is for increased COP travel in the cold condition but the variation between participants was greater than the difference between conditions.

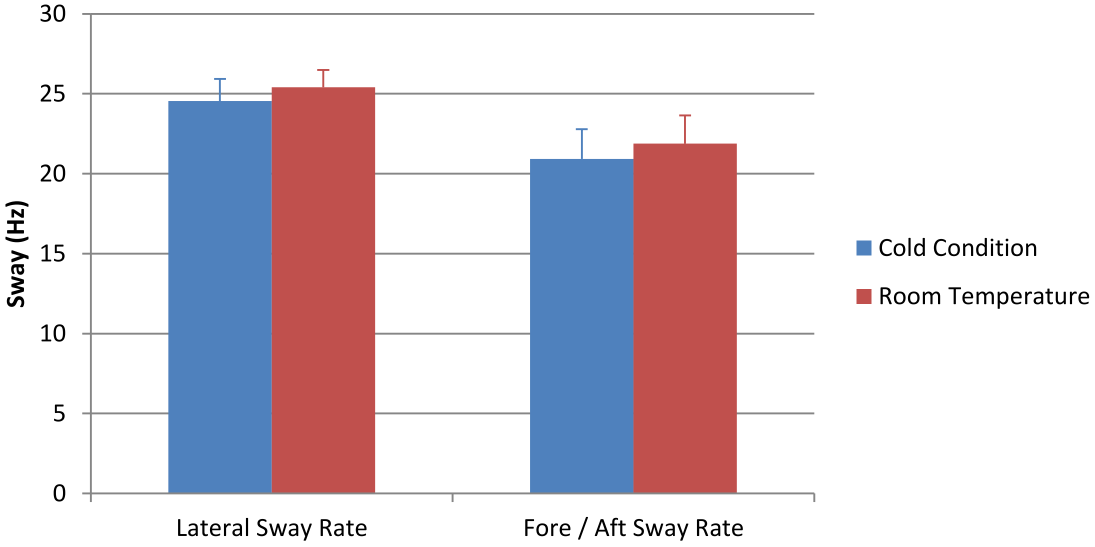


Figure 5.3. **Mean (SD) sway rates in cold and room temperature conditions for the two feet eyes open quiet standing balance test (*N* = 12).**

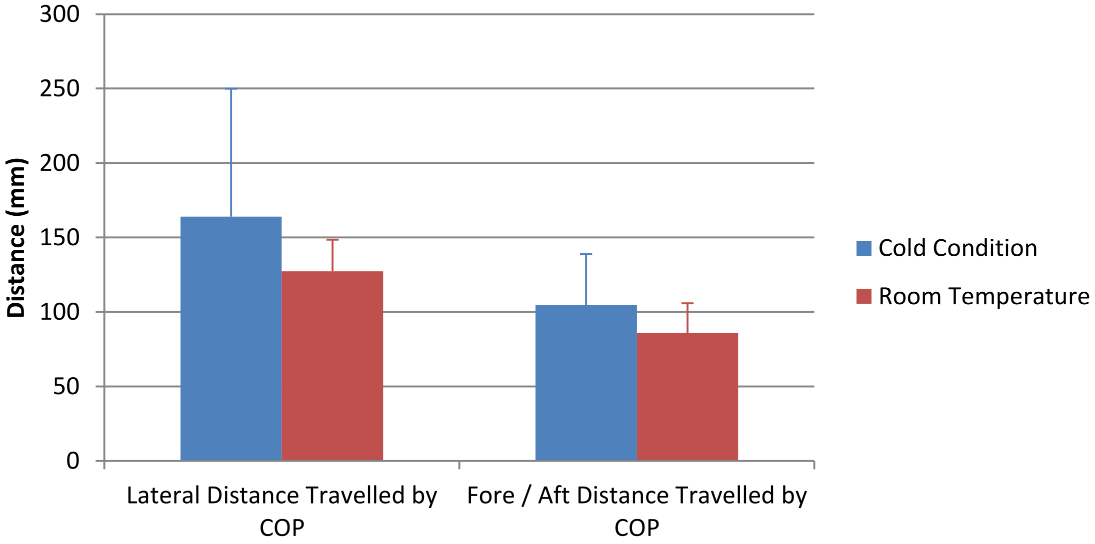


Figure 5.4. **Mean (SD) distance travelled of the COP in cold and room temperature conditions for the two feet eyes open quiet standing balance test (*N* = 12).**

Two Feet Eyes Closed Quiet Standing Balance Test

Sway rates.

The ANOVA for lateral sway rate showed no significant difference for Condition ($F_{1, 11}$ = 3.35, P = .094, η^2_p = .233, Power = .387). The ANOVA for fore / aft sway also showed no significant differences for Condition ($F_{1, 11}$ = 3.06, P = .108, η^2_p = .217, Power = .358). Figure 5.5 shows a very similar pattern to the sway rates for eyes open (figure 5.3) with a sway rate within 2 Hz for both cold and room temperature conditions. An effect size (η^2_p) of .2 would not be a large enough change to see with the naked eye but might become significant in a much larger study.

Distances travelled by the COP.

The ANOVA for lateral distance travelled by the COP showed a significant difference for Condition ($F_{1, 11}$ = 10.68, P = .007, η^2_p = .493, Power = .845). Figure 5.6 shows that the lateral distance travelled during postural maintenance was greater in the cold condition. Lateral distance travelled was 27.5 mm greater when the feet were cooled prior to the test.

The ANOVA for fore / aft distance travelled by the COP showed a significant difference for Condition ($F_{1, 11}$ = 7.60, P = .019, η^2_p = .409, Power = .709). Figure 5.6 shows that the fore / aft distance travelled was greater with pre-cooled feet with an increase in distance travelled of 27.0 mm.

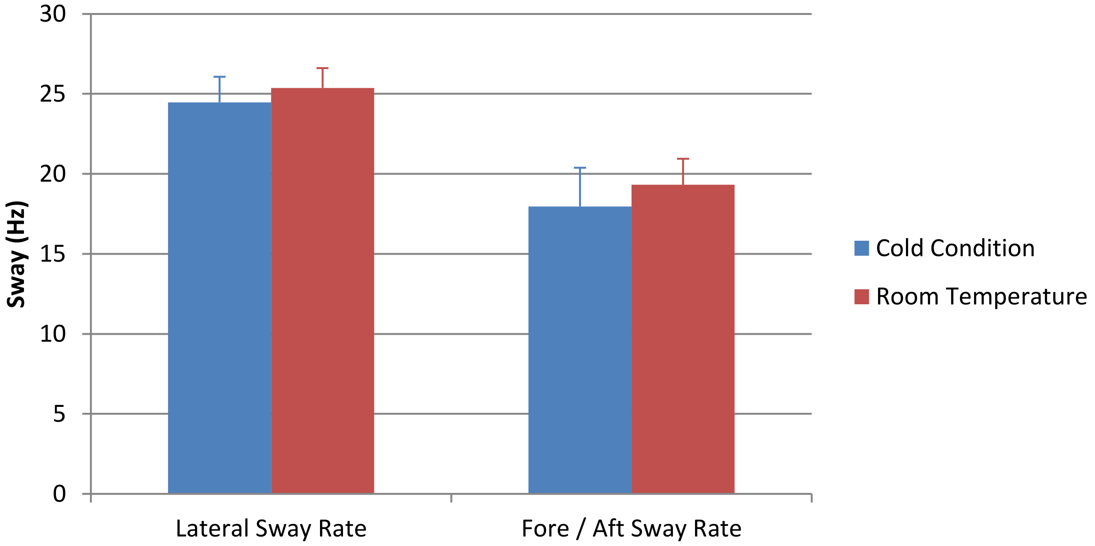


Figure 5.5. **Mean (SD) sway rates in cold and room temperature conditions for the two feet eyes closed quiet standing balance test (*N* = 12).**

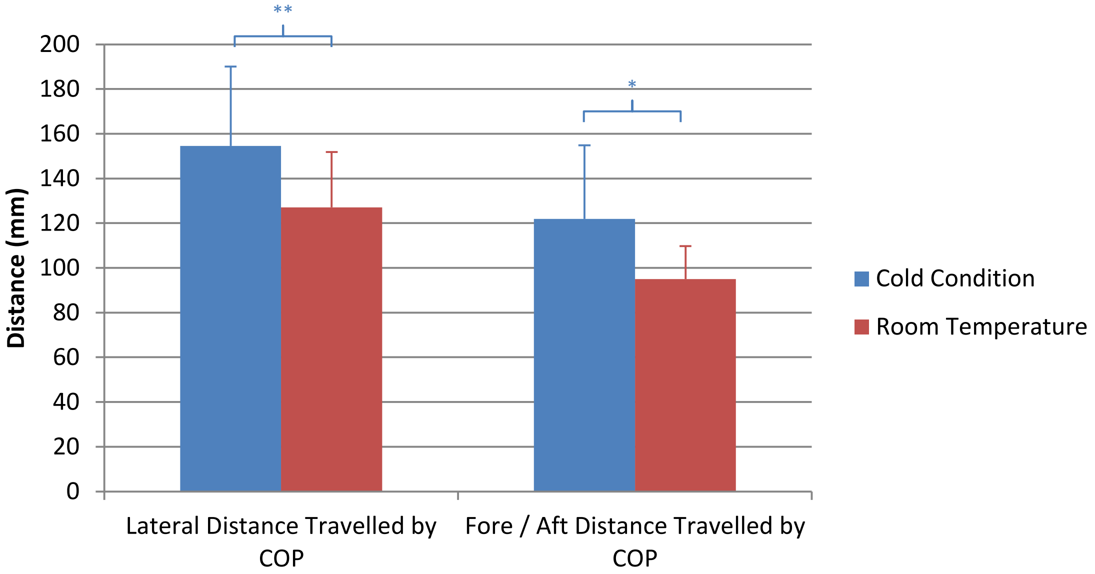


Figure 5.6. **Mean (SD) distances travelled by the COP in cold and room temperature conditions for the two feet eyes closed quiet standing balance test (*N* = 12).**

**$P < .01$; *$P < .05$

Single Footed Quiet Standing Balance Test

Sway rates.

The ANOVA for lateral sway rate showed no significant difference for Condition ($F_{1, 11}$ = 3.10, P = .106, η^2_p = .220, Power = .363). The ANOVA for Sway Y also showed no significant difference for Condition ($F_{1, 11}$ = 1.69, P = .220, η^2_p = .133, Power = .221). Figure 5.7 shows that sway rates are only marginally reduced in the cold condition with a mean difference of less than 1 Hz.

Distances travelled by the COP.

The ANOVA for lateral distance travelled by the COP showed a significant difference for Condition ($F_{1, 11}$ = 8.34, P = .015, η^2_p = .431, Power = .748). Figure 5.8 shows that the lateral distance travelled during postural on one foot was 58.5 mm greater in the cold condition than the room temperature condition.

The ANOVA for fore / aft distance travelled by the COP showed an alpha approaching significance for Condition ($F_{1, 11}$ = 4.10, P = .068, η^2_p = .271, Power = .455). Eta squared (η^2_p) effect sizes between .2 and .3 are described as small to medium effect and this means that there may well be a change here that would reach significance in a larger study. Figure 5.8 shows that the fore / aft distance travelled was 30.9 mm greater in the room temperature condition.

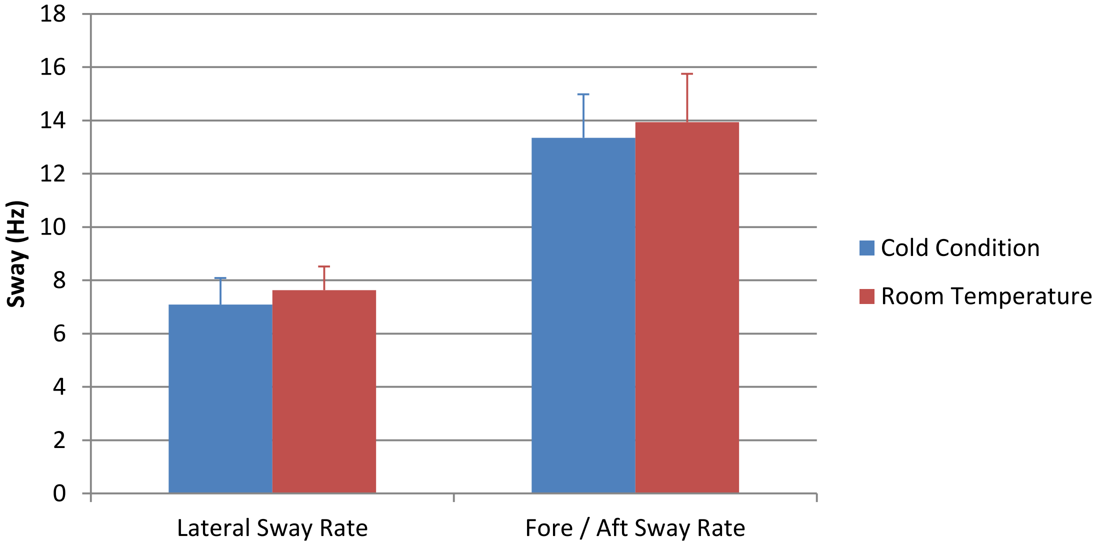


Figure 5.7. **Mean (SD) sway rates in cold and room temperature conditions for the single footed quiet standing balance test (*N* = 12).**

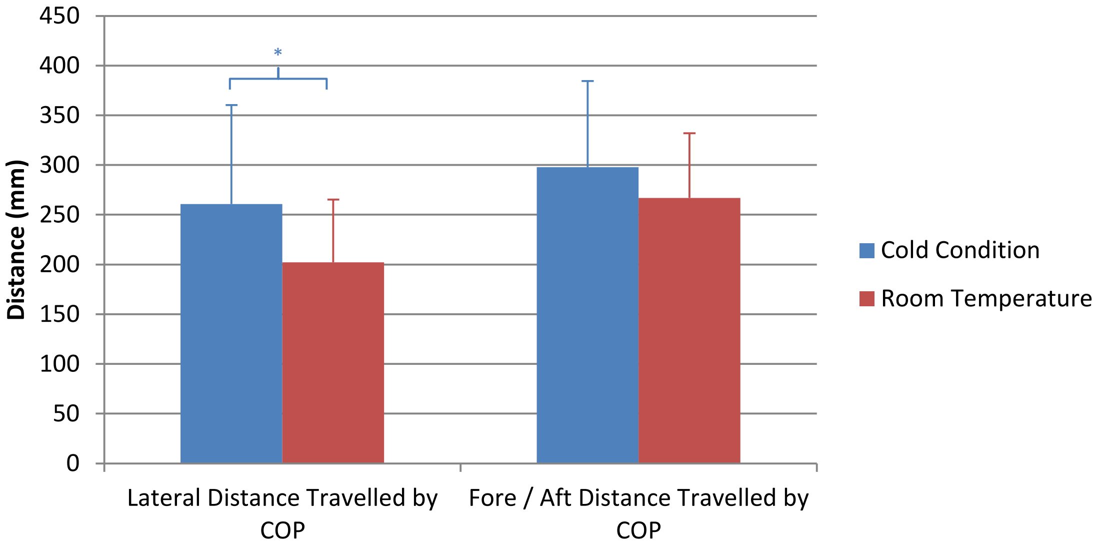


Figure 5.8. **Mean (SD) distances travelled by the COP in cold and room temperature conditions for the single footed quiet standing balance test (*N* = 12).**

**P* < .05

Discussion

The aims of this study were to establish what changes in postural control would occur when the feet were cooled in isolation. The hypothesis was that if participants' feet were cooled to temperatures that compared to the terminal temperatures in the cold condition of study 2 (The effects of acute cold exposure on body temperature, postural sway dynamics during quiet standing) then we would observe similar changes in postural control performance. An ice bath cooling protocol was employed to reduce foot skin temperatures to a target set at 10 °C.

Ice Bath Cooling and Skin Temperature

Despite the fact that Magnusson, Enbom, Johansson and Pyykkö (1990) report using ice bath cooling to explore the effects of somatosensory information of the feet on postural dynamics reducing foot temperatures to 10 °C for postural control tests in this study proved quite difficult. However, an improved ice bath protocol that suspended the feet in an ice bath maintained at approximately 1.0 °C by vigilant monitoring of the ice water ratio made it possible to reach this skin temperature with a bathing time of 10 minutes. Once cooled to 10 °C participants' feet would retain low temperatures for a short period before significant rewarming set in. After 2 – 3 minutes foot temperatures would rise to a point above 15 – 16 °C. This was considered too warm to replicate the effects of the whole body cooling protocol and so a re-cooling period was employed at 2 minutes after the second balance task was completed. For consistency the re-cooling began at the 2 minute mark but participants had actually completed the second balance task at around 90 seconds (the remaining 30 seconds being the time taken to save data in Footscan® 7. Unsurprisingly skin temperatures in the room temperature condition (21 °C) reflected those in the room temperature condition of study 2 at approximately 26 °C (foot skin temperature).

Overall it seems that the skin temperatures of the feet during this study was close enough to those in the environmental chamber at -20 °C to allow a real exploration into one of the mechanisms behind the change postural dynamics during study 2. Given the difficulties found in reaching, and maintaining, low skin temperatures during this study it is probably fair to accept that it is not possible to represent the full extent of foot cooling experienced in the environmental chamber with 100% accuracy without cooling larger body segments or applying dangerous levels of isolated thermal stress to the feet. Cooling in the ice bath was very effective in reducing superficial skin temperatures of the feet but deeper structures within the feet are almost certainly affected to a greater extent in whole body cooling at -20 °C. The relatively rapid rewarming rates after ice bath cooling may indicate that deeper cooling was limited during this protocol. In fact an advantage of the ice bath protocol may well be that it has allowed the examination of skin sensitivity without deeper or central cooling effects to come into play, however, muscle temperature data would be necessary to be confident about that conclusion. An alternative explanation maybe that although muscle cooling was limited in this study there was still enough superficial muscle cooling to have an effect on balance related moment output. A future study including muscle temperature data would help answer this question and clarify if anaesthetised skin effects, impaired muscle function muscle, or a combination of the two are responsible for postural control effects.

Postural Control

Postural control changes were observed in the present study but overall these were less pronounced than in study 2. For the two feet eyes open quiet standing balance test there were actually no significant differences between conditions for either of the sway rate of distance travelled by the COP variables. Lateral and fore / aft sway rates had lower absolute values in the ice bath cooled condition but by less than 1 Hz. Base line sway rates in this study were comparable to those in study 2.

Lateral distance travelled by the COP was increased by 36.6 mm (29%) in the ice bath cooled condition. The large standard deviation for the cold condition lateral sway rate probably prevented this result from reach statistical significance. In study 2 there had been a 100 mm increase in this measure at the end of the cold condition. In the current study fore / aft distance travelled by the COP was increased by 18.7 mm (22%) in the cold condition. In study 2 there had been an almost 200 mm increase in the two feet eyes open quiet standing fore / aft distance travelled measure. Given the trends and changes in the means themselves the effect sizes calculated for these measures are also small (η^2_p = .183 and η^2_p = .194). It seems that the effects of isolated cooling of the feet using this protocol were less severe than the impact of whole body cooling at -20 °C in study 2.

In the two feet eyes closed quiet standing balance test there were no significant differences for sway rates but the lateral sway rate was approaching significant values (*P* = .094) with an effect size (η^2_p) of 0.233 which Cohen (1988) would classify as small. This means there is probably a real change but it is of a small magnitude and would not be noticeable to the naked eye. Sway rates were less in the ice bath cooled condition but absolute values remained within 2 Hz of those in the room temperature condition. Reduced sway rates tend to indicate a delayed response time and can result from impaired sensory functioning (Shupert & Horak, 1999). This finding can be compared with changes of approximately 5 Hz at the end of the cold condition in study 2. Although we have changes in the same direction (reduced sway rates) we don't have the same magnitude of change in sway rates with the ice bath cooling protocol of the current study than those found with whole body cooling at -20 °C.

Both lateral and fore / aft distance travelled by the COP in the two feet eyes closed quiet standing balance test increased significantly after ice bath cooling. Lateral distance travelled by the COP was increased by 27.4 mm (22%) and fore / aft distance travelled by the COP was increased by 26.9 mm (28%) in the cold condition. This compares with an increase of between 150 mm and 200 mm after whole body exposure at -20 °C.

Magnusson et al. (1990) reported significant differences in body sway velocity for eyes open and eyes closed after ice bath cooling a result that is partially supported by the present study. Magnusson et al., who cooled their participants' feet for 20 minutes, had only tested sway in the fore / aft direction. They did report greater changes in the eyes closed condition than the eyes open condition and this fits with the pattern found in the present study where only the changes in the eyes closed condition reached statistically significant levels.

In the single footed quiet standing balance test there was no significant difference for sway rates which had a variation less than 1 Hz between the room temperature and ice bath cooled conditions. This was in line with the findings of study 2 and it had been concluded that the sway rates in the one footed tests were relatively fixed and that variation was only likely to be displayed in the COP distance travelled measurements. This result gives further support to that conclusion. Response scaling rather than the speed of response seems to be the problem elicited by the cold condition in single footed tests.

The lateral distance travelled by the COP was significantly different and the increase of 48.5 mm represents a 29% increase. The fore / aft distance travelled by the COP was approaching significance ($P = .068$) with an effect size (Π^{2}_{p}) of 0.271 which Cohen (1988) would define as small to medium; there is probably a real change of a small magnitude that would be significant with a larger sample. In absolute terms this was an increase in distance travelled of 30.9 mm which represents a 12% increase in this measure.

Overall it seems that although postural changes were evident in the current study these were somewhat smaller than the changes in study 2. It is possible that the reduction in somatosensory information from the feet during ice bath cooling is less significant than when whole body cooling is employed even when skin temperatures are comparable. This is quite possible if ice bath cooling affects mainly the superficial outer layers of tissue in the feet whilst not affecting deeper tissues so much. The speed of rewarming feet undergo when removed from the ice bath suggests this may be likely. Although the pressure sensitive mechanoreceptors in the skin may be anaesthetised (Stål et al., 2003) stretch receptors including the Golgi organs in the tendons and muscle spindle receptor organs were probably still functional during this study and would provide some proprioceptive feedback from the feet (Hassan, Mockett, & Doherty, 2001). Additionally it may be that there are other factors contributing to reduced performance with whole body cooling. Teichner (1958) and Ellis et al. (1985) identified distraction effects as a possible cause of performance drops in the cold and perhaps attentional processes are affected more with whole body cooling than with ice bath cooling of limited body segments. Ellis et al. had also shown that faster, more aggressive cooling (less time but colder exposures) resulted in arousal and performance changes not evident with slower cooling and it may be that arousal changes are also more pronounced as a result of whole body cold exposure; however arousal was not measured in this study. Donker et al. (2007) showed that an additional cognitive load can impair postural control performance and the experience of whole body cold exposure may provide such a load. Muscle functioning in peripheral structures such as feet may well be impaired during whole body exposure to cold (study 2) where reduced muscle temperatures are probable (Oksa, 2002; Oksa et al., 2002) but not during isolated cold stress such as in this study. In the current study it appears that ice bath cooling of the feet in isolation does replicate a significant element of the effects of whole body cooling but that there are certainly other effects of whole body cooling that are eliminated in ice bath cooling protocols.

Conclusion

Cooling the feet of participants with an optimised ice bath protocol proved successful in eliciting changes in postural sway dynamics. The distance travelled by the COP components of performance were affected more than the sway rates components. This wasn't completely unexpected as the distance measures had been affected more frequently in the whole body cooling condition of study 2. However this finding may also reflect the mechanism behind different performance changes. It may be that a significant proportion of changes in the distance travelled by the COP during whole body cooling results from skin cooling effects but that sway rate changes are actually a result of other processes. The magnitude of changes with the ice bath cooling protocol were smaller than with whole body cooling and this also implies that although the cooling of the feet themselves is a significant part of the picture there are other factors at play during whole body cooling that result in impaired performance.

This study has been particularly useful in showing that there are almost certainly a number of mechanisms at play in terms of postural control performance changes in the cold. These include the tactile somatosensory element replicated by ice bath cooling but this element does not explain all of the performance changes we find in whole body cooling. Other mediators on performance may include deeper tissue somatosensory elements (Hassan et al., 2001) as well as central effects, perhaps linked to attention and distraction (Donker et al., 2007; Ellis et al., 1985). The skin cooling effect does provide a possible avenue for a targeted intervention during whole body exposure to cold. The study also shows that the process of cooling can have a measurable impact on the performance outcomes even though superficial effects are very similar. Athletes or workers who perform in an environment where the cold effects are more isolated (for instance members of a curling team who stand on the ice for prolonged periods of relatively low level activity) may experience smaller drops in performance than those who experience a more whole body effect (for example workers in refrigeration plants or ski resorts). The study also demonstrates that caution should be applied when generalising the finds of cold studies as the effects and magnitude of changes may well be, to some extent, dependent of the mechanism of cooling.

CHAPTER 6

THE IMPACT OF ACTIVE HEATED FOOTBEDS DURING ACUTE COLD EXPOSURE ON BODY TEMPERATURE, HEART RATE VARIABILITY, AND POSTURAL SWAY DYNAMICS DURING QUIET STANDING

Introduction

The aim of this study was to examine the impact that electrically heated footbeds would have on postural control during acute cold exposure. In study 2, The Effects of Acute Cold Exposure on Body Temperature, Postural Sway Dynamics during Quiet Standing, and Heart Rate Variability, it was established that postural was negatively affected by exposure to extreme cold at -20 °C and study 3, The Effects of Isolated Cooling of the Feet on Postural Control Dynamics, had replicated significant impairment by employing an ice bath protocol that cooled the feet of participants otherwise exposed to room temperature conditions. Reduced skin temperatures and the resulting loss of tactile sensitivity had been identified as a likely potential mechanism for this impairment and it was thought that an intervention targeting this effect could be effective in maintaining performance or at least reducing the decline. Footbeds that employ an active, electrically heated circuit are an increasingly common method to maintain thermal comfort in cold conditions and Warmawear™ (Meika Limited, Winnersh, UK) heated insoles were selected because they are commercially available and promoted as suitable for activities including walking in the cold and skiing. These footbeds are powered by external 4.5V DC battery packs and have an output of 3 Watts. They are compatible with disposable AA batteries or the equivalent rechargeable batteries. As the manufacturers are very specific about only using higher rated rechargables it was decided to use high quality disposables (Energizer® Ultra+ alkaline batteries) and replace these after 2 hours or if the indicator lights showed any sign of dimming (Meika suggest that high quality disposables should provide over 3 hours of continuous use).

It had been clear in study 2 that performance changes could be established after 15 minutes of −20 °C cold exposure and so the additional stress of testing after 30 minutes of exposure time seemed unjustifiable; as participants would performance balance tests in the cold environment on two separate occasions it was important to make the cold condition no more uncomfortable than strictly necessary. It was decided that a 15 minute exposure time would be sufficient to establish if the heated footbeds provided any advantage in the −20 °C cold condition.

It was hypothesized that there will be differences between conditions in postural control performances and thermal comfort. It is also hypothesised that performance and comfort will degrade during the cold exposure conditions at −20 °C.

Method

Participants

For this study twelve participants (12) were recruited from the undergraduate population. Six were male and six female. All were unpaid volunteers. The mean age of participants was 21.0 ± 2.5 years. Anthropometric variables measured were height (171.91 ± 8.73 cm) and weight (73.08 ± 6.29 kg). As in study 2 participants were vetted for a history of cold injuries.

Overall Experimental Design

A repeated measures design was employed with participants completing three phases of testing: one in the cold condition (-20 °C), a second in the cold condition but employing electrically heated footbeds throughout the exposure (excluding the balance tests) and a third condition at room temperature (21 ± 1 °C). This was a counterbalanced crossover design with participants completing a rotation of three conditions; four participants began the rotation at each condition. Participants were allocated to the rotation on a random basis. Participants were given their test schedule on the initial visit to the laboratory for their orientation session.

All participants attended the orientation session where they completed health questionnaires (see appendix 2, page 202) and were briefed in detail about the data collection sessions and taught the positions for the balance tests. Participants completed 3 sets of practice tests as prescribed in study 1 (chapter 3, pages 47-63). Balance tests were carried out in the same sequence as the testing during the experimental conditions; two feet eyes open, two feet eyes closed, right foot and finally left foot. Testing in the chamber at -20 °C is particularly difficult for both participants and experimenters and so having well drilled participants is a distinct advantage. As in the previous studies participants were encouraged to feel an important part of the study and the value of their contributions alongside the level of care they would receive in the -20 °C conditions was made explicit.

The environmental chamber and RS Footscan® system was prepared in accordance with the protocol described in in study 2 (chapter 4, page 69).

Measurement

Body temperature.

Body temperatures were measured in the same manner as study 2 (chapter 4, page 69). Each participant arrived at the laboratory dressed, as instructed, in a single layer of light clothing that included long sleeves and trousers. The head, hands and feet were left bare. Participants were prepared for the protocol in a warm room close to the environmental chamber. Participants inserted a rectal thermometer (Edale Instruments (Cambridge) LTD, Cambridge, UK) 10 cm beyond the anus in order to measure core body temperature and Edale Instruments thermistors were attached to the participant's skin using self-adhesive hypoallergenic surgical tape. Thermistors were attached to the right hand side of the body at the temple, calf and the top of the foot. Calf thermistors were placed on the visual centre of mass of the calf muscle (between the lateral and medial heads of the gastrocnemius) and foot thermistors were placed on the joint of the intermediate cuneiform and the second metatarsal of the right limb.

Temperatures were displayed on a six channel Edale box model CD (Edale Instruments (Cambridge) LTD, Cambridge, UK) and recorded on hand written notes at zero and 15 minutes. During the rest of the cold exposure period the Edale box was set to read core body temperature for easy monitoring.

Thermal comfort scale.

The nine point perception of thermal comfort scale (Jendritzky et al., 2001) employed in study 2 (chapter 4, page 69) was used to gauge participants' subjective rating of their thermal status. Participants were briefed to report their perception of comfort rather than the environmental conditions. Thermal comfort ratings were taken between the temperature measurements and the balance tests at zero and 15 minutes.

Table 6.1. *Perception of Thermal Comfort Rating Scale*

Thermal Comfort Rating	Descriptor
9	Very hot
8	Hot
7	Warm
6	Slightly warm
5	Comfortable
4	Slightly cool
3	Cool
2	Cold
1	Very cold

Heart rate and variability.

As in study 2 (Chapter 4, page 69) participants were fitted with Polar RS810 (Polar Electro Inc., Lake Success, NY) hear rate monitors with beat by beat recording capability. This included a watch which acted as the recorder and coded chest strap and transmitter. Recording was activated one minute prior to entering the environmental chamber and beat by beat data was recorded continuously throughout the protocol to be downloaded and analysed later.

Postural control.

Postural control tests were conducted as described in study 1 (chapter 3, pages 47-63. The equipment was set up as in study 2 (chapter 4, page 69) so that the RS Footscan® plate was inside the chamber and easily visible through the chamber window and the Footscan® 3D Box and laptop running Microsoft Windows and the Footscan® 7 balance software package was on a desk immediately outside of the environmental chamber so that the operator outside would have a clear view of the participants and the experimenter inside the chamber. Participants were required to step off the footbeds / insulating matt and on to the RS Footscan® plate for the balance testing (approximately 2.5 minutes).

Protocol

Participants were given a short briefing to remind them of what to expect during the testing. The stance for each of the balance tests was described and demonstrated once again and heart rate monitors were checked and started. Heart rate monitors were ran for one minute before participants entered the chamber.

Participants entered the cold chamber and took their place on an insulating closed cell foam mat or the pre-warmed heated footbeds as appropriate. Immediately after entry the first tests were completed in the following order: skin temperatures, core body temperature, thermal comfort rating (approximately 1 minute) and finally participants stood on the RS Footscan® plate to complete the postural control / balance tests (approximately 3 minutes). The four balance tests were conducted in the rehearsed sequence; two feet eyes open, two feet eyes closed, right foot then left foot and then participants returned to their position on the foam mat / heated footbeds until the final balance test (approximately 12 minutes later).

After 15 minutes of exposure time participants completed a second round of testing and at 20 minutes they were allowed to leave the environmental chamber. This sequence is shown in Figure 6.1. Participants were accompanied by one of the research team during their time in the chamber and this researcher was responsible for in chamber measures and protocols and monitoring the on-going condition of participants. Participants were aware that they would be removed from the chamber if their core body temperatures dropped by 1.0 °C or if they requested it themselves.

The second researcher was stationed outside of the environmental chamber at the window in a position to operate the balance data recording software (Footscan® 7) and visually monitor the condition of the researcher in the chamber and the participants. As in study 2 the researcher in the chamber was dressed in appropriate cold climate protective clothing.

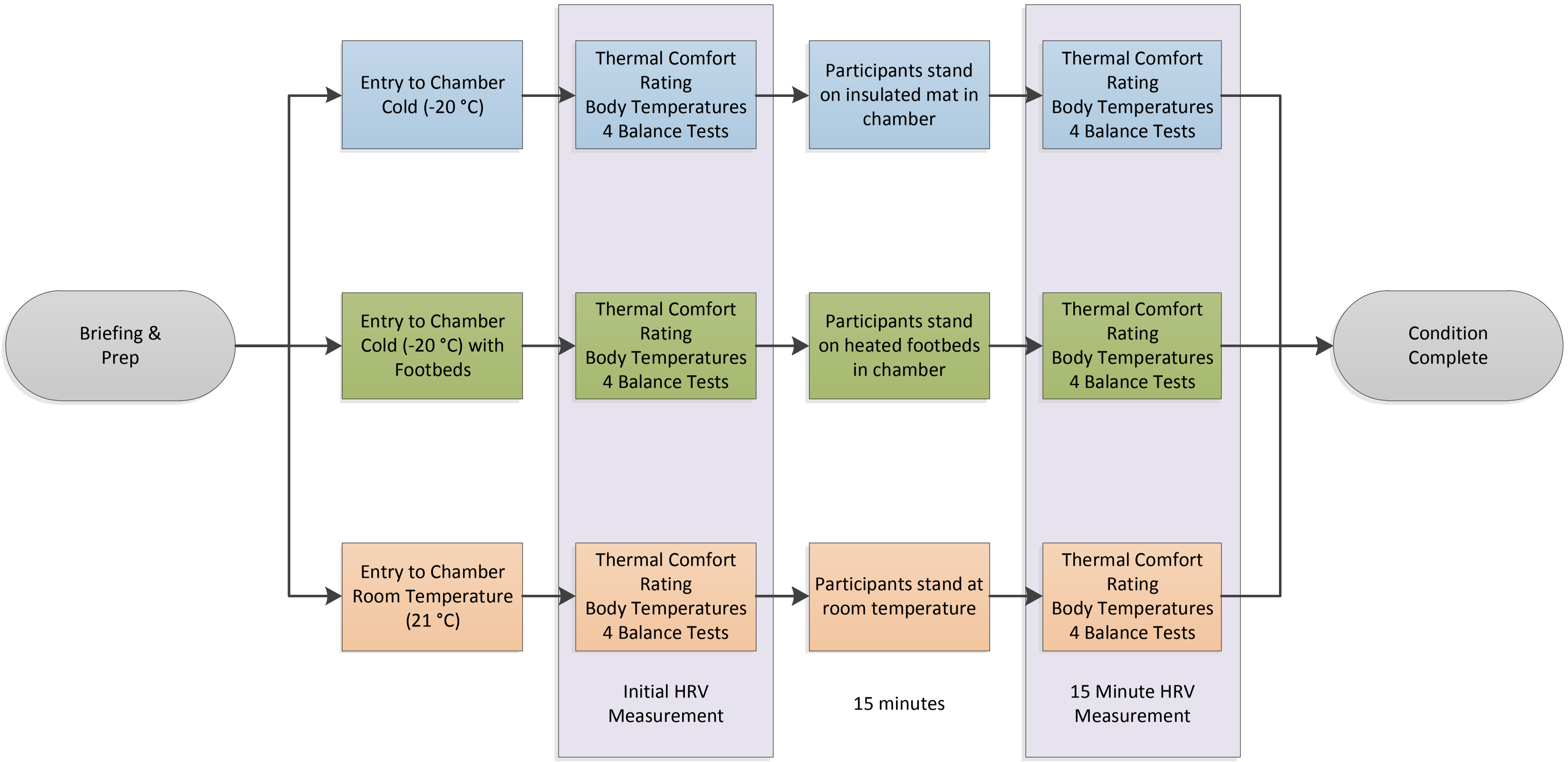


Figure 6.1. **Overview of the experimental protocol: room temperature, cold (-20 °C) and cold with footbeds conditions (-20 °C).**

Statistical Analysis

Body Temperatures (core, head calf and foot) and thermal comfort rating were each analysed for differences between conditions, time and interaction of condition x time with two way ANOVAs (appendix 9, page 304). Power and effect sizes (η^2_p) were calculated using IBM SPSS Statistics 20.

RR heart rate data were uploaded as text files to a PC running Microsoft® Windows and then imported to MATLAB® Kubios HRV 2.0 for anaylsis. Heart rate variability for the first 5 minutes in the chamber and 15 – 20 minutes was calculated from the beat by beat data using MATLAB® Kubios HRV 2.0. Mean RR, STD RR (SDNN), LF (0.04 – 0.15 Hz), HF (0.15 – 0.4 Hz) and LF/HF ratio were calculated and these were tested for significant differences using two way ANOVAs (appendix 10, page 322). Power and effect sizes (η^2_p) were calculated using IBM SPSS Statistics 20.

Sway data were exported from Footscan® 7 into Microsoft® Excel and the variables sway rate X (lateral) and Y (fore / aft) and distance travelled by centre of pressure X and Y were calculated using the programme described in study 1 (appendix 3, page 206). Sway data were analysed for differences between conditions, time and interaction of condition x time using two way ANOVAs for the variables within each stance (appendix 11, page 339). Power and effect sizes (η^2_p) were calculated using IBM SPSS Statistics 20.

Clark-Carter (1997) suggests that contrast analysis can be present for pre-planned (a priori) comparisons even when the ANOVA falls short of significance and so these are presented where P scores indicate either variables on the borderline of significance or variables approaching significance ($P < .10$). Sterne and Smith (2001) view significance scores up to P = .10 as potentially worthy of discussion.

Results

Body Temperature

Core body temperature showed little change throughout both cold exposure conditions with non-significant main effects for Condition ($F_{1,\,11}$ = 0.004, P = .948, η^2_p < .0005, Power = 0.050), Time ($F_{1,\,11}$ = 0.001, P = .970, η^2_p < .0005, Power = 0.050) and Interaction ($F_{1,\,11}$ = 0.86, P = .375, η^2_p = .072, Power = 0.135). Core temperatures remained within 0.1 °C of 37.6°C.

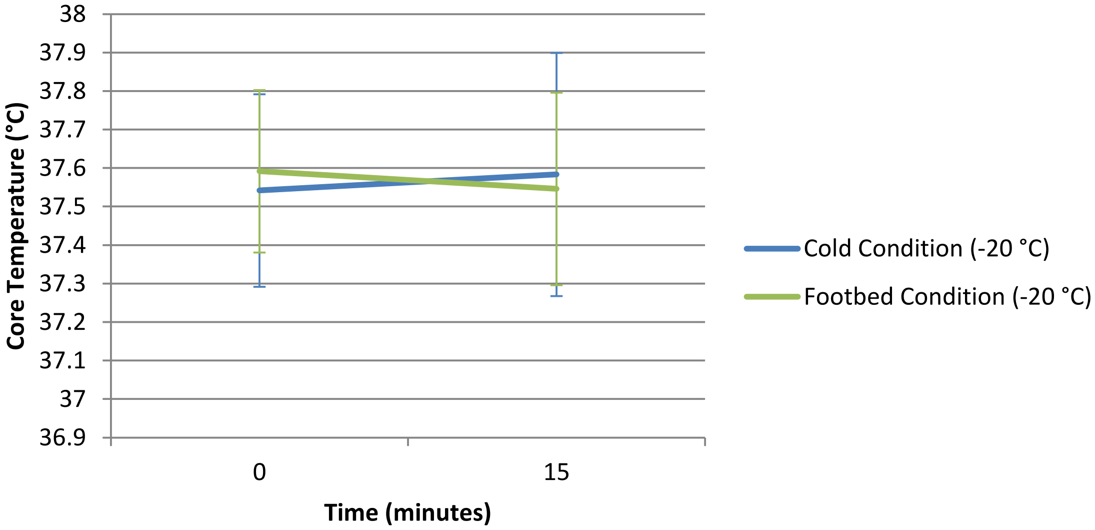


Figure 6.2. **Mean (SD) core body temperature (°C) during 15 minutes cold condition exposure (-20 °C) with and without heated footbeds (*N* = 12).**

Head temperatures remained very consistent throughout the room temperature condition, however the head temperature dropped significantly during the cold conditions with main effects for Condition ($F_{2, 16}$ = 88.41, P < .0005, η^2_p = .917, Power > .9995), Time ($F_{1, 8}$ = 137.00, P < .0005, η^2_p = .945, Power > .9995) and Interaction ($F_{2, 16}$ = 50.36, P < .0005, η^2_p = .863, Power > .9995). The temperature of the head dropped to 14.4 ± 3.01 °C after 15 minutes of cold exposure. Polynomial contrast analysis showed a linear effect for Condition ($F_{1, 11}$ = 182.20, P < .0005) there between conditions differences between the room temperature condition and the experimental conditions but no difference between experimental conditions. The Interaction contrast was linear change of time was consistent within the two experimental conditions ($F_{1, 11}$ = 70.86, P < .0005).

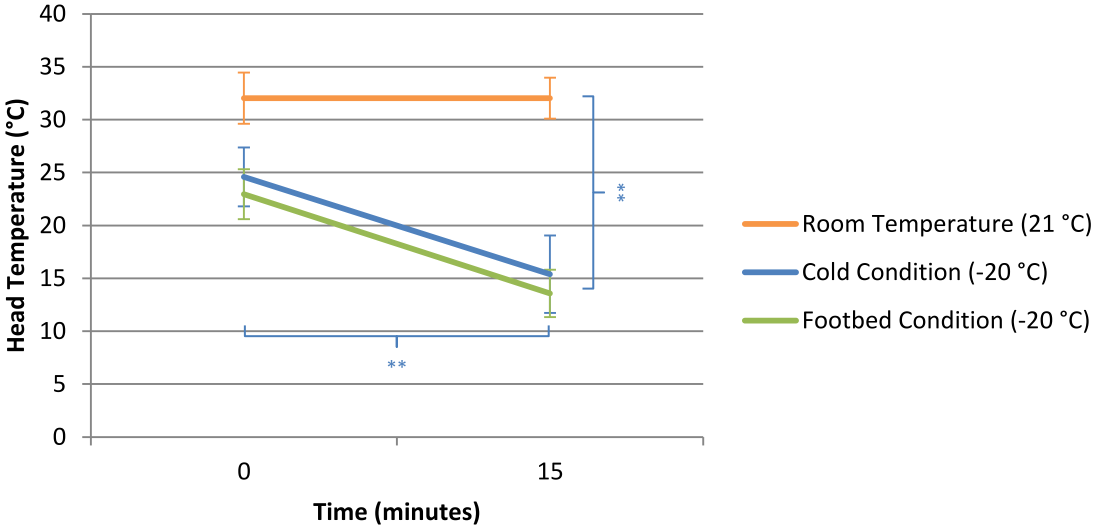


Figure 6.3. **Mean (SD) head temperature (°C) at room temperature and during 15 minutes cold condition exposure (−20 °C) with and without heated footbeds (*N* = 12).**

***P* < .01 linear effects for condition and interaction

Calf temperatures remained very consistent throughout the room temperature condition, but dropped significantly during the cold conditions with main effects for Condition ($F_{2,\,16}$ = 28.48, $P < .0005$, η^2_p = .740, Power > .9995), Time ($F_{1,\,8}$ = 235.77, $P < .0005$, η^2_p = .959, Power > .9995) and Interaction ($F_{2,\,16}$ = 49.36, $P < .0005$, η^2_p = .832, Power > .9995) . The temperature of the calf dropped to 17.32 ± 4.14 °C after 15 minutes of cold exposure. Polynomial contrast analysis showed a linear effect for Condition ($F_{1,\,11}$ = 35.53, $P < .0005$) with between conditions differences between the room temperature condition and the experimental conditions. The Interaction contrast was linear ($F_{1,\,11}$ = 145.32, $P < .0005$) indicating a consistent change over time for the two experimental conditions.

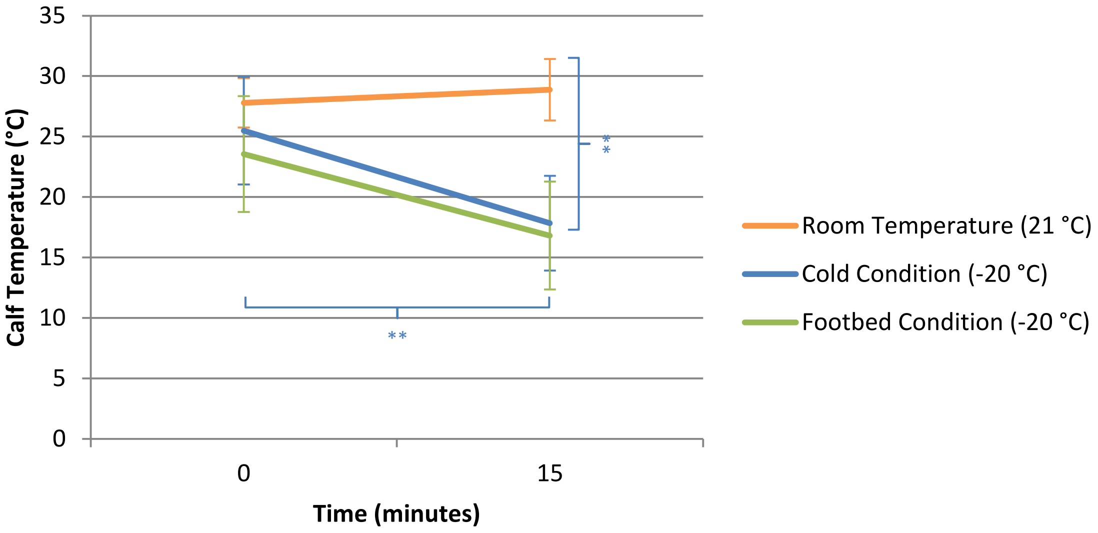


Figure 6.4. **Mean (SD) calf temperature (°C) at room temperature and during 15 minutes cold condition exposure (-20 °C) with and without heated footbeds (*N* = 12).**

**$P < .01$ linear effects for condition and interaction

Foot temperatures were consistent throughout the room temperature condition, however they dropped significantly during the cold conditions with main effects for Condition ($F_{2, 16}$ = 96.93, $P < .0005$, η^2_p = .898, Power = 1.0), Time ($F_{1, 8}$ = 270.20, $P < .0005$, η^2_p = .961, Power > .9995) and Interaction ($F_{2, 16}$ = 63.53, $P < .0005$, η^2_p = .852, Power > .9995). The temperature of the foot dropped to 11.21 ± 2.93 °C after 15 minutes in both of the cold exposure conditions. Polynomial contrast analysis showed a linear effect for Condition ($F_{1, 11}$ = 308.07, $P < .0005$) with a consistent difference between the control conditions and the experimental conditions. The Interaction contrast was quadratic ($F_{1, 11}$ = 41.76, $P < .0005$) and it appears that the between conditions differences between the room temperature and experimental conditions increased whilst the two experimental conditions became even closer matched over time.

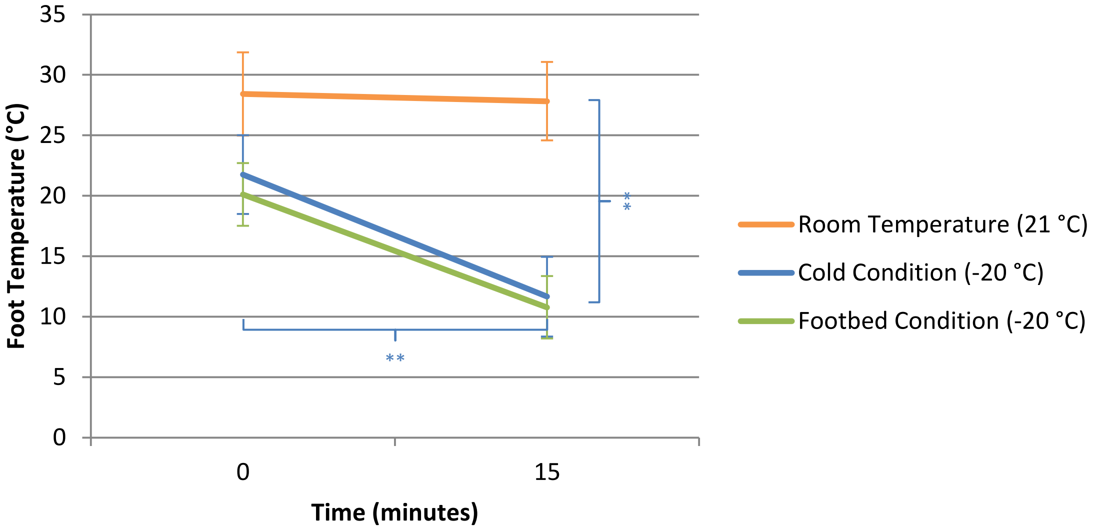


***Figure 6.5.* Mean (SD) foot temperature (°C) at room temperature and during 15 minutes cold condition exposure (−20 °C) with and without heated footbeds (*N* = 12).**

**$P < .01$ linear effect for condition and quadratic interaction

Thermal comfort ratings were also significantly different with differences for main effect Condition ($F_{2,\,22}$ = 64.66, $P < .0005$, $\eta^2_p = .855$, Power > .9995), Time ($F_{1,\,11}$ = 166.36, $P < .0005$, $\eta^2_p = .938$, Power > .9995) and Interaction ($F_{2,\,22}$ = 16.16, $P < .0005$, $\eta^2_p = .595$, Power = .999). Participants reported a drop in perceived comfort from 5.3 ± 0.6 (comfortable) in the room temperature condition to 2.4 ± 0.9 (cold to very cold) after 15 minutes at −20 °C. Unsurprisingly participants reported being comfortable at room temperature but gave much lower scores after they were exposed to the cold conditions (−20 °C). Polynomial contrast analysis showed a linear effect for Condition ($F_{1,\,11}$ = 129.72, $P < .0005$) and for Interaction ($F_{1,\,11}$ = 42.50, $P < .0005$). The experimental conditions were both consistently different from the control condition and this difference between control and experimental conditions increased over time. This can be seen in the way the experimental conditions were almost perfectly overlaid in figure 6.6.

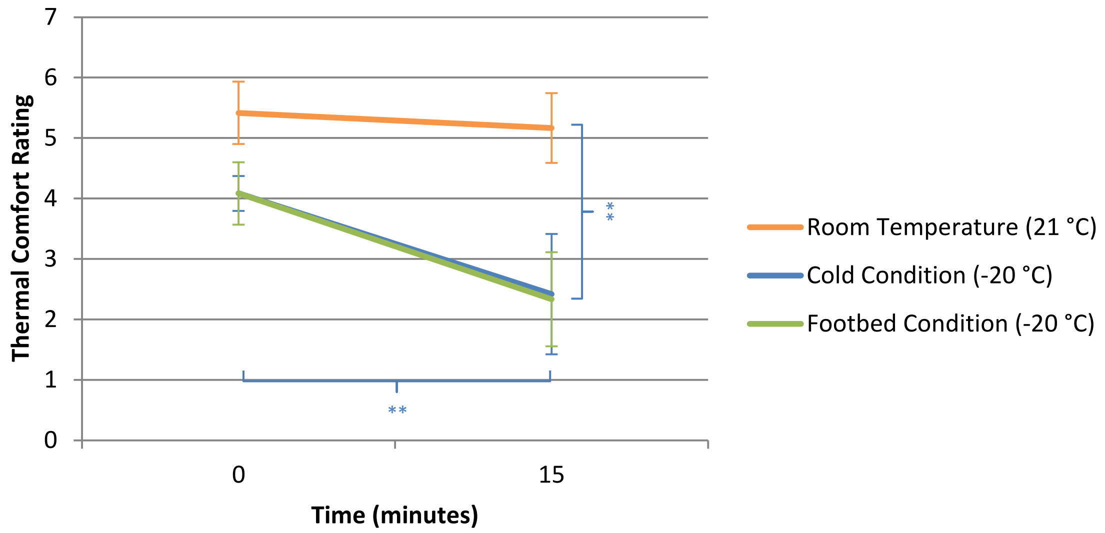


***Figure 6.6.* Thermal comfort rating at room temperature and during 15 minutes cold condition exposure (−20 °C) with and without heated footbeds (*N* = 12).**

***P* < .01 linear effects for condition and interaction

Heart Rate and Heart Rate Variability

The heart rate variability measures showed some significant differences for Mean RR interval, LF power and LF/HF ratio. Interestingly the footbed condition and cold condition appear to elicit different effects for LF power.

Time Domain Analysis

Mean RR interval.

A significant difference was found for mean RR interval for main effect Time ($F_{1, 8} = 7.07$, $P = .029$, $\eta^2_p = .469$, Power = .645), Condition ($F_{2, 16} = 7.86$, $P = .004$, $\eta^2_p = .495$, Power = .906) and the interaction Time x Condition ($F_{2, 16} = 7.91$, $P = .004$, $\eta^2_p = .497$, Power = .908). Figure 6.7 shows the initial depression in RR interval and decline in RR interval during both the -20 °C cold exposure conditions. This represents an increase in heart rate values during cold exposure. Polynomial contrast analysis showed a quadratic effect for Condition ($F_{1, 8} = 15.71$, $P = .004$) with a small difference between the experimental conditions but a much bigger difference between these and the control condition. The Interaction was also quadratic ($F_{1, 8} = 20.30$, $P = .002$). Over time the cold condition diverged very slightly more than the footbed condition during cold exposure.

SDNN.

The variation in RR beat interval (SDNN) was not statistically different for main effect Time ($F_{1, 8} = 0.38$, $P = .554$, $\eta^2_p = .046$, Power = .085), Condition ($F_{2, 16} = 1.09$, $P = .360$, $\eta^2_p = .120$, Power = .208) and the interaction Time x Condition ($F_{2, 16} = 0.83$, $P = .456$, $\eta^2_p = .094$, Power = .167). As can be seen in figure 6.8 the changes in values (approximately 15 milliseconds) are small in comparison to the variation within the group and the effect sizes ($\eta^2_p < .150$) are also consistent with no real difference for this element. It appears that SDNN Is not particularly sensitive to cold exposure.

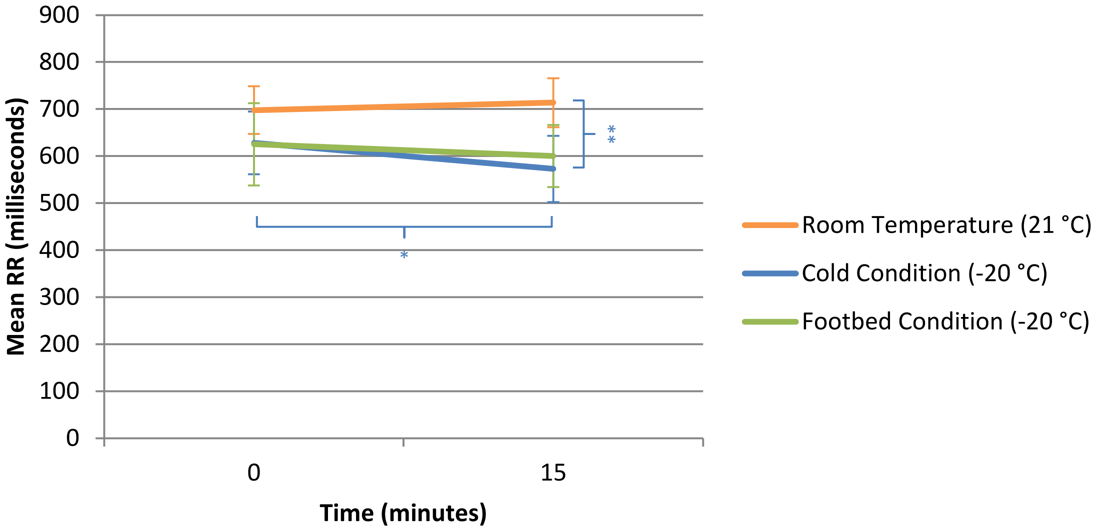


Figure 6.7. **Mean and standard deviation (*N* = 11) of the Mean RR Interval during room temperature, cold (−20 °C) and cold with footbeds conditions (−20 °C).**

***P* < .01; **P* < .05 quadratic effects

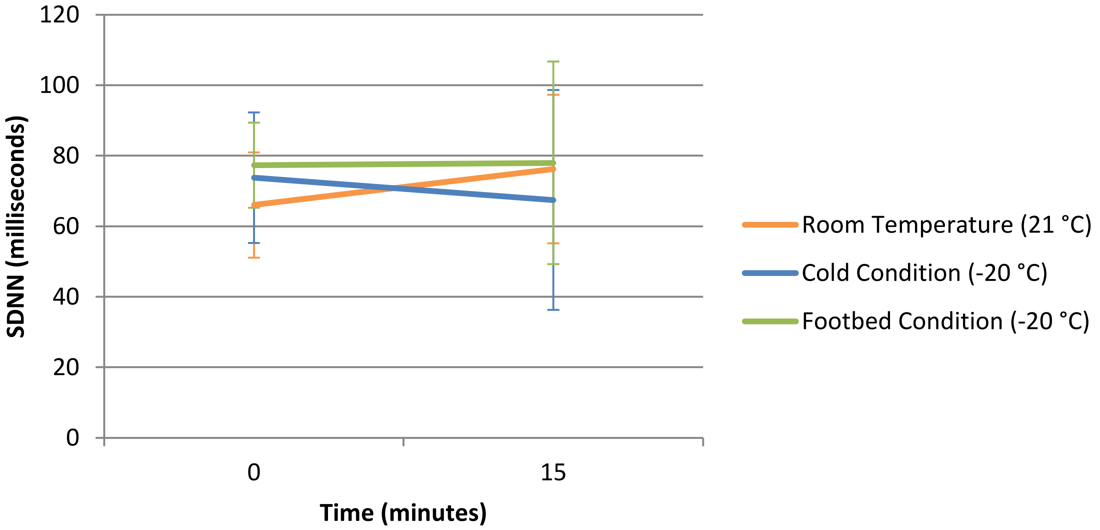


Figure 6.8. **Mean and standard deviation (*N* = 11) of the Mean RR SD (SDNN) during room temperature, cold (−20 °C) and cold with footbeds conditions (−20 °C).**

Frequency Domain Analysis

LF power.

Figure 6.9 shows a trend towards decreasing values for LF in the cold condition but increasing values in the room temperature and footbed condition. No significant difference was found for LF power for main effect Time ($F_{1, 8}$ = 0.06, P = .819, η^2_p = .007, Power = .055) or Condition ($F_{2, 16}$ = 0.07, P = .931, η^2_p = .009, Power = .059). However the interaction Time x Condition ($F_{2, 16}$ = 4.50, P = .028, η^2_p = .360, Power = .684) did show a significant difference. The LF power score decreased during the 15 minute cold exposure (-20 °C) condition but increased in the room temperature and footbed (-20 °C) condition. Polynomial contrast analysis showed a quadratic effect for Interaction ($F_{1, 8}$ = 5.42, P = .048) the change over time of differences between conditions showed the footbed condition behaving much more like the control condition whilst the LF power in the cold condition reduced markedly over time.

HF power.

Figure 6.10 shows a trend towards lower HF power scores in the room temperature condition. No significant difference was found for HF power for main effect Time ($F_{1, 8}$ = 0.15, P = .709, η^2_p = .016, Power = .064), however the main effect for Condition was approaching significance ($F_{2, 16}$ = 2.80, P = .088, η^2_p = .237, Power = .481) with a small to medium effect size (Cohen, 1988). The interaction Time x Condition ($F_{2, 16}$ = 0.941, P = .409, η^2_p = .095, Power = .187) did not show a significant difference. Polynomial contrasts are presented for Condition in accordance with the recommendations of Clark-Carter (1997). Polynomial contrast analysis indicated a quadratic effect for Condition ($F_{1, 9}$ = 6.56, P = .030) with a small difference between the experimental conditions and a marked difference between these and the control condition. HF power was lower throughout the room temperature condition and higher in the cold and footbed conditions at -20 °C. There was a very high variation in the values recorded during the cold exposure conditions (large individual differences) which is probably why statistical significance on the ANOVA was not reached.

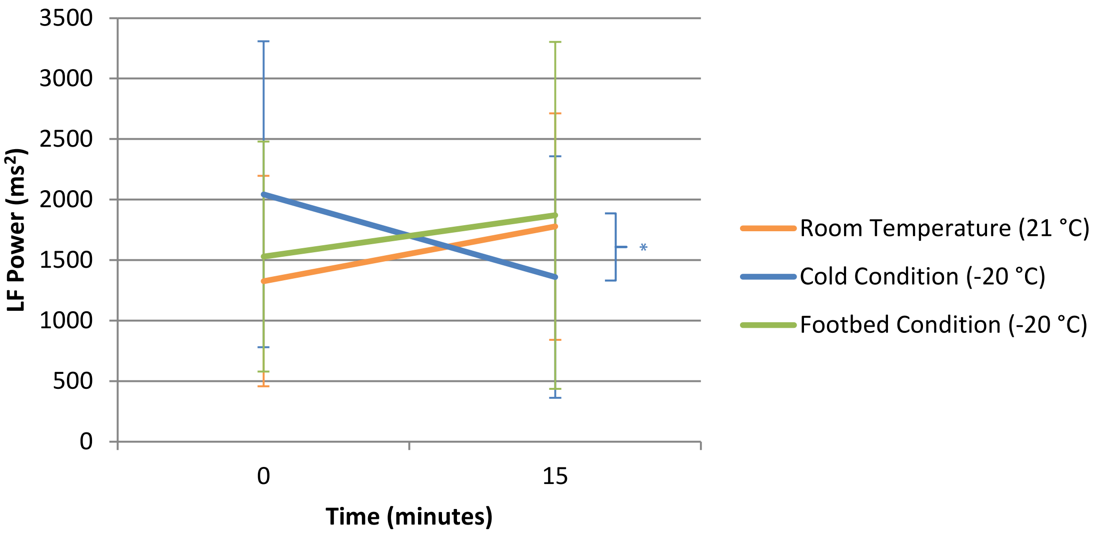


Figure 6.9. **Mean and standard deviation (*N* = 11) of the LF (0.04 – 0.15 Hz) power during room temperature, cold (−20 °C) and cold with footbeds conditions (−20 °C).**

*$P < .05$ quadratic interaction

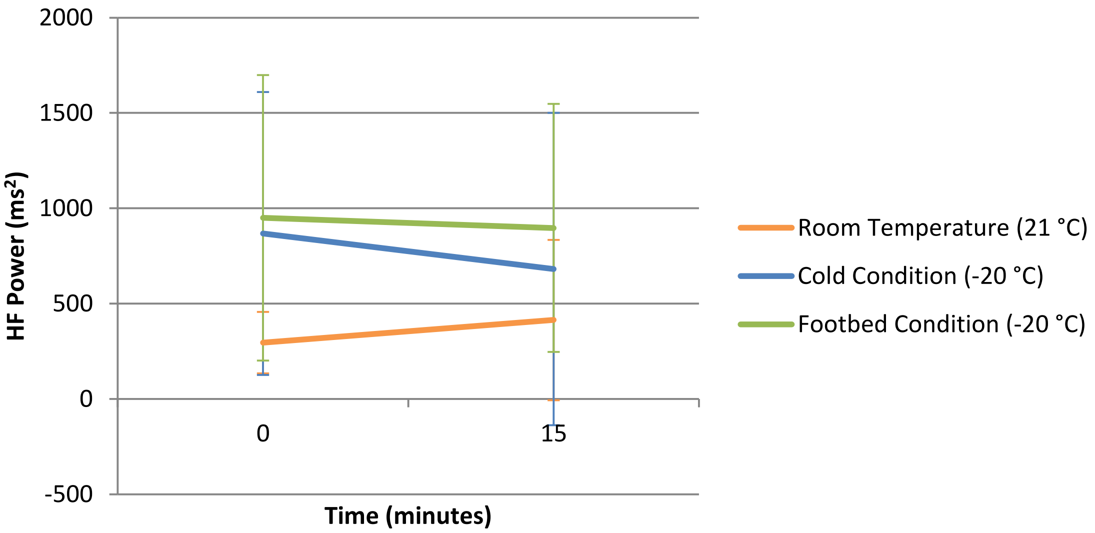


Figure 6.10. **Mean and standard deviation (*N* = 11) of the HF (0.15 – 0.4 Hz) power during room temperature, cold (−20 °C) and cold with footbeds conditions (−20 °C).**

LF/HF ratio.

As can be seen in figure 6.11 the LF/HF ratio was lower in the cold condition and footbed conditional indicating greater LF dominance in the cold exposure conditions which is indicative of increased sympathetic nervous system control over cardiac function. No significant difference was found for HF power for main effect Time ($F_{1,\,8} = 1.50$, $P = .256$, $\eta^2_p = .158$, Power = .191), however the main effect for Condition was significant ($F_{2,\,16} = 4.30$, $P = .032$, $\eta^2_p = .350$, Power = .662). The interaction Time x Condition ($F_{2,\,16} = 2.92$, $P = .083$, $\eta^2_p = .268$, Power = .490) was approaching significance and had an effect size classified as small to medium (Cohen, 1988). Polynomial contrast analysis showed a quadratic effect approaching significance for Condition ($F_{1,\,8} = 4.63$, $P = .064$) there was a marked difference between the room temperature condition and the two experimental conditions but no difference between these. The Interaction contrast indicated a non-significant quadratic effect ($F_{1,\,8} = 3.43$, $P = .101$).

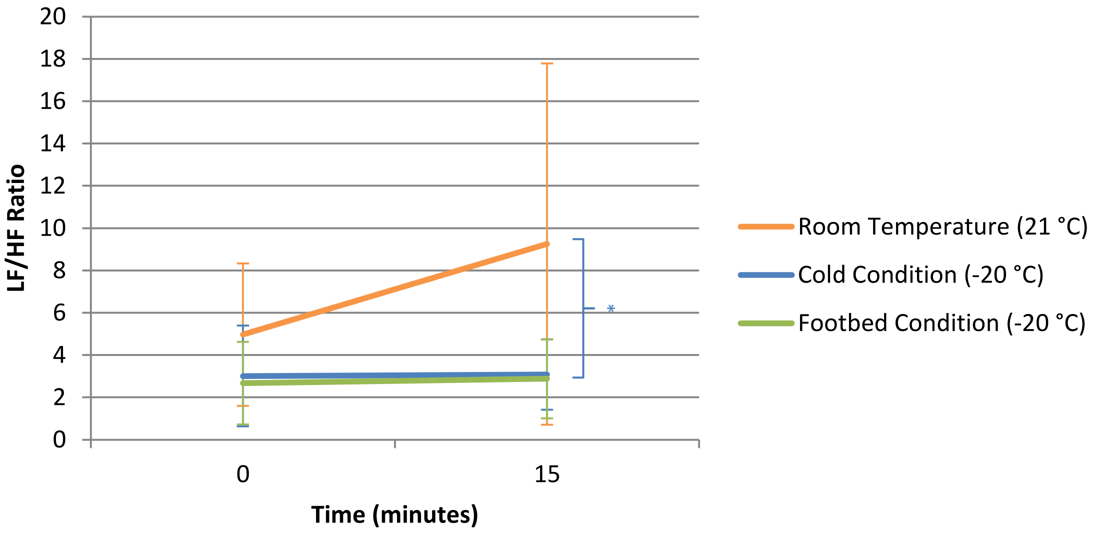


Figure 6.11. **Mean and standard deviation (*N* = 11) of the LF/HF power ratio during room temperature, cold (–20 °C) and cold with footbeds conditions (–20 °C).**

*$P < .05$ quadratic effect and interaction

Postural Control

Two Feet Eyes Open Quiet Standing Balance Test

COP sway rate.

The ANOVA for lateral sway showed significant differences for Time ($F_{1, 11} = 12.62$, $P = .005$, $\eta^2_p = .534$, Power = .898) and Condition ($F_{2, 22} = 20.41$, $P < .0005$, $\eta^2_p = .650$, Power > .9995). The interaction Time x Condition was not significantly different ($F_{2, 22} = 1.77$, $P = .193$, $\eta^2_p = .139$, Power = .331). In figure 6.12 it can be seen that the lateral sway rate in the cold conditions was approximately 4 Hz lower for the initial test and that the sway rates reduced after 15 minutes of cold exposure to 18.8Hz and 20.1 Hz. Polynomial contrast analysis indicated a linear effect for Condition ($F_{1, 11} = 25.96$, $P < .0005$) with between condition differences between the control condition and the experimental conditions but no differences between experimental conditions.

The ANOVA for Fore / aft sway also showed significant differences for Time ($F_{1, 11} = 9.05$, $P = .012$, $\eta^2_p = .451$, Power = .782), Condition ($F_{2, 22} = 28.23$, $P < .0005$, $\eta^2_p = .720$, Power > .9995) but not interaction Time x Condition ($F_{2, 22} = 1.15$, $P = .334$, $\eta^2_p = .095$, Power = .227). Figure 6.13 shows that the fore / aft sway rate was 4.5 Hz lower for the initial cold condition tests and the rate of sway reduced during the cold exposure to approximately 16 Hz irrespective of whether the footbeds were employed or not. Polynomial contrast analysis indicated a quadratic effect for Condition ($F_{1, 11} = 28.84$, $P < .0005$). Again there were between conditions differences between the control and experimental conditions but little difference between experimental conditions.

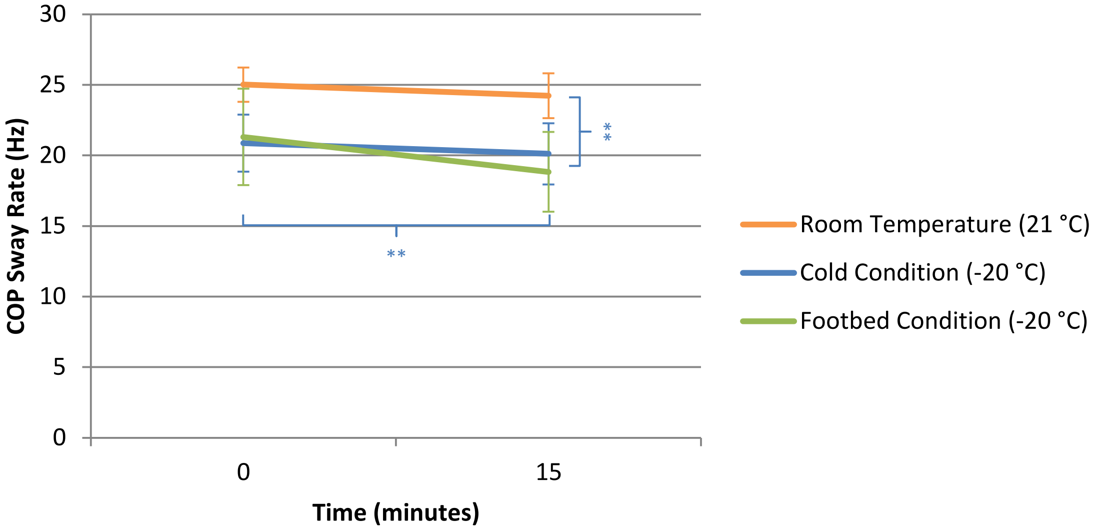


Figure 6.12. **Mean and standard deviation (*N* = 12) lateral sway rate for both eyes open balance test in room temperature, cold (–20 °C) and cold with footbeds conditions (–20 °C).**

***P* < .01 linear effects

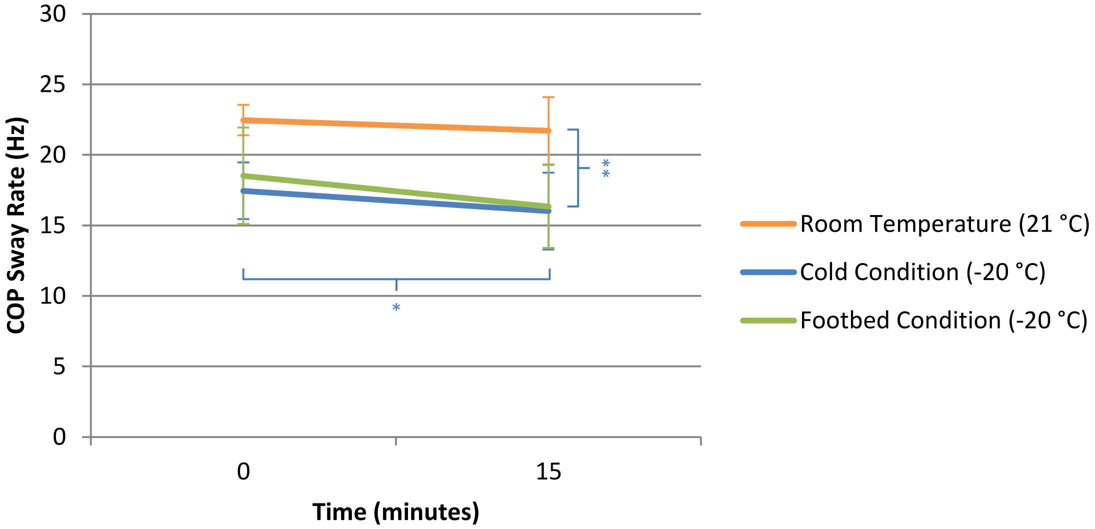


Figure 6.13. **Mean and standard deviation (*N* = 12) fore / aft sway rate for both eyes open balance test in room temperature, cold (–20 °C) and cold with footbeds conditions (–20 °C).**

***P* < .01; **P* < .05 quadratic effect for condition

Total distance travelled by the COP.

The ANOVA for total lateral distance travelled by the COP was approaching a significant difference for the main effects of Time ($F_{1, 11} = 3.95$, $P = .072$, $\eta^2_p = .264$, Power = .442) and was significant for Condition ($F_{2, 22} = 14.98$, $P < .0005$, $\eta^2_p = .577$, Power = .997). Cohen (1988) would describe .264 as a small to medium effect. The interaction time x condition ($F_{2, 22} = 31.19$, $P < .0005$, $\eta^2_p = .739$, Power > .9995) was also significant. Figure 6.14 shows that the lateral distance travelled during postural maintenance was slightly greater even during the initial cold exposure but there was a marked increase in distance travelled between the initial exposure and the 15 minutes tests in both cold conditions; the terminal tests indicating distances double that of the room temperature condition. Polynomial contrast analysis indicated a quadratic effect for Condition ($F_{1, 11} = 11.41$, $P = .006$) with large between conditions differences between the control and experimental conditions and a smaller difference between the two experimental conditions. The Interaction contrast was also quadratic ($F_{1, 11} = 70.77$, $P < .0005$) with the difference in between experimental conditions shrinking over time relative to the difference between these and the control condition.

The ANOVA for total fore / aft distance travelled by the COP showed significant differences for the main effects of Time ($F_{1, 11} = 20.72$, $P = .001$, $\eta^2_p = .653$, Power = .985) and was approaching significance for Condition ($F_{2, 22} = 3.18$, $P = .061$, $\eta^2_p = .224$, Power = .548). The interaction Time x Condition ($F_{2, 22} = 3.72$, $P = .040$, $\eta^2_p = .253$, Power = .620) was statistically significantly different. Figure 6.15 shows that the fore / aft distance travelled during postural maintenance was greater in the cold conditions even on initial exposure. There was also an increase in distance travelled during the cold exposure resulting in a distance measurement double that of the room temperature condition for the cold condition and 264% greater for the footbeds condition. Polynomial contrast analysis indicated a linear effect for Condition ($F_{1, 11} = 4.69$, $P = .053$) with equal between conditions differences with the cold condition lying between the footbed and control conditions. The Interaction contrast was linear ($F_{1, 11} = 9.00$, $P = .012$) with the relative differences between conditions being maintained during an overall increase in between conditions effect over time.

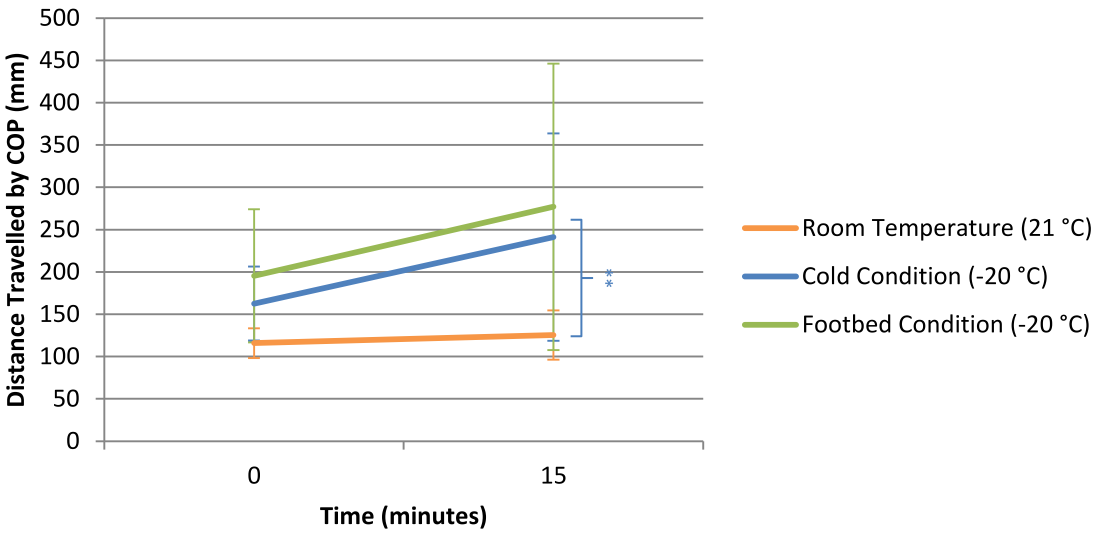


Figure 6.14. **Mean and standard deviation (*N* = 12) total lateral distance travelled by the COP for both eyes open balance test in room temperature, cold (−20 °C) and cold with footbeds conditions (−20 °C).**

***P* < .01 quadratic effect and interaction

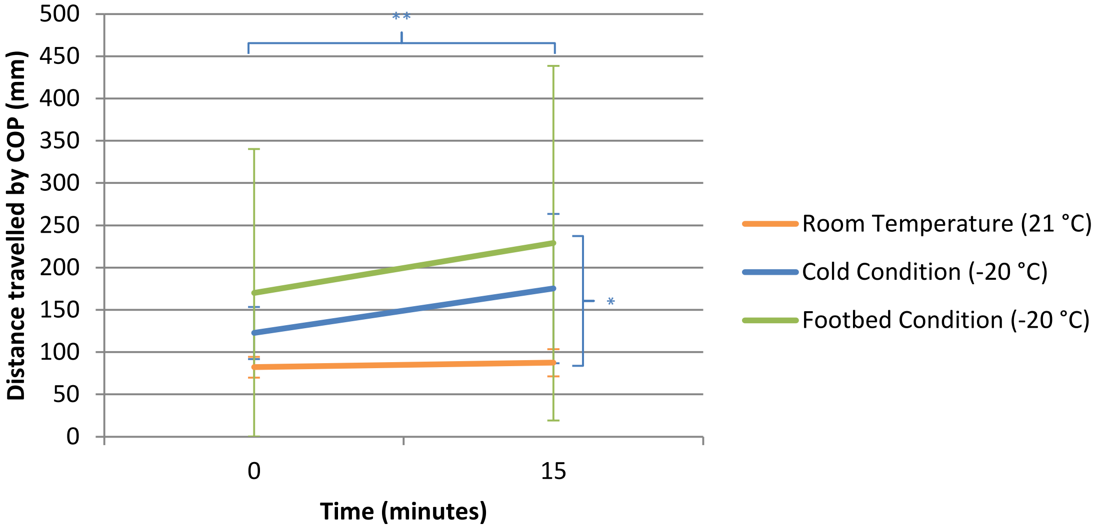


Figure 6.15. **Mean and standard deviation (*N* = 12) total fore / aft distance travelled by the COP for both eyes open balance test in room temperature, cold (−20 °C) and cold with footbeds conditions (−20 °C).**

***P* < .01; **P* < .05 linear effect for condition and interaction

Two Feet Eyes Closed Quiet Standing Balance Test

COP sway rate.

In the eyes closed condition the ANOVA for lateral sway showed significant differences for Time ($F_{1, 11} = 16.82$, $P = .002$, $\eta^2_p = .605$, Power = .961) and Condition ($F_{2, 22} = 20.36$, $P < .0005$, $\eta^2_p = .649$, Power > .9995). The interaction Time x Condition was not significantly different ($F_{2, 22} = 1.60$, $P = .225$, $\eta^2_p = .127$, Power = .301). In figure 6.16 it can be seen that the lateral sway rate in the cold conditions was approximately 3 Hz lower for the initial test and that the sway rates reduced after 15 minutes of cold exposure. Polynomial contrast analysis showed a quadratic effect for Condition ($F_{1, 11} = 30.08$, $P < .0005$) with small between condition differences for the two experimental conditions and a large between conditions effect between these and the control condition. The Interaction contrast was linear ($F_{1, 11} = 6.04$, $P = .032$) with the overall pattern of between condition effects maintained over time but with a small decrease in lateral sway values after 15 minutes of cold exposure in both experimental conditions.

The ANOVA for Fore / aft sway also showed significant differences for Time ($F_{1, 10} = 15.30$, $P = .003$, $\eta^2_p = .605$, Power = .940), Condition ($F_{2, 20} = 24.98$, $P < .0005$, $\eta^2_p = .714$, Power > .9995) and the interaction Time x Condition ($F_{2, 20} = 12.04$, $P < .0005$, $\eta^2_p = .546$, Power = .987). Figure 6.17 shows that the fore / aft sway rate was a little over 2 Hz lower for the initial tests in the cold conditions and reduced further during the cold exposure to a rate of approximately 13.5 Hz. Polynomial contrast analysis indicated a quadratic effect for Condition ($F_{1, 11} = 52.99$, $P < .0005$) with small difference between experimental conditions and a larger difference between experimental and the control conditions. The Interaction contrast was also quadratic ($F_{1, 11} = 13.75$, $P = .004$) with the difference between experimental conditions decreasing slightly but the difference between experimental and control conditions increasing over time.

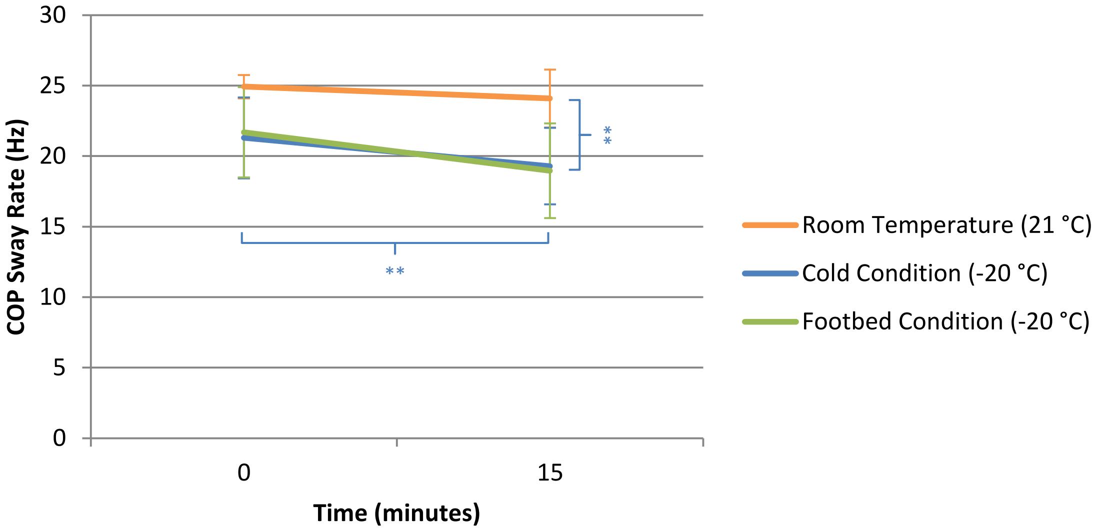


Figure 6.16. **Mean and standard deviation (*N* = 12) lateral sway rate for both eyes closed balance test in room temperature, cold (−20 °C) and cold with footbeds conditions (−20 °C).**

***P* < .01 quadratic effect for condition and linear interaction

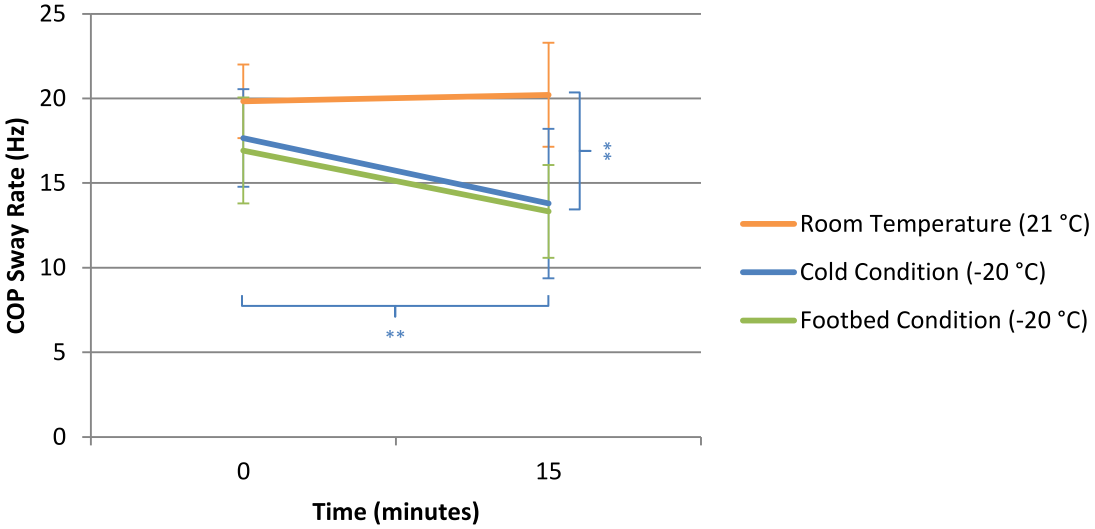


Figure 6.17. **Mean and standard deviation (*N* = 12) fore / aft sway rate for both eyes closed balance test in room temperature, cold (−20 °C) and cold with footbeds conditions (−20 °C).**

***P* < .01 quadratic effect for condition and interaction

Total distance travelled by the COP.

The ANOVA for total lateral distance travelled by the COP was significantly different for the main effects of Time ($F_{1, 11} = 13.85$, $P = .003$, $\eta^2_p = .557$, Power = .922) and Condition ($F_{2, 22} = 9.21$, $P = .001$, $\eta^2_p = .456$, Power = .957). The interaction time x condition ($F_{2, 22} = 4.87$, $P = .018$, $\eta^2_p = .307$, Power = .744) was also significant. Figure 6.18 shows that the lateral distance travelled during postural maintenance was greater on initial testing in the cold conditions and there was a marked increase in distance travelled between the initial exposure tests and the 15 minutes tests with final scores more than 250% greater than the room temperature condition. Polynomial contrast analysis showed a linear effect for Condition ($F_{1, 11} = 14.72$, $P = .003$) with initial performance in the differences between conditions the footbeds condition being worst and the control condition being best. The Interaction was also linear ($F_{1, 11} = 13.00$, $P = .004$) with a consistent increase in between conditions differences over time for both experimental conditions relative to the control condition.

The ANOVA for total fore / aft distance travelled by the COP showed significant differences for the main effects of Time ($F_{1, 10} = 7.63$, $P = .020$, $\eta^2_p = .433$, Power = .702) and Condition ($F_{2, 20} = 4.91$, $P = .018$, $\eta^2_p = .329$, Power = .741). The interaction Time x Condition ($F_{2, 20} = 4.47$, $P = .025$, $\eta^2_p = .309$, Power = .698) was also statistically significantly different. Figure 6.19 shows that the fore / aft distance travelled during postural maintenance was greater throughout both the cold conditions and that there was also an increase in distance travelled during the cold exposure conditions resulting in values over 250% greater for the cold condition than the room temperature condition and 300% greater for the footbeds condition. Polynomial contrast analysis indicated a linear effect for Condition ($F_{1, 11} = 6.82$, $P = .026$) and Interaction ($F_{1, 11} = 13.98$, $P = .004$). Between effects differences been conditions were evident with lowest values for the control condition followed by the cold condition then the footbed condition. The experimental conditions maintained this pattern of between conditions differences despite an overall increase over time relative to a very stable control condition.

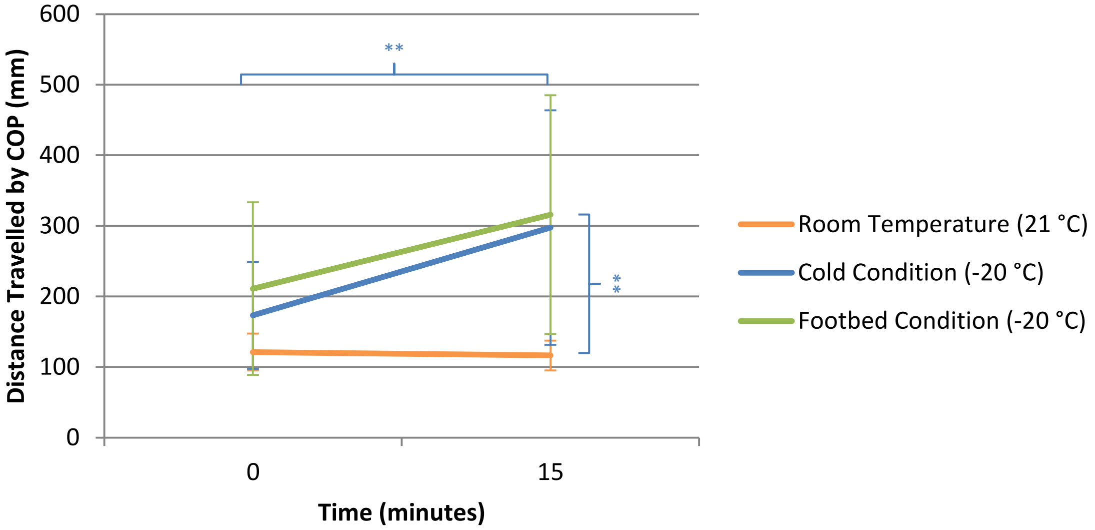


Figure 6.18. **Mean and standard deviation (*N* = 12) total lateral distance travelled by the COP for both eyes closed balance test in room temperature, cold (−20 °C) and cold with footbeds conditions (−20 °C).**

**P < .01 linear effect for condition and interaction

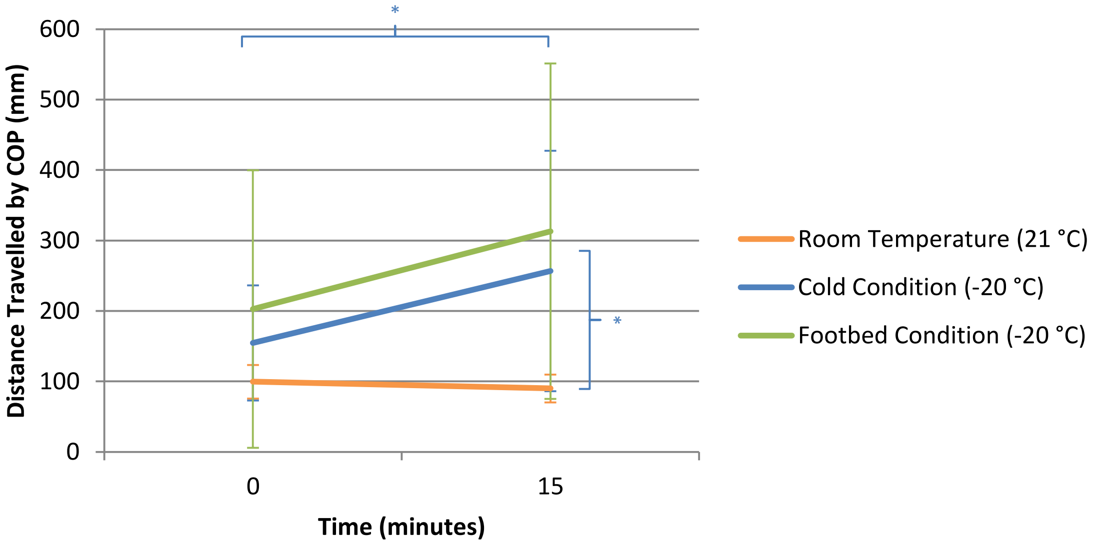


Figure 6.19. **Mean and standard deviation (*N* = 12) total fore / aft distance travelled by the COP for both eyes closed balance test in room temperature, cold (−20 °C) and cold with footbeds conditions (−20 °C).**

*P < .05 linear effect for condition and interaction

Single Footed Quiet Standing Balance Test

COP sway rate.

The ANOVA for lateral sway showed no significant difference for Time ($F_{1, 11}$ = 1.12, P = .314, η^2_p = .092, Power = .162). The main effect Condition was approaching significance ($F_{2, 22}$ = 2.88, P = .077 η^2_p = .208, Power = .506) and the interaction Time x Condition was also approaching significance ($F_{2, 22}$ = 2.84, P = .080, η^2_p = .205, Power = .499). The absolute sway rates only deviate by around 1 Hz but the Time and Interaction effect sizes would be classified as small (Cohen, 1988). Clark-Carter (1997) recommends presenting pre-planned polynomial contrasts even when ANOVAs are do not show significance and polynomial contrast analysis was approaching a quadratic effect for Condition ($F_{1, 11}$ = 4.48, P = .058). The Interaction exhibited a linear effect ($F_{1, 11}$ = 5.58, P = .038) with increasing between condition differences over time and a greater divergence evident for the footbed condition.

The ANOVA for fore / aft sway showed no significant differences for the main effects Time ($F_{1, 11}$ = 0.51, P = .489, η^2_p = .045, Power = .101) but Condition was significant ($F_{2, 22}$ = 5.17, P = .014, η^2_p = .320, Power = .770). The interaction Time x Condition ($F_{2, 22}$ = 0.609, P = .553, η^2_p = .052, Power = .138) was not significantly different. The cold condition and footbeds condition sway rate reduced by approximately 1 Hz. Polynomial contrast analysis indicated a quadratic effect for Condition ($F_{1, 11}$ = 5.44, P = .040) with both experimental conditions exhibiting consistent but lower sway rates than the control condition.

Figures 6.20 and 6.21 show there is actually very little absolute difference between the conditions and during the cold exposure but the small variation in scores makes the small changes more apparent.

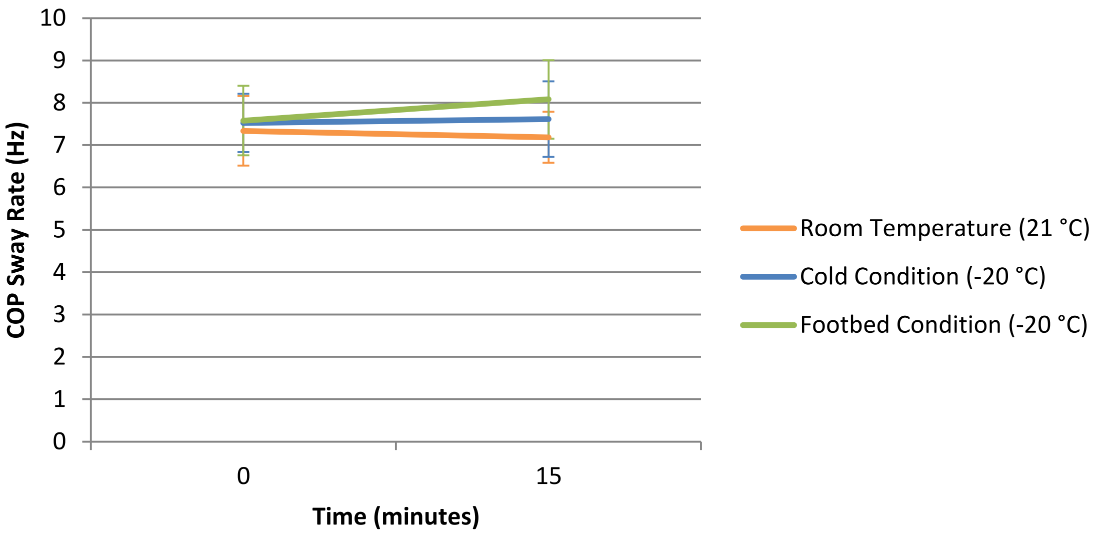


Figure 6.20. **Mean and standard deviation (*N* = 12) lateral sway rate for single footed quiet standing balance test in room temperature, cold (–20 °C) and cold with footbeds conditions (–20 °C).**

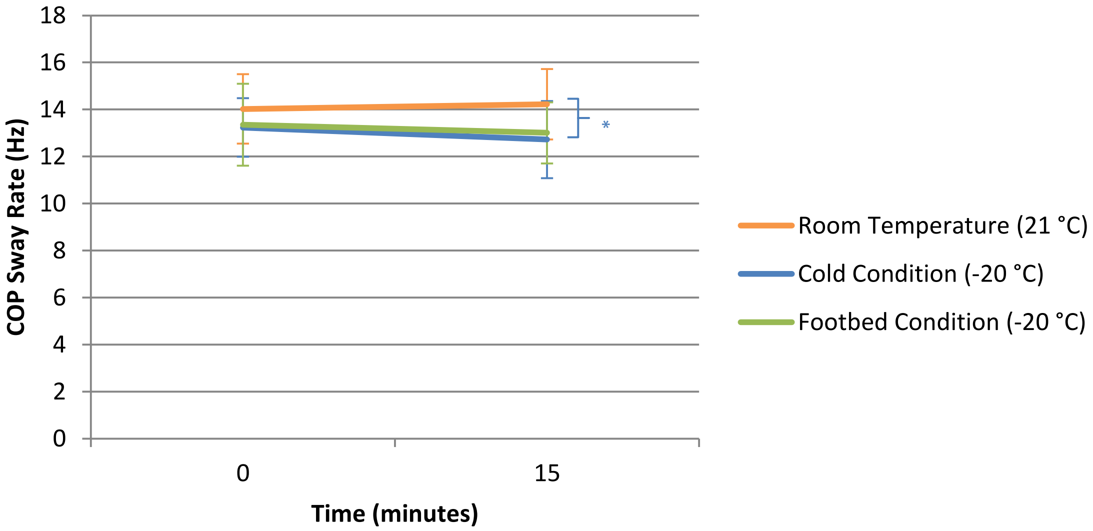


Figure 6.21. **Mean and standard deviation (*N* = 12) fore / aft sway rate for single footed quiet standing balance test in room temperature, cold (–20 °C) and cold with footbeds conditions (–20 °C).**

**P* < .05 quadratic effect for condition

Total distance travelled by the COP.

The ANOVA for total lateral distance travelled by the COP showed a significant difference for the main effects Time ($F_{1, 11} = 6.77$, $P = .025$, $\eta^2_p = .381$, Power = .660) and Condition ($F_{2, 22} = 22.45$, $P < .0005$, $\eta^2_p = .671$, Power > .9995). The interaction Time x Condition ($F_{2, 22} = 2.53$, $P = .103$, $\eta^2_p = .187$, Power = .452) was not significantly different. Polynomial contrast analysis showed a linear effect for Condition ($F_{1, 11} = 27.76$, $P < .0005$) with clear between condition differences between the experimental conditions, which appear to be identical, and the control condition. Figure 6.22 shows that distance travelled by the COP is greater even on initial exposure in both the cold conditions and increases after 15 minutes of cold exposure to almost 200% of the room temperature values. It seems surprising that the ANOVA interaction and corresponding contrast analysis were not significant. This may be due to the high standard deviations evident in the cold condition.

The ANOVA for total fore / aft distance travelled by the COP was approaching a significant difference for the main effect Time with a small to medium effect size ($F_{1, 11} = 3.73$, $P = .080$, $\eta^2_p = .253$, Power = .422) and was significantly different for main effect Condition ($F_{2, 22} = 11.17$, $P < .0005$, $\eta^2_p = .504$, Power = .982). Interaction Time x Condition ($F_{2, 22} = 2.08$, $P = .149$, $\eta^2_p = .159$, Power = .381) was not significantly different. Figure 6.23 shows an increase in fore / aft distance travelled by the COP during the cold exposure condition and the further increase after 15 minutes exposure to approximately 200% of the room temperature values. Polynomial contrast analysis indicated a linear effect for Condition ($F_{1, 11} = 15.05$, $P = .003$) with similar levels of performance for both experimental conditions and clear between condition effects relative to the control condition. Again it seems surprising that the ANOVA interaction component was not significantly different but fore / aft distance travelled by the COP values in the experimental conditions do exhibit a high degree of within conditions variance.

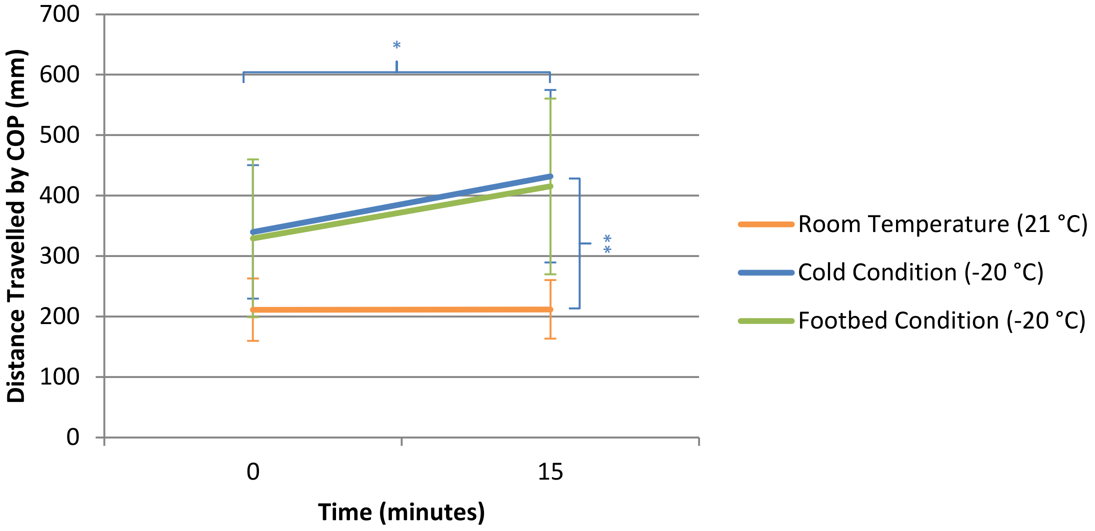


Figure 6.22. **Mean and standard deviation (*N* = 12) total lateral distance travelled by the COP for single footed quiet standing balance test in room temperature, cold (−20 °C) and cold with footbeds conditions (−20 °C).**

***P* < .01; **P* < .05 linear effect for condition

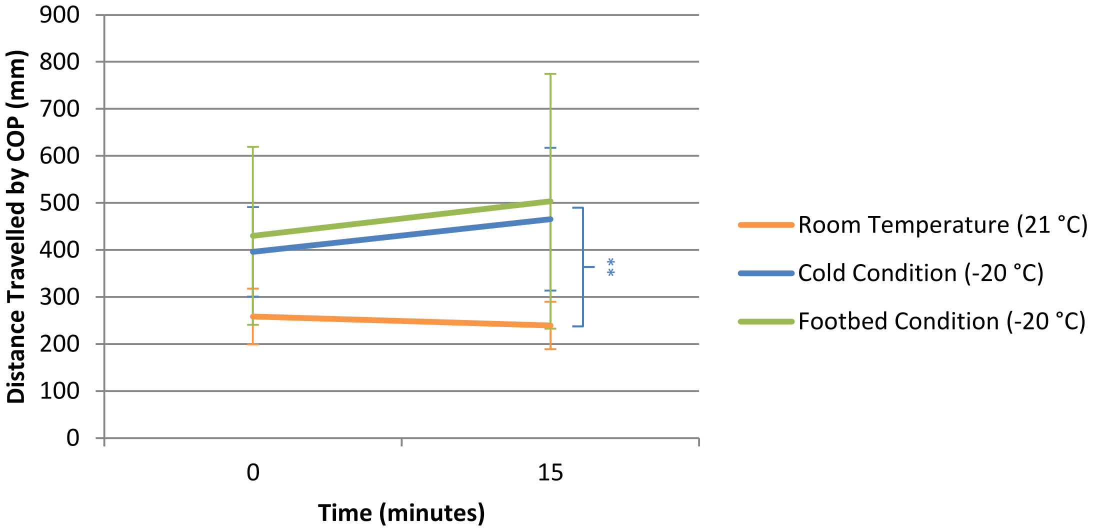


Figure 6.23. **Mean and standard deviation (*N* = 12) total fore / aft distance travelled by the COP for single footed quiet standing balance test in room temperature, cold (−20 °C) and cold with footbeds conditions (−20 °C).**

***P* < .01 linear effect for condition

Discussion

Body Temperature

As in the previous study in the environmental chamber (Chapter 4, pages 65-100) there were no changes to core body temperature in the -20 °C in conditions. The almost insignificant effects sizes ($\eta^2_p < .0005$) indicate that the thermal stress in the study is simply not great enough to have an effect on the core temperature of healthy adults during the 15 minutes of exposure. This seems to fit with the findings of Ellis (1982) who reported that there were no changes to core temperature during what he described as initial exposure at -12 °C (the participants in Ellis study completed 90 or 120 minutes of exposure).

The skin temperature at the temple was lower during initial testing in the cold conditions and dropped during the cold exposure. The drop in head temperature was consistent in both of the -20 °C in conditions which was to be expected as the only difference in the conditions was that the participants were stood on heated footbeds or a passive insulating mat which would have no impact on head temperature. Calf skin temperatures showed a similar pattern with consistent drops in temperature during the -20 °C conditions; this result might also have been expected. Again this broadly confirms the findings of Ellis (1982) that although core body temperature was not compromised in early exposures skin temperatures fall from the onset of exposure.

Foot skin temperatures dropped immediately in the cold conditions and dropped further during the cold exposure. Again the pattern of temperatures and the temperature values were very consistent in both the -20 °C conditions. After 15 minutes exposure at -20 °C the skin temperature of the foot was 11.2 °C and in fact the absolute temperatures when the footbeds were used were very slightly lower (0.9 °C) though not significantly different. Although the footbeds only directly heat the underside of the feet it might have been expected that this effect would result in slightly higher overall foot temperatures if overall blood flow had been improved. The circulation in participants feet, based on the experimenter's observation of visible skin colour of the toes, did not appear to differ between the -20 °C condition and the -20 °C condition with heated footbeds. As discussed in chapter 4 (page

93), Enander (1989) who studied manual dexterity and sensitivity of the hands suggested a critical skin temperature of 8 – 10 °C resulted in a loss of tactile sensitivity.

On initial viewing of the skin temperature figures (figures 6.3, 6.4 & 6.5) all of the mean skin temperatures appear to be around one degree colder during the footbeds trials. The standard deviations for skin temperatures were approximately 3 °C and statistically there was no significant difference. Most tellingly it really isn't plausible that the 3 Watt heating effect of the footbeds could have an effect on skin temperature at the temple and so this small non-significant difference really just seems to be an artefact of random effects rather than a real effect that did not reach the level of statistical significance.

Thermal Comfort

Thermal comfort ratings were significantly lower in the cold conditions and reduced further by the 15 minute tests. The ratings during the -20 °C conditions were identical irrespective of whether participants were using the heated footbeds or the insulated mat. During unstructured interviews after the trials participants reported mixed views on the usefulness of the footbeds in terms of comfort. Half of the participants reported that the footbeds felt warm against the soles of the feet and thought this was an advantage to them. The other half of the group felt either that the footbeds did not feel any warmer than the passive insulated mat, or thought that although the footbeds were warmer their feet were more painful in the heated footbed condition. The footbeds do not appear to have made any impact on the rating that participants gave for their thermal comfort. Any localised comfort advantage of the heated footbeds in the extreme environment of the environmental chamber must be judged on a case by case basis and was probably marginal; quantitatively there was no measureable effect. As Parsons (2003) has stated the pure psychological effects of thermal stress are largely un-researched but behaviour and comments from participants whilst in the chamber would support the view that footbed use didn't really have an impact on their experience or attitudes.

It seems that overall thermal comfort did not appear to benefit from the use of the footbeds. It is quite possible that in a less extreme cold environment that there could be a distinct advantage in terms of comfort but any hypothetical advantage is overtaken during more extreme cold like this study.

Heart Rate and Heart Rate Variability

There were significant differences for RR interval with increased heart rates on initial exposure to the cold and a further increase after 15 minutes of exposure at -20 °C. Since there is no exercise load in either case these increases seem to be a direct response to the cold condition. Previous research suggests that moderate cooling depresses the heart rate (Yamazaki & Sone, 2000) however in the present study cold stress resulted in elevated heart rates. This finding is consistent with the findings of study 2 (chapter 4, pages 77-80).

The mean scores for SDNN were all within 15 milliseconds and there were no real trends for this variable as the standard deviations were all much greater than the differences between any two measures. The previous studies examining HRV and cold exposure (Yamazaki & Sone, 2000; Huang et al., 2011 Matsumoto et al., 1999) had not used SDNN as a measure but in study 2 there had been no significant difference for SDNN (chapter 4, pages 77-78).

There was a significant interaction for LF power and it seems that this measure decreased during the cold exposure but increased during the footbed and room temperature conditions. This was unexpected because LF power is generally viewed as a marker of sympathetic activity (Lopes & White, 2005) so we would expect it to be higher in higher stress conditions; in this case the -20 °C cold exposure condition.

The HF power component was approaching significance for condition with the room temperature (21 °C) values being lower than the cold condition and cold condition with heated footbeds. Again this is a result that in isolation appears counter intuitive as HF power is a marker for parasympathetic activity and higher values would be associated with a more relaxed state. Here the higher values were seen in the -20 °C cold condition and -20 °C footbeds condition. However this finding is consistent with Matsumoto et al. (1999).

There was a significant difference between the two cold conditions and the room temperature condition for LF/HF ratio with lower ratios for the two cold conditions indicating a greater proportion of LF activity and the likelihood of a dominant sympathetic nervous system control response (the fight-or-flight response) of the cardiac system (Lopes & White, 2005). The interaction was approaching significance and this can be seen as a further increase of the LF/HF ratio in the room temperature condition; it seems that participants in the room temperature condition had a greater proportion of parasympathetic activity and became more relaxed during the test. Participants in the cold conditions had a sympathetic dominant response which was maintained during the exposure. Hung et al. (2011) had also found a decrease in LF/HF ratio (their result was approaching significance) when cold stress was applied.

The LF/HF ratio result helps explain the previous power spectrum results. It seems that although the individual LF and HF components did not appear indicative of a classic stress response when viewed in isolation the balance of activity expressed in the LF/HF ratio overall is indeed a stress response with more emphasis on the sympathetic nervous system in the more stressful conditions.

Postural Control

Overall postural control dynamics showed significant differences indicating impaired performance in the cold condition and cold with footbeds condition. In the two footed balance tests sway rates were significantly reduced in the cold conditions. In the two feet eyes open quiet standing balance test sway rates were reduced by around 4 – 5 Hz and the -20 °C cold condition and -20 °C footbeds cold condition had identical profiles. In the two feet eyes closed quiet standing balance test the reduction in sway rates was similar at around 5 – 6 Hz. A 25% reduction in sway rates represents a considerable change to the rate at which participants correct postural movements and it is quite possible that a change of this magnitude could have performance or safety implications in difficult circumstances in a real world environment. Another way to look at the change is that it is an increased response time of 1/100 second for every movement which in more benign circumstances may not pose too many difficulties.

Both lateral and fore / aft distances travelled by the COP were increased in both cold conditions with differences that were either significant or approaching significance. In the eyes open test there were initial increases and an increase after 15 minutes of cold exposure whilst distance travelled by the COP in room temperature conditions remained consistent. The variation in the cold conditions was also much greater with larger standard deviations so although the performance in the footbeds condition appears worse the difference is actually between the cold conditions and room temperature. The two feet eyes closed quiet standing balance test had a very similar pattern of an initial rise followed by a further increase in distance travelled by the COP after 15 minutes of cold exposure. All of the ANOVA scores reached statistical significance. Again, the real difference was between the room temperature condition, which was very consistent with small standard deviations, and the cold condition tests with higher scores and increased variation within the group. Actual scores for the footbeds condition were worse than the cold condition but not significantly. This kind of pattern with fewer responses (indicative of slower ability to respond) and impaired scaling of responses (resulting in greater overall movement) is similar to the effects of somatosensory loss described by Shupert and Horak (1999) in their study of diabetic patients. Mäkinen et al. (2005) described differences in the rates of distance travelled by the COP in eyes open and eyes closed tests of around 20% (the increase for eyes closed tests being greater) and the increases in this study follow a similar pattern with increases of 200% (lateral) and 260% (fore / aft) in the two feet eyes open test and 250% and 275% in the two feet eyes closed test. As a comparison Melzer, Benjuya and Kaplanski (2004) report the difference between elderly patients with a history of falling those who did not was approximately 10% on distances travelled by the COP for two feet eyes open tests. However it needs to be remembered that the elderly patients had other confounding issues such as decreased muscle strength. The greater increase for eyes closed tests is generally considered as a result of a greater reliance on internal (somatosensory) feedback for eyes closed balance tests; in the cold condition the information from mechanoreceptors in the soles of the feet is limited (Magnusson, Enbom, Johansson and Wiklund., 1990). However it needs to be remembered that the evidence for mechanoreceptor anesthetisation in this and the Magnusson, Enbom, Johansson and Wiklund study is only circumstantial.

In the single footed quiet standing balance test there were a number of significant differences and scores approaching significance for sway rates. These were accompanied by small to medium effect sizes. The absolute differences in sway rates were no greater than around 1 Hz but the group variation for single footed sway rates is, as in the other studies, very small and these changes were statistically significant as a result.

The was a clear increase in distances travelled by the COP for single footed quiet standing balance tests in the cold and a further rise after 15 minutes of exposure but no real difference between cold conditions. The lateral distance travelled tests for both cold conditions were remarkably consistent in terms of mean scores and standard deviations there was a noticeably greater variation in the scores for fore / aft distance travelled by the COP for the footbeds condition when compared to the cold condition despite the similarity in mean scores. Increased distances travelled by the COP in the cold conditions were expected for all of the balance tests as these finding fit with the earlier studies and with the findings of Mäkinen et al. (2005) who reported sacrum path length increases for participants who had been exposed to 10 °C for 90 minutes.

Overall the postural control dynamics for the room temperature and cold conditions were as could be expected from the earlier studies with sway and distance changes for two footed tests and distance changes for single footed tests. The significant differences for the single footed sway measures were somewhat unexpected as this measure had not shown any signs of changes previously. It is clear that the actual magnitude of the changes was small but previous to this result it had appeared that the sway rates for one footed tests, even in room temperature conditions, might be to be low enough to exhibit a floor effect where the resulting decrement in postural control was expressed entirely in the distances travelled by the COP.

Overall the performances in the cold chamber with the heated footbeds yielded unequivocal results; it appears that performance was no better than in the basic cold condition in any of the balance tests or performance measures. However this result does fit with the evidence of the temperature and the thermal comfort data as no improvement was discernible in the physical or perceived comfort of the participants when the footbeds were employed.

Conclusion

In conclusion the use of low output electrically heated footbeds for cold exposures of -20°C did not appear to offer any performance or comfort advantage to participants. There is a distinct possibility that a 'Goldilocks zone' (McMichael, 2013) of thermal stress exists where the use of these footbeds would provide participants with comfort or performance advantages but this is likely to be at a much less stressful level of cold exposure. Speculatively zero to -5 °C may be a range where a beneficial effect can be established. The footbeds may also be effective in slowing cooling when combined with other PPE (personal protective equipment) like well insulated winter boots. Heated footbeds and boots may be more effective than boots alone.

There is continued support for the hypothesis that reduction in tactile sensitivity of the soles of the feet is a key factor in the reduction in postural control performance during acute cold exposure.

HRV seems to offer real promise as a biomarker for thermal stress, at least at the cold end of the thermal stress spectrum. A potential problem is that HRV responses to cold appear to be complex and cold stress can be expressed in different ways among the frequency domain outputs. The LF/HF ratio may be of particular value for cold stress research.

CHAPTER 7

CONCLUSIONS AND IMPLICATIONS

Validity and Reliability of Postural Control Measures

The first study in this thesis (chapter 3) examined the reliability of the RSscan International Footscan® Plate System (RSscan International, Olen, Belgium) for use in evaluating postural control in cold conditions and over repeated tests. The conclusions were that performance in room temperature conditions would plateau after 3 trials and that the RS Footscan® Plate System would be reliably operational at -20 °C in the environmental chamber. During the subsequent studies (chapters 4 and 6) these assumptions appear to have held true with consistent room temperature performances by participants after the initial familiarisation protocol carried out in each of the cold stress studies.

A key recommendation for future research is that a familiarisation protocol of a minimum of three trials should be adopted for any standing postural control test that participants will repeat in different conditions or at multiple time points. Not all of the previous research on postural control had adopted such a rigorous approach to the familiarisation and learning effects associated with postural sway and this has undermined the findings of studies such as Gribble et al. (2007). In study 1 it appeared that the more demanding balance tests appear to benefit more from familiarisation. In this thesis the hardest task was the one footed quiet standing balance test which was conducted with both eyes open, if more difficult balance tests are employed then researchers should certainly consider increasing the number of familiarisation trials.

Thermoregulation during Acute Cold Exposure

Results from studies 2 and 4 indicate that during relatively short cold exposures up to 35 minutes, even in extremely low temperatures of -20 °C, healthy humans are able to maintain a constant core temperature that does not differ from expected during room temperature (21 °C) conditions (pages 75 & 131). Maintenance of core body temperature does, however, appear to be at the expense of the extremities and superficial skin temperature which reduces almost immediately in these conditions and can reach very low, potentially dangerous values after 15 minutes of exposure (pages 75 & 131-135). These findings support and add specific details to the findings of Ellis (1982) who made similar comments about short exposures at -12 °C but did not provide quantitative support for 15 minute and 30 minute exposure times. Skin temperatures are compromised relatively quickly in the -20 °C environment with extremities like the feet suffering even more than the head or calf areas. Again this finding supports the comments of Ellis (1982). An apparent difference when studies 2 and 4 are compared to those of Ellis is the impact of medium term exposure. Ellis had participants complete 60 and 90 minute trials at -12 °C, dressed in shorts, but experiences with participants at -20 °C have lead this researcher to question how that was possible without participants suffering significant cold injuries. On one occasion a participant had to be removed from the environmental chamber after 20 minutes of exposure at -20 °C during the 35 minute protocol (study 2) and a number of participants in the 20 minute protocol condition of study 4 had early signs of compromised circulation in their toes which would have meant they could not have completed longer exposures. The difficulties found completing 35 minutes of exposure in study 2 was one of the key factors in the decision to limit exposure times to 20 minutes in study 4.

Localised cooling elicited very different responses to those during whole body exposure. When cooling effects are localised the skin temperatures of cooled body parts are more robust and also recover relatively quickly. In study 3 (The Effects of Isolated Cooling of the Feet on Postural Control Dynamics) it took 10 minutes of cooling with an ice water mix at 1.0 °C to reduce skin temperatures of the feet to the same extent as whole body cooling at -20 °C (figure 5.2, page 110). This is despite the fact that heat transfer is much quicker in water than air due to the increased thermal conductivity of water (Somers, 2014). Even when skin temperatures of the feet were reduced to 10 °C by cold water immersion at 1.0 °C skin temperatures had recovered 5 °C after only 2 - 3 minutes at room temperature (21 °C).

In the literature on thermoregulation of the hands and feet during cold exposure it is common to read about a response known as cold induced vasodilation (CIVD) where at skin temperatures around 12 °C hands and feet can become periodically flushed with blood and rewarm (Parsons, 2003; Van der Struijs et al., 2012). During studies 2, 3 and 4 there was no sign of vasodilation responses in the feet of any participants whilst the cold stress was applied. The number of cold treatments administered totalled 48 trials and 36 different individual participants and not one case of CIVD was observed. This finding is not uncommon and other researchers have reported that CIVD is not always a universal response (Flouris & Cheung, 2009; Van der Struijs et al., 2012). CIVD responses have been a controversial topic in the literature and Van der Struijs et al. report that out of 11 participants 6 exhibited CIVD as a response to air cooling of the toes and 2 participants had declines of toe temperatures down to 4 °C with no signs of CIVD, and that air based cooling is much less likely to produce CIVD than water based cooling protocols. Flouris and Cheung (2009) have argued that CIVD is really a response to an increase in core body temperature (when the body can tolerate a loss of thermal energy) and not peripheral body temperatures, and is unlikely to happen whilst cold conditions are resulting in an overall active threat to homeostasis even through peripheral cooling. This might explain why CIVD responses were not seen in the current series of studies and in fact it could be argued that in the situation participants were exposed to CIVD responses would be unlikely (M.J. Barwood, personal communication, June 2, 2014). The studies in this thesis support the view that the response does not occur whilst the overall thermal situation of participants is tipped towards heat loss and there is an overall threat to thermoregulation homeostasis.

Measurement of Skin Temperatures

Measuring skin temperatures with thermistors has been an effective technique during studies 2, 3 and 4 and is well supported in past research. Thermistors are operational during immersion in water and researchers such as Van der Struijs et al. (2012) have exploited thermistors to make comparisons between cold air and cold water induced thermal stress.

Piloting during study 3 demonstrated that thermistors could report artificially low temperatures when ‘wetted out’ with cold water and this provided a genuine threat to the validity of skin temperature data (pages 103-108). It is strongly recommended that efforts should be made to exclude water from the thermistor / skin interface in order to improve the validity of the reported skin temperatures. Waterproof bagging of the feet proved an effective way to achieve this during study 3 excluding water but allowing good thermal contact and heat transfer. Waterproof tape may be an alternative solution for situations where this approach would not be possible.

Despite the commonly held view that skin thermistors are an appropriate way of measuring temperature during immersion without careful controls the readings may not reflect accurately the actual temperature status of participants. Caution should be applied whenever thermistors are used in an aquatic environment or for temperature measurements after immersion. Thermistors that have been wetted out are likely to report artificial low temperatures, fitting thermistors after immersion takes time and thermistors at room temperature take a not insignificant period of time to accurately reflect skin temperatures of precooled participants and has the additional drawback of making it difficult to monitor the cooling process. The best solution wherever possible is to fit thermistors in advance and exclude water from the interface between thermistors and the skin.

Thermal Comfort

Thermal comfort ratings in participants in the -20 ° C conditions were very low even though core body temperature was not affected (pages 75 & 131). The literature surrounding the assessment of thermal comfort suggests that reporting thermal comfort on rating scales produces inherently reliable measures irrespective of the scale used (McIntyre, 1980 cited by Parsons, 2003). The reliability of these scales may be good but some results have led to questions about the actual construct of thermal sensation ratings. Experiences using these scales during studies 2 and 4 have led to the question being raised as to how participants were integrating their central and peripheral somatic sensations and cognitive responses into a single global measure of thermal comfort. Often mean skin temperature is the main driver for thermal comfort (Frank et al., 1999). One participant who superficially appeared to rate thermal comfort relatively highly compared to others after 30 minutes of exposure at -20 °C in study 2 also had the warmest feet. Other body temperatures were similar to that of other participants but it appears that for this participant at least a less cold ‘coldest body part’ may have resulted in their higher overall rating which would be consistent with Arens et al. (2006) findings. They reported that overall thermal comfort follows the sensation in the most uncomfortable body parts. Additionally they reported that in cold conditions the feet are often the major source of discomfort; further supporting the view that an intervention in this area was likely to produce good results.

As an experimenter working in the chamber it seemed that thermal comfort rating may be mediated to some extent by expectations about exposure time. Many participants, and even the researchers, in the chamber may have employed a ‘pacing’ or ‘countdown’ style paradigm to their cognitive appraisals of comfort in an effort to manage their perceived stress. Participants in exercise studies have been shown to ration their physical energies to match the expected task duration (St Clair Gibson, Lambert, Rauch, Tucker, Baden, et al., 2006) and it may be that in the cold chamber participants ration the mental effort required to complete the exposure. Participants in the 30 minute trials seemed to retain some ‘headroom’ in terms of thermal comfort at 15 minutes that they could use up in the second half of the exposure whereas in the 15 minute trials participants didn’t appear to have the reserves to tolerate another 15 minutes at the 15 minute point. Mason’s (1975a, 1975b) view that stress response is mainly related to the intensity of the individual’s perceptions of the stressor rather than the intensity of the stressor itself may offer an insight here. There is a process of cognitive appraisal of the task demands and the expected timeline of the protocol may play an important role in the judgements participants make about their ability to cope with the demand. Baker and Kirsch (1991) identified expectancy effects as having a role in tolerating painful stimuli and subjective experience generally. They also identify a tendency for expectations in this area to become self-confirming. It may be that participants assume that they will be at the limit of their endurance at the end of the experimental protocol irrespective of the actual level of stressor (time of exposure). During the cold condition protocols, in the environmental chamber, participants are very limited in terms of the responses that they can employ. In ‘real world’ cold conditions behavioural responses to the cold would include clothing choices and the opportunity to increase rates of exercise to generate heat and divert attention from the discomfort. These kinds of options were very limited for participants in the environmental chamber and this reduction in perceived choice and control may also escalate the cognitive component of the stress response. This phenomenon of cognitive appraisal of the duration and stress level of the task and subsequent modulation of responses is an interesting avenue of enquiry for subsequent environmental stress research. The impact of the perception of freedom of choice over coping behaviours that participants can employ may also be worth exploring. Even the ability to determine a coping strategy may be of emotional benefit to personnel working in the cold irrespective of the actual physical benefits.

Heart Rate Variability as a Cold Stress Biomarker

The use of heart rate variability as a cold stress biomarker is attractive as it offers a non-invasive and effectively invisible technique to monitor the status of participants. Previous studies (Yamazaki & Sone, 2000; Huang et al., 2011) have had limited success with this measure but had used very different cooling methodologies using either water cooled suits at 10 °C or cold water immersion of an individual limb (left hand) at 7 °C. In the Huang et al. cold water immersion study LF/HF ratio was approaching significance ($P = .076$). Yamazaki and Sone had significant increases in LF and HF power values but no significant difference for LF/HF ratio. Matsumoto et al. (1999) had shown increases in HF power during cold exposure in 10 °C air.

The results of studies 2 and 4 indicate that HRV might provide an important link between exposure to the conditions in the environmental chamber and a generalised stress response for whole body acute cold exposure. Changes were either significantly different or approaching significance on a number of HRV variables.

Mean RR interval was reduced in the cold conditions of both studies and reduced further during exposure (significant differences in study 4 and medium effect size for study 2, pages 77-78 & 136-140). This finding is synonymous with increasing heart rates which is somewhat against the trend in the literature. This may well be because a lot of cold exposure literature is limited to moderate cold between 1 and 10 °C. Van Orden, Benoit and Osga (1996) reported increased heart rates when exposure at 4 °C was paired with a cognitive stressor but no increase for either of the single stressors in isolation. It may be that heart rate increases as a response to cold only occurs when the total stress exceeds a level of stress beyond 1 °C exposure as an isolated stressor. This drew strong agreement between the findings of studies 2 and 4.

The LF/HF ratio is particularly interesting. LF/HF ratio is generally considered to be a measure of sympathetic to vagal activity. Higher values represent sympathetic dominance and lower values represent vagal dominance. A move towards sympathetic dominance (the fight-or-flight response) during higher stress conditions such as initial cold exposure or during cold exposure would provide evidence that HRV is a good biomarker of cold stress (a secondary aim of the project). A point of caution here might be that a subgroup of participants who are particularly sensitive to the stressor could have their HRV response modified by previous cold exposure (Lunt et al., 2010). Lunt et al. found that this effect modified the HF power during exposure to a hypoxic stressor.

In study 2 (The Effects of Acute Cold Exposure on Body Temperature, Postural Sway Dynamics during Quiet Standing, and Heart Rate Variability) there was a trend towards sympathetic dominance during exposure at -20 °C, a classic stress response (pages 95-97). Whilst it might be easy to assume that exposure to extreme environmental conditions such as -20 ° C will result in threats to homeostasis and associated responses it is much better to be able to establish that this is the case through objective measures. In study 4 (The Impact of Active Heated Footbeds during Acute Cold Exposure on Body Temperature, Heart Rate Variability, and Postural Sway Dynamics during Quiet Standing) the LF/HF ratio seemed not only to be consistent during the cold exposure conditions but also exhibited lower scores than the room temperature condition (page 140). It is hard to explain this discrepancy between the studies with almost identical environmental demands but it does reflect problems in establishing repeatable stress effects from HRV data that is a common theme in the literature (Yamazaki & Sone, 2000; Huang et al., 2011).

A clear trend across the HRV variables in studies 2 and 4 is that there is a consistently greater degree of between subjects differences in the room temperature conditions and much less variation between subjects in the cold exposure condition. This is not an uncommon effect with HRV as in low stress conditions individual differences can have a greater effect on cardiac control; as stress is increased participants' cardiac measures tend to converge. Studies have shown compressed group ranges in participants with medical conditions (Osterhues, Groβmann, Kocks & Homback, 1998) and increased age (Umetani, Singer, McCraty & Atkinson, 1998). It may be that reduced group range is a useful indicator of a stress causing situation.

The Effects of Acute Cold Exposure on Postural Control

On exposure to extreme cold air conditions (-20 °C) there are immediate changes to postural control dynamics that would generally be interpreted as impaired performance (Hrysomallis, 2011; Ragnarsdóttir, 1996). For balance tests on two feet these changes manifest themselves in the form of reduced sway rates and increased COP path lengths (pages 81-88 & 141-148). This increasing centre of pressure (COP) displacement during static balance tests is consistently viewed by researchers as a poorer performance (Mancini et al., 2012). Results from the current studies show that during one footed tests sway rates tend to remain constant and changes are expressed as increases in COP path lengths (pages 89-92 & 149-152). Some researchers (Enander, 1987; Van Orden et al., 1996) have linked a general increase in arousal produced by cold stress to faster reaction times. The sway rate data in the current studies suggest that if there any processing speed benefit for postural control then this effect is offset by other factors. Ellis (1982) suggested that arousal increases and distraction effects both played a role in changes in performances on tasks in the cold and that the outcome changes are resultant when one of these factors is dominant for the task. Additionally, Donker et al. (2007) have shown that carrying out cognitive tasks can impair postural control performance; presumably because the amount of attention that can be invested in postural maintenance is reduced. These writers would lead us to interpret the initial reduction in performance on postural control for acute cold exposure as a consequence of the distraction effect of cold air on the skin.

Further exposure to acute cold results in increasing impairment in postural control (measured at 15 minutes and 30 minutes in the studies of this thesis). This decrease in performance seems most likely to be a result of lost somatosensory information from pressure sensors in the soles of the feet at low skin temperatures. Mechanoreceptors have been identified by Magnusson et al. (1990) as a possible factor in postural control performance during isolated cooling of the feet and isolated cooling effects became the focus of study 3.

It was possible to produce similar skin temperatures during isolated cooling of the feet using an ice bath protocol. The result was a similar pattern of postural control changes but at a lower magnitude of effect than with whole body cooling (pages 111-116). The implication here was that a significant amount of the performance decline during whole body cooling may be attributed to the physical effects of cooling the feet themselves, but also that there are additional factors at play (perhaps attentional) during whole body cooling.

As expected the performances were generally a little worse during eyes closed balance tasks than the eyes open equivalent but the impairment in eyes closed tests was not as dramatic as may have been originally predicted. In the eyes closed condition when compensation for the loss of somatosensory information after cooling should be harder to achieve (Magnusson et al., 1990) a catastrophic impairment to the postural maintenance process would not have been too surprising however this level of effect did not occur. Johansson and Magnusson (1991) identify three sources of sensory input that are combined in order for the central nervous system to identify our position in space and calculate the continuous adjustments that are needed to maintain an upright position: somatosensory information, vestibular information and visual field information. It would seem that the compensatory mechanisms available for postural maintenance are actually quite adaptable and although the concurrent loss of vision and reduced information from mechanoreceptors of the feet do result in a slightly greater impairment in performance the vestibular and residual somatosensory feedback is sufficient to prevent a catastrophic breakdown in postural maintenance in eyes closed balance tests, even after significant cooling of the feet. It was an interesting result as it might be expected that the decline in the performance of postural control might accelerate under the combined stressor of reduced tactile somatosensory information and total loss of visual field information. Mäkinen et al. (2005) also reported that they found the relative increase in postural sway was greater after cold exposure in the eyes open condition than the eyes closed condition. They did not explain their result but it seems that initial losses of sensory information may have relatively large effects on postural control and further sensory losses do lead to further impairments, but at a reducing rate.

Mäkinen et al. (2005) had suggested that impairments in postural control may be due to changes in sensory functioning or neuromuscular control. The data from whole body cooling and isolated foot cooling suggest that in fact both of these effects probably play a role in postural control impairment. Figure 7.1 shows a process based model of postural control which is a useful tool in understanding where cooling effects can interrupt the effective function of the postural control system. Postural information is gathered by the visual, vestibular and somatosensory systems. Sensory impairment begins with the sensory systems but the main effect of sensory signal loss is in the ability of an organism to estimate its postural state. The resulting control strategy responses are less accurate and motor command output result in movements that are not as effective in managing the upright state. The somatosensory system can be subdivided into the tactile sensory system and the proprioceptive sensory system, and study 3 has demonstrated that a loss of tactile somatosensory information results in a worsening of postural control. However, this change was not to the same extent as found during whole body cooling. Stål et al. (2003) also commented that although there were effects in their ice bath cooling study they were not as great as they had expected and provided more evidence that although mechanoreceptors in the feet play a vital role in effective postural control, the balance system can still cope remarkably well when they are anaesthetised.

Vestibular sensory information was almost certainly unaffected during the cold exposure in the current studies. Impairment of the vestibular organs is normally a result of permanent damage such as vestibular hair cell loss, vestibular neuritis or lesions (Green & Angelaki, 2010), or temporary impairment from disruption caused by large movement generated forces such as the disorientation that occurs on a fairground ride. There is no reason to believe that the vestibular system would be affected by even 35 minutes of exposure at -20 °C.

Proprioceptive information from deeper tissues such as muscles and tendons (muscle spindles and Golgi tendon organs) was still available during whole body cooling however it may be that there is some impairment of proprioceptive information from extremities like the feet during whole body cooling but not during ice bath cooling. This may explain some of the difference in the size of impairment effects of the different cooling protocols.

Previous research has indicated that additional attentional demands can impair postural control (Donker et al., 2007) and it is quite possible that during whole body cooling there is greater competition for attentional processes. This effect would impact on the performance of the controller elements of figure 7.1: state estimation and control strategy formulation. Ellis (1982) suggested that distraction effects were a problem for performance in the cold on cognitive tasks and is quite possible that processing the thermal and pain related stimuli during whole body cold exposure diverts central nervous system resources away from postural control.

An interesting line of research may be to see what the effects of additional cognitive tasks may have on postural control during environmental stress. At present few practitioners would consider the implications of cognitive problem solving on their ability to move safely over difficult terrain but it may be that impaired postural control process increase the risk of combining these activities much more than we may have thought. It may be that a stop-start strategy is actually much safer.

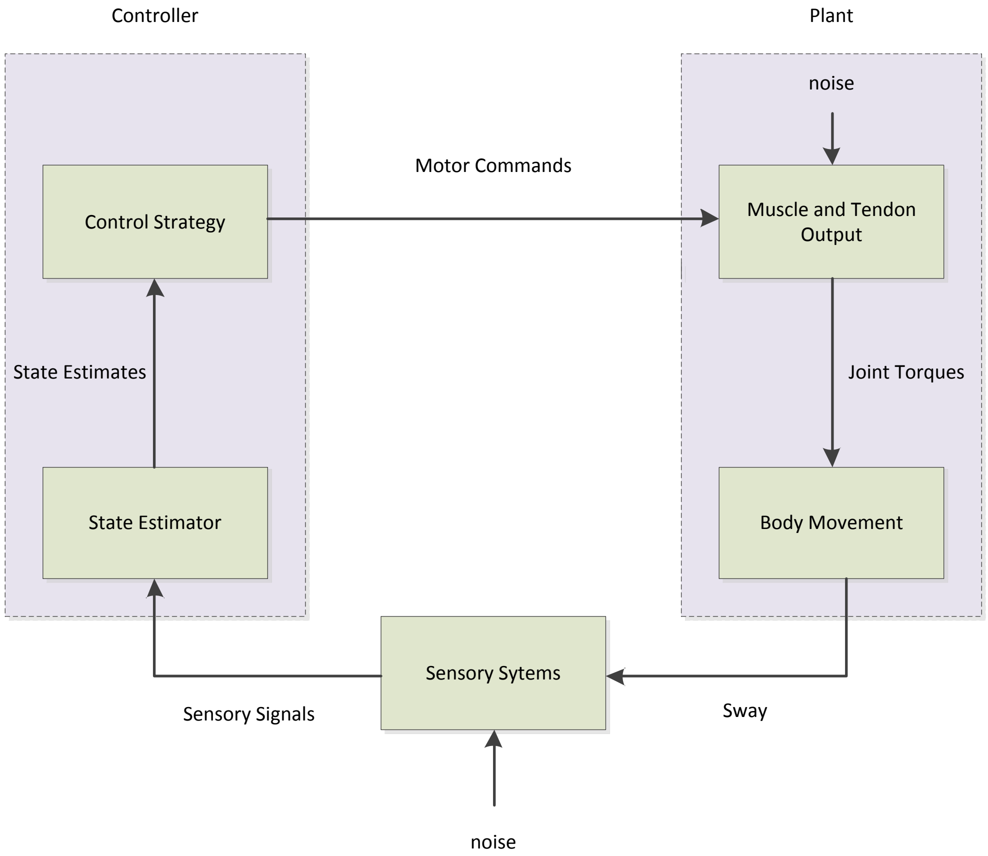


Figure 7.1. **A schematic representation of the postural control system from a control theory perspective.**

Note. From M.D. Binder, N. Hirokawa, and U. Windhorst (Eds.), 2009, *Encyclopedia of Neuroscience.* New York: Springer.

Postural Control System Compensation

An important outcome from the cold condition studies (2, 3 & 4) is the finding that although additional impairment / reduction in the amount or channels of sensory information available to the postural control system results in an increasingly poor performance, the rate of impairment does not appear to be linear. It appears likely that there is a certain level of duplication and redundancy in the sensory information that the central nervous system normally receives, and therefore attentional switching to prioritise alternative information may be the mechanism behind our ability to cope with visual or somatosensory losses. Peterka (2002) refers to this process as ‘sensory channel reweighting' as participants more their reliance on sensory information to account for environmental effects. Where the source of sensory information contributing to postural control can be shifted then this kind of nonlinear effect is possible. If there is no possibility of shifting to a new source of information (for example if the vestibular organs were damaged in some way) then a reduction in sensory information will result in a much greater reduction in the quality of postural control. Figure 7.2 shows a model of sensory integration that includes an element of sensory channel weighting. This model allows the postural control system to prioritise sensory information based on its relevance and reliability in particular environmental, organismic and task conditions. In study 2, when only the feet were cooled in the ice bath protocol, the performance drop during the eyes closed condition and eyes open condition was of a very similar absolute magnitude. This can be explained by the ability of the postural control system to increase the weighting of the unaffected vestibular and proprioceptive elements of the somatosensory stimuli.

If some sensory stimuli are confusing or misleading then it is actually possible for the postural control system to deprioritise these and switch to a more reliable source of sensory information. However Peterka (2002) showed that if the incoming information is limited by damage or environmentally induced limits then it can be impossible to ignore information that is actually detrimental to performance. In their study on sensorimotor integration, where visual information was deliberately manipulated to make it misleading, participants with damage to the vestibular organs performed better with their eyes closed because unlike the control group they could not ignore the misleading stimuli. The control group were able to weight the reliable information from the vestibular and somatosensory systems. In cold conditions with anesthetised feet participants may be particularly vulnerable to misleading sensory information. It could be particularly interesting to test this effect in relation to anesthetised mechanoreceptors in the feet. This phenomenon may help to explain the problems skiers have in stormy conditions with combined cold and poor visibility. It is not uncommon to suffer from impaired balance or even motion sickness in these conditions and this is hypothesised to be a result of sensory information conflict (Häusler, 1995).

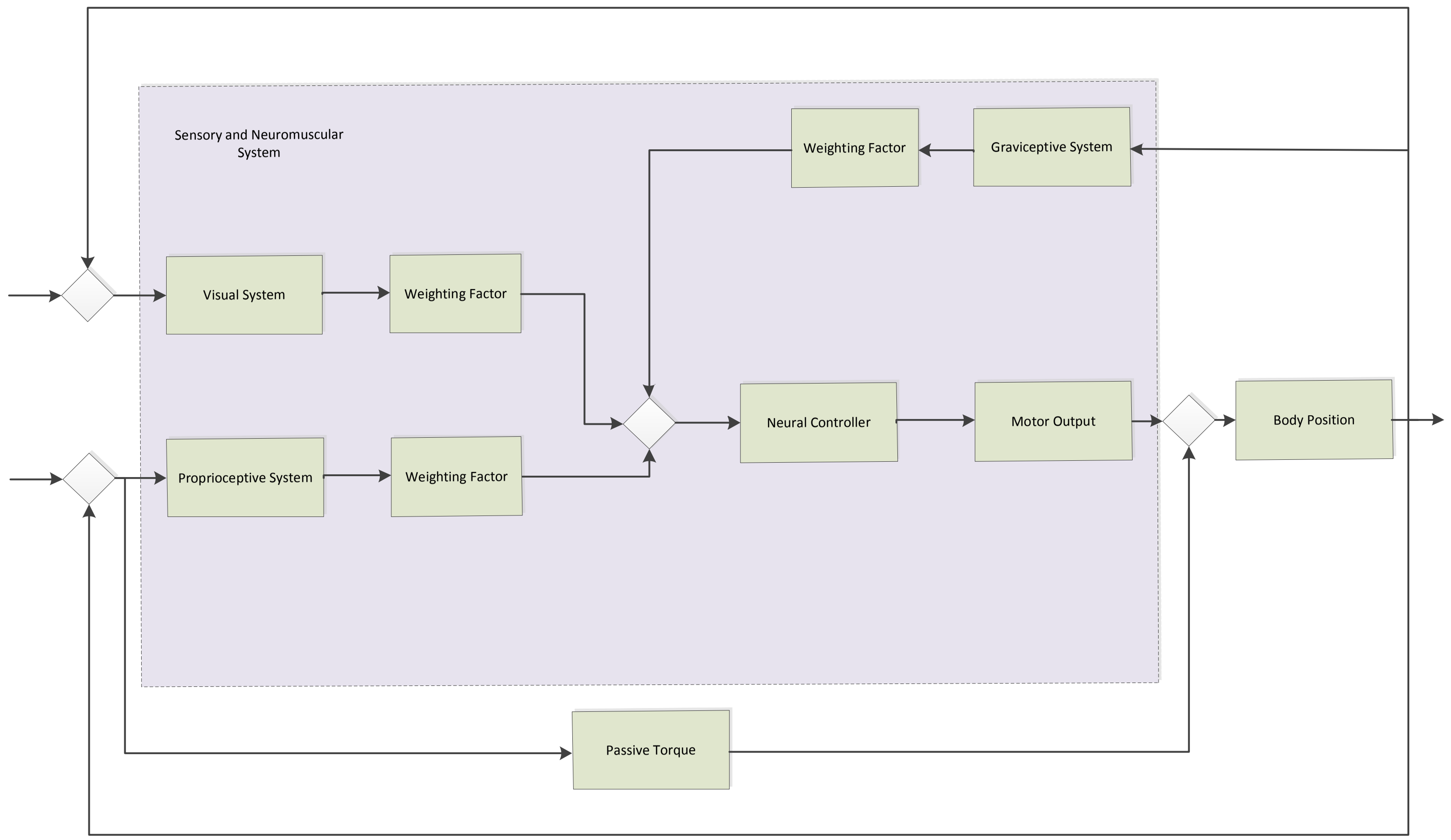


Figure 7.2. **"Independent channel" model of sensory integration in postural control showing a weighted addition of contributions from visual, proprioceptive, and graviceptive systems.**

Note. Adapted from R.J. Peterka, 2002, Sensorimotor Integration in Human Postural Control, *Journal of Neurophysiology, 88,* 1097–1118.

Implications and Generalizability of Results Beyond the Laboratory

One of the initial delimitations regarding this thesis was that data would be collected in a controlled laboratory setting. However, the findings were intended to relate to work in alpine and arctic environments. It is reasonable to evaluate how useful the data from the laboratory would be in predicting ‘real world’ effects. The rate of cooling that participants experienced in the environmental chamber and foot bath was undoubtedly higher than we would normally expect when appropriate cold weather clothing in a comparable outdoor environment. However the body temperatures and subjective thermal comfort experienced by participants is realistic if exposure was for a few hours or more. During informal interviews after the experimental sessions at -20 °C some participants who had been involved in skiing confirmed that their feet sometimes felt as cold during the activity as they had in the chamber. In their study on the effectiveness of military ski boots Heus et al. (2005) reported skin temperatures for the feet of approximately 12 to 13 °C after 90 minutes at -18 °C so the 10 °C skin temperatures achieved in the studies in this thesis are reasonably comparable.

At present it is not really possible to confirm that postural control is affected in exactly the same manner in ‘real world’ settings but there seems little reason to suspect that it does not. Other factors that occur in the natural alpine or arctic setting such as fatigue from working on unstable or complex terrain, exposure to wind, and energy depleting physical tasks, mean that it is likely that, when foot temperatures reach the equivalent temperature to the laboratory scenario, postural control is actually impaired to a greater extent because of the compound stress situation that would be inevitably experienced. Compound stress effects are very interesting, and have strong real world ecological validity, but were deliberately avoided in this thesis because of the problems involved in attributing effects to any of the individual components of compound stressors.

Future research should certainly examine the isolated effects of working in windy conditions and other components of environmental stress that are exhibited in alpine and arctic environments. Combined stress studies then can examine interaction effects from a solid foundation.

Conclusion

The aim of this thesis was to investigate the impact of cold exposure on postural control during static balance tasks. It was intended to establish the impact of short term cold exposure on human postural maintenance, identify key processes that lead to performance changes, and finally to examine approaches to maintaining performance of postural control during acute cold exposure. The findings were that postural control is impaired on initial whole body cold exposure and is impaired further after short (15- 30 minutes) exposures. The main effects are in terms of response scaling with a lesser impact on the speed of responses. Key mechanisms that impact on performance are reduced localised skin temperatures and the resulting decline in the effectiveness of mechanoreceptors in the feet alongside generalised stress responses that appear to impact on attention and the processing of postural sway information. Despite a strong link between reduced skin temperature and impaired performance a targeted intervention, using active heated footbeds to maintain skin temperature in the feet, was found to be ineffective in providing any measurable benefit in terms of comfort or performance.

Areas for Future Research

- The use of HRV as a biomarker for environmental stress.
- The impact of cold as an element of compound stress.
- The role of attention on performance on motor control in the cold.
- The impact of expectation on experience, comfort and performance in the cold.
- The impact of perceived choice on perceived cold stress levels.
- The limits of sensory compensation in the cold.
- The possibility of a ‘goldilocks zone’ for effective use of heated clothing such as footbeds during cold exposure as an intervention for cold related declines in motor performance.

There are a number of areas highlighted in this thesis where follow up research would be interesting. These fall into two groups; those that follow up directly on the aims of studies within the thesis, and those that occurred as a result of unexpected effects that appear to offer interesting avenues of enquiry. Continuing work on targeted interventions such as the heated footbeds in study 4 is very much an applied area for future research with clear benefits for practitioners. Areas such as expectation effects and the role of perceived choice in stress responses offers more theoretical insight into the process behind performance during environmental stress but may also have applied outcomes.

Despite over a half a century of research into stress since Selye’s (1956) work there are still aspects of human behavioural, emotional and cognitive responses to stress that are worthy of exploration. The interaction between these effects makes stress research a complicated and continuingly interesting field.

REFERENCES

Alpini, D., Botta, M., Mattei, V., & Tornese, D. (2009). Figure ice skating induces vestibulo-ocular adaptation specific to required athletic skills. *Sport Science for Health, 5,* 129-134.

Araujo, D., Davids, K.W., & Hristovski, R. (2006). The ecological dynamics of decision making in sport. *Psychology of Sport and Exercise, 7,* 653-676.

Arens, E.A., Zhang, H., & Huizenga, C. (2006). Partial- and whole-body thermal sensation and comfort, Part I: Uniform environmental conditions. *Journal of Thermal Biology, 31,* 53-39.

ASHRAE (1966) *Thermal comfort conditions, ASHRAE standard 55.66.* New York.

ASHRAE (1997) *Thermal comfort, ASHRAE Handbook of Fundamentals.* Atlanta USA.

Baker, S.L., & Kirsch, I. (1991). Cognitive Mediators of Pain Perception and Tolerance, *Journal of Personality and Social Psychology, 61,* 504-510.

Barbieri, R., Matten, E.C, Alabi, A.R.A., & Brown, E.N. (2004). A point-process model of human heartbeat intervals: new definitions of heart rate and heart rate variability. *American Journal of Physiology, 288,* H424-H435.

Bedford, T. (1936). *The warmth factor in comfort at work.* MRC Industrial Health Report Number 76, HMSO.

Berg, K. (1989). Balance and its measure in the elderly. *Physiotherapy Canada, 41, 5,* 240-245.

Bergh, U., & Ekblom, B. (1979). Influence of muscle temperature on maximal muscle strength and power output in human skeletal muscles. *Acta Physiologica Scandinavica,, 107,* 33-37.

Binder, M.D., Hirokawa, N., & Windhorst, U. (2009). *Encyclopedia of Neuroscience.* New York: Springer.

Bland, J.M., & Altman, D.G. (1990). A note on the use of the intraclass correlation coefficient in the evaluation of agreement between two methods of measurement. *Computers in Biology and Medicine, 20,* 337-340.

Bland, J.M., & Altman, D.G. (1997). Statistics notes: Cronbach's alpha. *British Medical Journal, 314,* 572.

Blascovich, J., Vanman, E.J., Berry Mendes, W., & Dickerson, S. (2011). *Social Psychophysiology: for Social and Personality Psychology.* LA: Sage.

Brager, G.S., Fountain, M.E., Benton, C.C., Arens, E.A., & Bauman, F.S. (1993). A comparison of methods for assessing thermal sensation and acceptability in the field. In N. Oseland (Ed). *Proceedings of Thermal Comfort: Past, Present and Future* (pp.17-39). Watford: British Research Establishment.

Bressel, E., Yonker, J.C., Kras, J., & Heath, E.M. (2007). Comparison of Static and Dynamic Balance in Female Collegiate Soccer, Basketball, and Gymnastics Athletes. *Journal of Athletic Training, 42,* 42-46.

Cappaert, T.A., Stone, J.A., Castellani, J.W., Krause, B.A., Smith, D., & Stephens, B.A. (2008). National athletic trainers' association position. *Journal of Athletic Training, 43,* 640-658.

Statement: Environmental Cold Injuries

Carman, K.W., & Knight, K.L. (1992). Habituation to cold-pain during repeated cryokinetic sessions. *Journal of Athletic Training, 27(3),* 223-230.

Carpenter, M.G., Allum, J.H., & Honegger, F. (2001). Vestibular influences on human postural control in combinations of pitch and roll planes reveal differences in spatiotemporal processing. *Experimental Brain Research, 140,* 95-111.

Casa, D.J., Becker, S.M., Ganio, M.S., Brown, C.M., Yeargin, S.W., Roti, M.W., Siegler, J., Blowers, J.A., Glaviano, N.R., Huggins,R.A., Armstrong, L.E., & Maresh, C.M. (2007). Validity of devices that assess body temperature during outdoor exercise in the heat. *Journal of Athletic Training, 42,* 333-342.

Chapman, D.W., Needham, K.J., Allison, G.T., Lay B., & Edwards, D.J. (2008). Effects of experience in a dynamic environment on postural control. *British Journal of Sports Medicine, 42,* 16-21.

Charkoudian, N. (2010). Mechanisms and modifiers of reflex induced cutaneous vasodilation and vasoconstriction in humans. *Journal of Applied Physiology, 109(4),* 1221-1228.

Chida, Y., & Hamer, M. (2008). Chronic psychosocial factors and acute physiological responses to laboratory-induced stress in healthy populations: A quantitative review of 30 years of investigations, *Psychological Bulletin, 134*, 829-885.

Clark-Carter, D. (1997). *Doing Qualitative Psychological Research: From Design to Report.* Psychology Press: Hove.

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences.* Hillsdale: Lawrence Erlbaum.

Contrada, R., & Bum, A. (2011). *The Handbook of Stress Science: Biology, Psychology, and Health.* New York: Springer Publishing Company.

Crawford, M.H., Bernstein, S.J., Deedwania, P.C., DiMarco, J.P., Ferrick, K.J., Garson, A., Green, L.A., Greene, H.L., Silka, M.J., Stone, P.H., Tracy, C.M., Gibbons, R.J., Alpert, J.S., Eagle, K.A., Gardner, T.J., Garson, A., Gregoratos, G., Russell, R.O., Ryan, T.J., Smith, S.C. (1999) ACC/AHA Guidelines for Ambulatory Electrocardiography: Executive Summary and Recommendations A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. *Circulation,* 100; 886-893.

Cross, K., Wilson, R., & Perrin, D. (1996). Functional performance following an ice immersion to the lower extremity. *Journal of Athletic Training, 31,* 113-116.

Cymerman, A., Young, A.J., Francis, T.J.R., Wray, D.D., Ditzler, D.T., Stulz, D., Bovill, M., & Muza, S.R. (2002). Subjective symptoms and postural control during a disabled submarine simulation. *Undersea and Hyperbaric Medicine, 29(3),* 204-215.

Daanen, H. (2009). Cold-induced vasodilation. *European Journal of Applied Physiology, 105,* 663-664.

Daanen, H.A.M., Koedam, J., & Cheung, S.S. (2012). Trainability of cold induced vasodilation in fingers and toes. *European Journal of Applied Physiology, 112,* 2595-2601.

Darwin, C. (1871). *The Descent of Man and Selection in Relation to Sex.* London: Murray.

Davlin, C.D. (2004). Dynamic balance in high level athletes. *Perceptual & Motor Skills, 98,* 1171-1176.

Dawkins, R. (2004). *The Ancestor's Tale: A Pilgrimage to the Dawn of Life.* London: Weidenfeld & Nicolson.

Delaney, J.P.A., & Brodie, D.A. (2000). Effects of short-term psychological stress on the time and frequency domains of heart-rate variability. *Perceptual and Motor Skills, 91,* 515-524.

DeLucia, (2013). Aims and scope. *Human Factors,* cover page.

Deschamps, T., Magnard, J., & Cornu, C. (2013). Postural control as a function of time-of-day: influence of a prior strenuous running exercise or demanding sustained-attention task. *Journal of NeuroEngineering and Rehabilitation, 10,* 26.

Dewhurst, S., Riches, P.E., & De Vito, G. (2007). Moderate alterations in lower limbs muscle temperature do not affect postural stability during standing in both young and older women. *Journal of Electromyography and Kinesiology, 17,* 292-298.

Donker, S.F., Roerdink, M., Greven, A.J., & Beek, P.J. (2007). Regularity of center-of-pressure trajectories depends on the amount of attention invested in postural control. *Experimental Brain Research, 181(1),* 1-11.

Doubt, T.J. (1991). Physiology of exercise in the cold. *Sports Medicine, 11,* 367-381.

Doyle, F., Zehner, W.J., & Terndrup, T.E. (1992). The effect of ambient temperature extremes on tympanic and oral temperatures. *American Journal of Emergency Medicine. 10(4),* 285-289.

Draper N., & Hodgson, C. (2008). *Adventure Sport Physiology.* Chichester: Wiley - Blackwell.

Ellis, H.D. (1982). The effects of cold on the performance of serial choice reaction time and various discrete tasks. *Human Factors, 24,* 589-598.

Ellis, H.D., Wilcock, S.E., & Zaman, S.A. (1985). Cold and performance: The effects of information load, analgesics, and the rate of cooling. *Aviation, Space and Environmental medicine, 56,* 233-237.

Enander, A.E. (1989). Effects of thermal stress on human performance. *Scandinavian Journal of Work, Environment and Health, 15(suppl 1),* 27-33.

Enander, A.E., & Hygge, S., (1990). Thermal stress and human performance. *Scandinavian Journal of Work, Environment and Health*, *16(suppl 1)*, 44-50.

Enander, A., Skoldstrom, B., & Holmer, I. (1980). Reactions to hand cooling in workers occupationally exposed to cold. *Scandinavian Journal of Work and Environmental Health, 6,* 58-65.

Fanger, P.O. (1970). *Thermal comfort.* Copenhagen: Danish Technical Press.

Fanger , P.O. (1973). Assessment of man's thermal comfort in practice. *British Journal of Industrial Medicine, 30,* 313-324.

Flouris, A.D., & Cheung, S.S. (2009). Influence of thermal balance on cold-induced vasodilation. *Journal of Applied Physiology, 106*, 1264-1271.

Frank, S.M., Raja, S.N., Bulcao C.F., & Goldstein D.S. (1999). Relative contribution of core and cutaneous temperatures to thermal comfort and autonomic responses in humans. *Journal of Applied Physiology, 86,* 1588-1593.

Frank, M., Zhou, S., Bezerra, P., & Crowley, Z. (2009). Effects of long-term recreational surfing on control of force and posture in older surfers: A preliminary study. *Journal of Exercise and Fitness, 7(1),* 31-38.

Fröberg, J., Karlsson, C., Levi, L. & Lidberg, L. (1972). Circadian variations in performance, psychological ratings, catecholamine excretion, and diuresis during prolonged sleep deprivation. *International Journal of Psychobiology, 2,* 23-36.

Gescheider, G.A., Thorpe, J.M., Goodarz, J., & Bolanowski, S.J. (1997). The effects of skin temperature on the detection and discrimination of tactile stimulation. *Somatosensory and Motor Research, 14(3),* 181-188.

Glaister, M., Howatson, G., Abraham, C.S., Lockey, R.A., Goodwin, J.E., Foley, P., & McInnes, G. (2008). Caffeine supplementation and multiple sprint running performance. *Medicine and Science in Sports and Exercise,* 40, 1835-1840.

Glaser, E.M., Hall, M.S., & Whittow, G.C. (1959). Habituation to heating and cooling of the same hand. *Journal of Physiology, 146,* 152-164.

Goel, A., & Addison, A.K.L. (1992). Fell walking injuries in Cumbria: a review. *British Journal of Sport Medicine, 26,* 143-144.

Green A.M., & Angelaki D.E. (2010). Internal models and neural computation in the vestibular system. *Experimental Brain Research, 200,* 197-222.

Gribble, P.A., Tucker, W.S., & White, P.A. (2007). Time-of-day influences on static and dynamic postural control. *Journal of Athletic Training, 42(1),* 35-41.

Haman, F. (2006). Shivering in the cold: from mechanisms of fuel selection to survival. *Journal of Applied Physiology, 100,* 1702-1708.

Häusler R. (1995). Ski Sickness. *Acta Otolaryngology, 115,* 1-2.

Hassan, B.S., Mockett, S., & Doherty, M. (2001). Static postural sway, proprioception, and maximal voluntary quadriceps contraction in patients with knee osteoarthritis and normal control subjects. *Annals of the Rheumatic Diseases, 60,* 612-618.

Hensel, H. (1981). *Thermoreception and Temperature Regulation.* London: Academic Press.

Heus, R., Schols, E., & Kistemaker, L. (2005). Frostbite in Ski Boots for Marines. In *Prevention of Cold Injuries* (7), 1-8. Meeting Proceedings RTO-MP-HFM-126, http://www.rto.nato.int/abstracts.asp.

Hewes, G.W. (1961). Food transport and the origin of hominid bipedalism. *American Anthropologist, 63,* 687-710.

Horak, F.B. (1987). Clinical measurement of postural control in adults*, Physical Therapy, 67,* 1881-1885.

Horak, F.B., Wrisley, D.M., & Frank J. (2009). The Balance Evaluation Systems Test (BESTest) to differentiate balance deficits. *Physical Therapy, 89*, 484–498.

Hrysomallis, C. (2011). Balance ability and athletic performance. *Sports Medicine, 41(3),* 221–232.

Huang, C.-M., Chang, H.-C., Kao, S.-T., Li, T.-C., Wei, C.-C., Chen, C., Liao, Y.-T., & Chen, F.-J. (2011). Radial pressure pulse and heart rate variability in heat- and cold-stressed humans. *Evidence-Based Complementary and Alternative Medicine,* Article ID 751317, 9 pages.

Jáuregui-Renaud, K. (2013). Postural Balance and Peripheral Neuropathy In N. Souayah (Ed.), *Peripheral Neuropathy - A New Insight into the Mechanism, Evaluation and Management of a Complex Disorder* (pp. 125–146). Publisher: InTech.

Jendritzky, G., Maarouf, A., & Staiger, H. (2001). Looking for a universal thermal climate index UTCI for outdoor applications. *Windsor-Conference on Thermal Standards,* Windsor, UK.

Jex, S.M. (2002). *Organizational Psychology: A Scientist-Practitioner Approach.* Chichester: John Wiley & Sons.

Johansson, R., & Magnusson, M. (1991). Human postural dynamics. *Critical Reviews in Biomedical Engineering, 18(6),* 413–37.

Jutte, L.S., Merrick, M.A., Ingersoll, C.D., & Edwards, J.E. (2001). The relationship between intramuscular temperature, skin temperature, and adipose thickness during cryotherapy and rewarming. *Archives of Physical Medicine and Rehabilitation, 82,* 845–850.

Kennedy P.M., & Inglis, J.T. (2002). Distribution and behaviour of glabrous cutaneous receptors in the human foot sole. *Journal of Physiology, 538,* 995–1002.

Kernozek, T.W., Greany, J.F., Anderson, D.R., Van Heel, D., Youngdahl, R.L., Benesh, B.G., & Durall, C.J. (2008). The effect of immersion cryotherapy on medial-lateral postural sway variability in individuals with a lateral ankle sprain. *Physiotherapy Research International, 13,* 107–118.

Kirkman, N.F., & Hartley, M.K. (1968). Mountain accidents. *British Medical Journal, 4,* 107.

Kirschbaum, C., & Hellhammer, H. (1989). Salivary cortisol in psychobiological research: An overview. *Neuropsychobiology, 22,* 150–169.

Leppäluoto, J., Korhonen, I., & Hassi, J. (2001). Habituation of thermal sensations, skin temperatures, and norepinephrine in men exposed to cold air. *Journal of Applied Physiology, 90*, 1211–1218.

Ley, P. (1972). *Quantitative Aspects of Psychological Assessment.* London: Gerald Duckworth & Co Ltd.

Livingstone, S.D., Grayson, J., Frim, J., Allen, C.L., & Limmer, R.E. (1983). Effect of cold exposure on various sites of core temperature measurements. *Journal of Applied Physiology, 54(4),* 1025–1031.

Lopes, P., & White, J. (2005). Heart rate variability: Measurement methods and practical implications. In P.J. Maud & C. Foster (Eds.), *Physiological Assessment of Human Fitness* (pp. 39–62) Champaign, IL: Human Kinetics Publishers.

Lovejoy, C.O. (1988). Evolution of human walking. *Scientific American. 259(5),* 82–89.

Lunt, H.C., Barwood, M.J., Corbett, J. & Tipton, M.J. (2010). 'Cross-adaptation': habituation to short repeated cold-water immersions affects the response to acute hypoxia in humans. *Journal of Physiology, 588,* 3605–3613.

Magnusson, M., Enbom, H., Johansson, R., & Pyykkö, I. (1990). Significance of pressor input from the human feet in anterior-posterior postural control. *Acta Otolaryngologica, 110(3-4),* 182–188.

Magnusson, M., Enbom, H., Johansson R., & Wiklund, J. (1990). Significance of pressor input from the human feet in lateral postural control. *Acta Otolaryngologica, 110,* 321–327.

Mahieu, N.N., Witvrouw, E., Van de Voorde, D., Michilsens, D., Arbyn, V., & Van den Broecke, W. (2006). Improving strength and postural control in young skiers: Whole-body vibration versus equivalent resistance training. *Journal of Athletic Training 41(3),* 286–293.

Mäkinen, T.M., Rintamäki, H., Korpelainen, J.T., Kampman, V., Pääkkönen, T., Osa, J., Palinkas, L.A., Leppäluoto, J., & Hassi, J. (2005). Postural sway during single and repeated cold exposures. *Aviation, Space, and Environmental Medicine, 77(10),* 947-953.

Malliani, A., Lombardi, F., & Pagani, M. (1994). Power spectrum analysis of heart rate variability: a tool to explore neural regulatory mechanisms. *British Heart Journal, 71,* 1-2.

Mancini, M., Salarian, A., Carlson-Kuhta, P., Zampieri, C., King, L., Chiari, L., & Horak, FB., (2012). ISway: a sensitive, valid and reliable measure of postural control. *Journal of Neuroengineering and Rehabilitation, 9,* 59.

Mason, J.W. (1975a). A historical view of the stress field. Part I. *Journal of Human Stress, 1,* 6-12.

Mason, J.W. (1975b). A historical view of the stress field. Part II. *Journal of Human Stress, 1,* 22-36.

Massion J. (1994). Postural control system. *Current Opinion in Neurobiology. 4(6),* 877-87.

Matsuda, S, Shinichi, D., Masanobu, U. (2008). Centre of pressure sway characteristics during static one-legged stance of athletes from different sports. *Journal of Sports Sciences, 26,* 775-779.

Matsumoto, T., Miyawaki, T., Ue, H., Kanda, T., Zenji, C., & Moritani, T. (1999). Autonomic responsiveness to acute cold exposure in obese and non-obese young women. *International Journal of Obesity, 23,* 793-800.

Mazerolle, S.M., Ganio, M.S., Casa, D.J., Vingren, J., & Klau, J. (2011). Is oral temperature an accurate measurement of deep body temperature? A systematic review. *Journal of Athletic Training, 46(5),* 566-573.

McIntyre, D.A. (1980). *Indoor climate.* London: Applied Science.

McGrath, J.B. (1976). Stress and Behavior in Organizations, In M.D. Dunnette (Ed.) *Handbook of Industrial and Organizational Psychology* (pp. 1351-1396) Chicago: Rand McNally.

McMichael, A.J. (2013). Impediments to comprehensive research on climate change and health. *International Journal of Environmental Research and Public Health, 10,* 6096-6105.

McMorris, T., Harris, R.C., Howard, A.N., Langridge, G. Hall, B., Corbett, J., Dicks, M., & Hodgson, C. (2006). Creatine supplementation, sleep deprivation, cortisol, melatonin and behavior. *Physiology and Behavior, 99,* 21-28.

Melzer, I., Benjuya, N., & Kaplanski, J. (2004). Postural stability in the elderly: a comparison between fallers and non-fallers. *Age and Ageing, 33,* 602-607.

Miller, L.H., & Smith, A.D. (2013). Stress: The different kinds of stress. *American Psychological Association.* Retrieved January 5, 2013, from http://www.apa.org.

Moran, D.S., & Mendal, L. (2002). Core temperature measurement: Methods and current insights. *Sports Medicine, 32,* 879-885.

Morgan, E. (1982). *The Aquatic Ape*. New York: Stein & Day Publishers.

Morrison, S.F. & Nakamura, K. (2011). Central neural pathways for thermoregulation. *Frontiers in Bioscience, 16,* 74-104.

Nakamura, K. & Morrison, S.F. (2011). Central efferent pathways for cold-defensive and febrile shivering. *Journal of Physiology, 589,* 3641-3658.

Noe, F. & Paillard,T. (2005). Is postural control affected by expertise in alpine skiing? *British Journal of Sports Medicine, 39,* 835-837.

Oksa, J. (2002). Neuromuscular performance limitations in cold. *International Journal of Circumpolar Health, 61,* 154-162.

Oksa, J., Ducharme, M.B., & Rintama, H. (2002). Combined effect of repetitive work and cold on muscle function and fatigue. *Journal of Applied Physiology, 92,* 354-361.

Osterhues, H-H., Groβmann, G., Kocks, M., & Homback, V. (1998). Heart-rate variability for discrimination of different types of neuropathy in patients with insulin-dependent diabetes mellitus. *Journal of Endocrinology Investigation, 21,* 24-30.

Paillard, T., Margnes, E., Portet, M., & Breucq, B. (2011). Postural ability reflects the athletic skill level of surfers. *European Journal of Applied Physiology, 1111(8),* 1619-1623.

Palinkas, L.A. (2001). Mental and cognitive performance in the cold. *International Journal of Circumpolar Health, 60,* 430-439.

Parsons, K. C. (2003). *Human Thermal Environments.* London: Taylor & Francis Group.

Peterka, R.J. (2002). Sensorimotor Integration in Human Postural Control. *Journal of Neurophysiology, 88,* 1097-1118.

Pilcher, J.J., Nadler, E., & Busch, C. (2002). Effects of hot and cold temperature on performance: a meta-analytic review. *Ergonomics, 45,* 682-698.

Pollard, T. (1995). Use of cortisol as a stress marker: Practical and theoretical problems. *American Journal of Human Biology, 7,* 265-274.

Price, D.D., Bush, F.M., Long, S., & Harkins, S.W. (1994). A comparison of pain measurement characteristics of mechanical visual analogue and simple numerical rating scales. *Pain, 56,* 217-226.

Ragnarsdóttir, M. (1996). The concept of balance. *Physiotherapy, 82,* 368-375.

Rammsayer, T.H., Bahner, E., & Netter, P. (1995). Effects of cold on human information processing: Application of a reaction time paradigm*. Integrative Physiological and Behavioral Science, 30,* 34-45.

Reynolds, L.F., Mekjavic, I.B., & Cheung, S.S. (2007). Cold-induced vasodilation in the foot is not homogenous or trainable over repeated cold exposure. *European Journal of Applied Physiology, 102,* 73-78.

Riemann BL, Guskiewicz KM, Shields EW. (1999). Relationship between clinical and forceplate measures of postural stability. *Journal of Sport Rehabilitation, 8,* 71-82.

Sawasakia, N., Iwasea, S., & Manoa, T. (2001). Effect of skin sympathetic response to local or systemic cold exposure on thermoregulatory functions in humans. *Autonomic Neuroscience, 87,* 274-281.

Selye, H. (1956). *The stress of life.* New York: McGraw-Hill.

Shupert, C.L., & Horak, F.B. (1999). Adaption of postural control in normal and pathologic aging: Implications for fall prevention programs. *Journal of Applied Biomechanics, 15,* 64–74.

Šrámek, P., Šimečková, M., Janský, L., Šavlíková, J., & Vybíral, S.(2000). Human physiological responses to immersion into water of different temperatures. *European Journal of Applied Physiology, 81,* 436–44.

Stål, F., Fransson, P.A., Magnusson, M., & Karlberg, M. (2003). Effects of hypothermic anesthesia of the feet on vibration-induced body sway and adaptation. *Journal of Vestibular Research, 13,* 39–52.

Starr, C.J., Houle, T.T., & Coghill, R.C. (2010). Psychological and Sensory Predictors of Experimental Thermal Pain: A Multifactorial Model, *Journal of Pain, 11,* 1394–1402.

Sterne, J.A.C. & Smith G.D. (2001). Sifting the evidence—what's wrong with significance tests? *Physical Therapy, 81,* 1464–1469.

Somers, S. (2014). *Thermal Management Part 1.* CA: Extron Electronics.

St Clair Gibson, A., Lambert, E.V., Rauch, L.H.G., Tucker, R., Baden, D.A., Foster, C., & Noakes, T.D. (2006). The Role of Information Processing Between the Brain and Peripheral Physiological Systems in Pacing and Perception of Effort. *Sports Medicine, 36,* 705–22.

Stocks, J.M., Taylor, N.A.S., Tipton, M.J., & Greenleaf, J.E. Human physiological responses to cold exposure. *Aviation Space and Environmental Medicine, 75,* 444–457.

Stokes, A.F., & Kite, K. (2001). On grasping a nettle and becoming emotional. In P.A. Hancock, & P.A. Desmond (Eds*.), Stress, workload, and fatigue.* Mahwah, NJ: L. Erlbaum.

Swift, C.G. (1984). Postural instability as a measure of sedative drug response. *British Journal of Clinical Pharmacology, 18,* 83s–90s.

Tarvainen, M.P., & Niskanen, J-P. (2012). *Kubios HRV version 2.1: User's Guide.* Finland: The MathWorks, Inc.

Teichner, W.H. (1958). Reaction time in the cold. Journal of Applied Psychology, 42, 54-59.

Thomas, J.R., & Nelson, J.K. (2001). *Research methods in physical activity*. Champaign, IL: Human Kinetics.

Todnem, K., Knudsen, G., Riise, T.H., & Aarli, J.A. (1989). The non-linear relationship between nerve conduction velocity and skin temperature. *Journal of Neurology, Neurosurgery, and Psychiatry, 52,* 497-501.

Tzelgov, J., Henik, A., & Berger, J. (1992). Controlling Stroop effects by manipulating expectations for color words. *Memory and Cognition, 20,* 727-735.

Umetani, K., Singer, D.H., McCraty, R., & Atkinson, M. (1998). Twenty-Four Hour Time Domain Heart Rate Variability and Heart Rate: Relations to Age and Gender Over Nine Decades. *Journal of the American College of Cardiology, 31,* 593-601.

Van der Struijs, N.R., Van Es, E.M., Raymann, R.J., & Daanen, H.A. (2008). Finger and toe temperatures on exposure to cold water and cold air. *Aviation Space and Environmental Medicine, 79,* 941-946.

Van Orden, K.F., Benoit, S.L. and Osga, G.A. (1996). Effects of cold air stress on the performance of a command and control task. *Human Factors, 38,* 130-141.

Jose A. Vega J.A., López-Muñiz, A., Calavia, M.G., García-Suárez, O., Cobo, J., Otero, J., Arias-Carrión, O., Pérez-Piñera, P., & Menéndez-González, M. (2012). Clinical implication of Meissner's corpuscles. CNS & Neurological Disorders - Drug Targets, 2012, 11, 1-17.

Whitney, S.L., Roche, J.L., Marchetti, G.F., Lin, C.C., Steed, D.P., Furman, G.R., Musolino, M.C., & Redfern, M.S. (2011) A comparison of accelerometry and center of pressure measures during computerized dynamic posturography: a measure of balance. *Gait Posture, 33(4),* 594-9.

Wilkerson, J.A. (1992). *Medicine for mountaineering and other wilderness activities.* California: The Mountaineers.

Yamazaki, F., & Sone, R. (2000). Modulation of arterial baroreflex control of heart rate by skin cooling and heating in humans*. Journal of Applied Physiology, 2,* 393–400.

Zhang, H., Huizenga, C., Arens, E., & Wang, D. (2004). Thermal sensation and comfort in transient non-uniform thermal environments. *European Journal of Applied Physiology, 92,* 728–733.

Appendix 1

ETHICAL APPLICATION

ETHICAL REVIEW APPLICATION

Supervisors:
If possible, please submit this form electronically to: s.jenkinson@chi.ac.uk

This form should be used for all undergraduate, postgraduate research and any other research conducted under the name of the University of Chichester. It **MUST BE COMPLETED AND APPROVED** by your supervisor before you start.

If referred the Ethics Committee will make a decision on the basis of the information you have supplied. In order for the Committee to consider to your application quickly it would be very helpful if you could also attach the rationale and outline procedures which you are intending to use. This will help the Committee to reach its decision without the need to request further information. The Committee also finds it helpful to have an outline of requests to participants, questionnaires and information regarding the final destination of the results.

Applicant Christopher I Hodgson …. …………………………………………	Supervisor's Judgement	Proceed	A
		Proceed with caution	B
		Needs Committee Scrutiny	C
Name of Supervisor:	*Prof. Terry McMorris*		
Name of Head of School/named staff member with responsibility for ethical issues *(sign only if project initiated by member of staff or graded B or C)*	*Prof. Chris Laws*		
Programme and Module:	*PhD*		

1. Title or focus of study: The effects of acute cold exposure on human psychomotor performance.	
2. Brief description of methods; *noting a) where similar work has been undertaken and reviewed by the Ethics Committee and b) where proposed techniques are being carried out in accordance with written standard operating procedures (SOP's) held by the School and which have been approved by the Ethics Committee directly or in the course of reviewing and approving a previous project.* The study will involve exposing participants to cold temperatures down to -20 °C. Body temperature (core and peripheral) will be monitored and postural sway and control of participants will be measured. Blood samples may also be taken during some elements of the study. UoC Guidelines for operating in extreme cold environments already exist (attached).	Supervisor's/ Ethics Ctte comment
3. Location of study and details of any special facilities to be used: Environmental chamber.	
4. Basis for selection and rejection of subjects/respondents in the study: Subjects must be healthy and not have a history of cold injury.	

5. Is either the process of the study and/or its results likely to produce distress or anxiety in the subjects/respondents ***beyond*** what they would normally experience in your work with them? *(See note 1)*	No	[✓ Yes]
6a. If the answer to 5 is yes – please elaborate if you think this may not be clear from previous answers: Participants will be exposed to cold temperatures which will be uncomfortable and some participants may well find this stressful. **6b.** What steps will you take to deal with any distress or anxiety produced? Participants will be forewarned about the procedures and will be aware that they can re-warm immediately testing is completed. Participants will also be made aware that they will be removed from the cold chamber if their condition deteriorates before they reach a level that could be harmful.		
7. Can the study be described as being part of some role you already have, therefore not requiring any special consideration or scrutiny? (this should be confirmed by subsequent answers)	[✓ No]	Yes
8. Does your proposal raise other ethical issues apart from the potential for distress, anxiety, or harm?	[✓ No]	Yes
9. **I**f your answer to no.8 was ‘yes’, on what grounds would you defend the proposal?		
10. Is it necessary to obtain the consent of the subjects/respondents of the study? (see note 2)	No	[✓ Yes]
Date consent obtained:	Written consent will be obtained prior to testing	
Please Specify.	Written	Oral
Copy Attached?	No	Yes
11. Will any payment, gifts, rewards or inducements be offered to subjects/respondents to take part in the study?	[✓ No]	Yes
Please give brief details:		

12. Will they have the right/facility to withdraw from the study?	No	[✓ Yes]
13. In formal/legal terms, is there anyone whose permission has to be sought in order to conduct your study? Please give details:	[✓ No]	Yes
Date permission obtained :		
Please specify:	Written	Oral
Copy Attached?	No	Yes
14. Do you think you need to seek the permission of any other individuals or groups? (eg parents, carers) Please give details:	[✓ No]	Yes
Date permission obtained:		
Please specify if yes:	Written	Oral
Copy Attached?	No	Yes
15. Will your results be available in the public arena? (e.g. dissertation in the library)	No	[✓ Yes]
16. Is it necessary to guarantee and ensure confidentiality for the respondents?	[✓ No]	Yes
17. Is it necessary to guarantee and ensure anonymity for the respondents?	[✓ No]	Yes
18. Will the respondents have any right of comment or veto on the material you produce about them? Please elaborate if you wish.	[✓ No]	Yes

19. Is there any additional comment or information you consider relevant? Procedures will follow the University of Chichester health and safety guidelines relating to cold work in the environmental chamber (attached). In addition a full risk assessment of the procedure for each experiment will be completed prior to testing and appropriate control procedures and protocols put in place.		
For student supervisors: **In your view, does the proposed study potentially contravene any aspect of established codes of practice in your discipline?** (The codes of practice of the British Sociological Association, British Psychological Association, the British Association of Applied Linguistics and British Education Research Association are available on the Intranet and in a file in the library.)	No	Yes
Please give details if 'yes' and you wish the Ethics Committee to resolve the issue:		

Signature of applicant: ……………………………………………..…… Date: ……………….…………

Signature of supervisor: ………………………………………………… Date: ……….……………..….

Signature of Head of School: ………………………………………………………………………….………
(or named staff member with responsibility for ethical issues)

Date of application: …………………………………………………………………………………….…....

Notes

1. Workplace settings, like classrooms, day centres or sports centres are not special facilities in this sense. Specialised measuring apparatus may be, and mention should be made of particular equipment not available at UoC, where relevant.

2. The Ethics Committee makes a distinction between distress and harm. It is conceivable that research may cause distress (eg interviewing about a sensitive subject) and as long as due care is taken to deal with this it would not necessarily rule out a particular enquiry. Harm, however, is considered to be longer-lasting distress over which the researcher has little control. Harm can also be caused by disadvantaging respondents in some way (perhaps by being seen talking to a

researcher). Studies may also involve clinical risk, which will be in addition to distress or harm. Under some circumstances research which may cause distress may be sanctioned. This is extremely unlikely for any research likely to cause harm or pose a serious clinical risk.

3. The University's insurance policy covers almost all aspects of its' liability in the course of its' normal work to a figure of several million pounds. If the nature of your research is particularly unusual or runs a particular risk of litigation then your supervisor should discuss it with the Finance Officer ***before*** seeking ethical approval.

4. Informed consent from participants/respondents/subjects is usually necessary for all social research, so it is necessary also to consider questions 11,14,15 and 23 carefully. The issue barely arises in the case of anonymous questionnaires; but is clearly called for if for example you were asking 15 year olds about their smoking habits (but from whom?), and is unclear if you are covertly watching people's behaviour (the study may well be compromised by asking for consent, however, such observation should only take place where people would normally expect to be in public view).

   The Ethics Committee is concerned not to put bureaucratic obstacles in the way of the small-scale research that forms a part of many students' courses, nor to intervene in established patterns of professional development. In the case of teaching, social work or nursing, for example, the 'reflective practitioner' model necessarily involves a degree of action research upon one's own practice as a means of professional development, and it would be beyond the brief of the Committee to seek to comment on this. Supervisors and students should, however, be prepared to seek Committee approval when a proposed research study goes beyond the student's usual professional role, even though it may be part of a taught course. The questions on the form are designed to clarify this. **The issue of 'harm' aside, the key point in such cases is whether the study could be described as being part of a student's usual professional role and therefore not requiring any special consideration or scrutiny.**

   If you decide to seek written consent the form you intend to give to respondents ***must*** be attached to this form.

5. In some instances an Enhanced Disclosure from the Criminal Record Bureau may be required and this should be discussed with supervisor.

Updated 4 July 2005

The effects of acute cold exposure on human psychomotor performance

The aim of the study is to examine the effects of cold exposure on postural control and the potential to maintain performance during cold stress as a result of practice and habituation.

1. To establish that acute cold exposure results in measurable performance changes to postural sway patterns.

2. To describe the nature of changes to postural sway and establish durations and intensity of cold exposure likely to elicit measurable changes in performance of motor tasks including postural control.

3. To examine mechanisms behind declining performance in cold conditions.

4. To explore strategies for maintaining performance during cold exposure.

There is little published research on the effects of environmental stress on upright postural control, however, a study of participants during a simulated submarine incident that employed compound stressors including an ambient temperature of 4 °C over 5 days suggested that postural control was affected (Cymerman, Young, Francis, Wray, Ditzler et al., 2002). As a result of this study Mäkinen, Rintamäki, Korpelainen, Kampman, Pääkkönen et al. (2005) examined postural sway during the single environmental stressor of moderate cold exposure of 10 °C and found a significant decline in performance when compared to 25 °C. The mechanisms behind changes in postural sway were not examined in these studies but could include arousal levels, neurological efficiency, biochemical changes, sensory impairment and muscle efficiency.

The research will be conducted in three stages: -

The first stage will establish which performance changes can be measured during acute cold exposure and describe the effects of acute cold exposure on human performance during a range of environmental conditions. Participants will be tested during exposure to a range of ambient temperatures and durations to establish the magnitude and nature of effects that can be expected. The expected temperature for this stage will include exposure to temperatures as low as -20 °C. Core temperature and skin temperature will be monitored to ensure that participants are not allowed to experience dangerous levels of thermal stress. The data generated by this phase of the study will be mainly descriptive and will be used to establish criteria for the second and third stages of testing. This will include the temperatures participants will be exposed to and the duration of exposure

The second stage of the study will involve measuring some of the key mechanisms behind postural control and is intended to provide data with explanative power. These mechanisms may include testing the alertness of the central nervous system and the nervous and muscular activity involved in upright posture. Other variables measured may include chemical messengers (neurotransmitters and/or hormones) associated with motor control and stress. The data from this stage of the study would be intended to contribute to an explanation of performance variations between conditions and the responses of individual participants. This stage of the study will also be concerned with establishing the reliability of the measures used.

The third stage of the study would examine the ability of participants to maintain performance during cold stress. The effects of practice in temperate conditions, practice during repeated cold exposures and cold exposures without practice are likely to be examined. The impact of increased effort levels during more arduous conditions will also be explored as there is some evidence from other environmental stressors and fatigue studies that suggest that performance can be maintained but the effort level of participants rises in order to achieve this (McMorris, Harris, Howard, Langridge, Hall et al., 2006).

This research will generate new knowledge because at present no researcher has published studies into postural control colder than +10° C and this study will examine effects in temperatures as low as -20° C. Explanations for performance changes in cold environments include central effects and peripheral effects. Processing ability of the central nervous system, nervous transition of sensory information and/or motor commands and muscular efficiency have been suggested as mechanisms that may impair motor performance in the cold. The question remains as to which of these mechanisms may contribute to effects on postural control.

Participants for this research will be volunteers. Core body temperatures will not be allowed to drop more than 2.0 °C during testing and rewarming facilities will be available, this is in line with existing health and safety policies. Previous researchers such as Lockhart, Jamieson, Steinman and Giesbrecht (2005) have dropped body temperature to as low as 34 °C during testing. Particular care will be taken in the early stages of the study which will act as a pilot in terms of what exposures are reasonable. All procedures will follow the guidelines of the health and safety policy for the University of Chichester environmental chamber which has been used in previous research projects. Participants' physical conditions will be monitored at all times and will be removed from the environment if necessary.

The practical applications of the research will include a greater understanding of the effects of cold on sports people such as skiers and mountaineers. Personnel who are required to work in cold environments could also benefit including applications to military situations and refrigeration facilities. In addition the study could generate data that have implications within the discipline of neuroscience.

References

Cymerman, A., Young, A.J., Francis, T.J.R., Wray, D.D., Ditzler, D.T., Stulz, D., Bovill, M. and Muza, S.R. (2002). Subjective symptoms and postural control during a disabled submarine simulation. *Undersea and Hyperbaric Medicine*, **29(3)**, 204-215

Lockhart, Jamieson, Steinman and Giesbrecht (2005). Life jacket design affects dorsal head and chest exposure, core colling, and cognition in 10 degrees C water. *Aviation, Space, and Environmental Medicine*, **76(10)**, 954-962.

Mäkinen, T.M., Rintamäki, H., Korpelainen, J.T., Kampman, V., Pääkkönen, T., Osa, J., Palinkas, L.A., Leppäluoto, J. and Hassi, J. (2005). Postural sway during single and repeated cold exposures. *Aviation, Space, and Environmental Medicine*, **77(10)**, 947-953.

McMorris, T., Harris, R.C., Howard, A.N., Langridge, G. Hall, B., Corbett, J., Dicks, M. and Hodgson, C. (2006). Creatine supplementation, sleep deprivation, cortisol, melatonin and behavior. *Physiology and Behavior*, **99**, 21-28.

Clarification Points

Rewarming facilities will include a dry, warm seated area and the showers adjacent to gyms 1 and 2. All through doors will be unlocked during testing and showers will be checked for water temperature prior to each morning / afternoon block of testing. Preheated towels and blankets will also be available.

Physical condition will be monitored in a number of ways. Firstly core and skin temperatures will be continuously monitored. Exposed skin will also be monitored visually. Mental condition will be subjectively monitored during regular interactions with the experimenter.

Participants will not be left unsupervised during testing or rewarming and the experimenter is a qualified first aider. A defibrillator trained member of staff will also be available during testing.

Appendix 2

CONSENT
AND
MEDICAL INFORMATION SHEET

The University of Chichester

CONSENT FORM

I, …………………..……………………………………………….. (PRINT NAME)

hereby give my consent to participate in the following test/activity *[please delete as appropriate].* **[insert details]**

By signing this form I confirm that:

- the purpose of the test/activity has been explained to me;
- I am satisfied that I understand the procedures involved;
- the possible benefits and risks of the test/activity have been explained to me;
- any questions which I have asked about the test/activity have been answered to my satisfaction;
- I understand that, during the course of the test/activity, I have the right to ask further questions about it;
- the information which I have supplied to The University of Chichester prior to taking part in the test/activity is true and accurate to the best of my knowledge and belief and I understand that I must notify promptly of any changes to the information;
- I understand that my personal information will not be released to any third parties without my permission;
- I understand that my participation in the test/activity is voluntary and I am therefore at liberty to withdraw my involvement at any stage;
- I understand that, if there is any concern about the appropriateness of my continuing in the test/activity, I may be asked to withdraw my involvement at any stage;
- I understand that once the test/activity has been completed, the information gained as a result of it will be used for the following purposes only:

[insert details]

NAME OF THE SUBJECT ……………………………………….
SIGNATURE OF THE SUBJECT ………………………………..
DATE ………………………………………………………………..

HEALTH HISTORY QUESTIONNAIRE

University of Chichester

Bishop Otter Campus

Before we can carry out any physiological tests on you, we have to check that you are in a reasonably healthy condition to undergo strenuous exercises.
PLEASE complete the following questionnaire about yourself.

College Lane, Chichester
West Sussex,
PO19 6PE UK
Tel:+44 (0)1243 816000
Fax:+44 (0)1243 816080
www.chi.ac.uk

ALL information will be treated as **strictly confidential**.

NAME: **DATE OF BIRTH:**

Specialist Sport: **SEX (M/F)** ☐ ☐
AGE:

☐ **1** **How best would you describe your present level of activity in both your work and recreation?**

Sedentary ☐ Moderate ☐ Highly ☐ Acti ☐
Activity
Active

☐ **2** **In terms of fitness how would you best describe your present level?**

Very ☐ ledium ☐ Trained ☐ Highly ☐
Unfit
Fitness
Trained

3 **How do you view your current bodyweight? Are you?**

☐ Under ☐ Ideal ☐ Very ☐ Slightl ☐
Weight
Weight Overweight
Overweight

☐ **4** **Are you, or have you ever been, a smoker?** ☐ ☐

YES:
NO: ☐ ☐
If YES, how many did you smoke?
Still
do smoke?

☐ **5** **Do you drink alcohol?** ☐ ☐

YES: NO:

If YES, do you consider yourself to be a -?

Very light ☐ Light ☐ Moderate ☐ ☐
Heavy
Drinker Drinker Drinker
Drinker

6 **Have you had to consult a doctor within the last 6 months?** **If so, say briefly why:**

7 **Have you suffered from a bacterial/viral infection in the last 2 weeks** YES: ☐ NO: ☐

If so, say briefly what:

8 **Are you taking any form of medication?** YES: ☐ NO: ☐
If YES, give details:

9 **Are you a Diabetic?** YES: ☐ NO: ☐
If YES, give details:

10 **Are you a current or past Asthmatic?** YES: ☐ NO: ☐
If YES, give details:

11 **Have you ever suffered from Bronchitis?** YES: ☐ NO: ☐
If YES, give details:

12 **Do you suffer from any form of Heart Disease?** YES: ☐ NO: ☐
If YES, give details:

13 **Is there any history of Heart Disease in your family?** YES: ☐ NO: ☐
If YES, give details:

14 **Do you currently have any muscular or joint injury?** YES: ☐ NO: ☐
If YES, give details:

15 **Have you ever suffered from Hepatitis?** YES: ☐ NO: ☐
If YES, give details:

16 **Have you ever had a blood transfusion?** YES: ☐ NO: ☐
If YES, give details:

17 **Are you/or have you ever been considered as, at risk from AIDs – {Acquired Immune Deficiency Syndrome}?**

If YES, give details: YES: ☐ NO: ☐

18 **Have you had to suspend your normal training for any reason in the last 2 weeks?**
If YES, give details: YES: ☐ NO: ☐

19 **Lastly, is there anything to your knowledge, that could prevent you from completing the tests that have been outlined to you?**
If YES, give details: YES: ☐ NO: ☐

SIGN: **DATE:**

Appendix 3

POSTURAL
SWAY
CALCULATIONS

<-- Actual RS Scan International Footscan® plate roll-offs have 999 rows -->

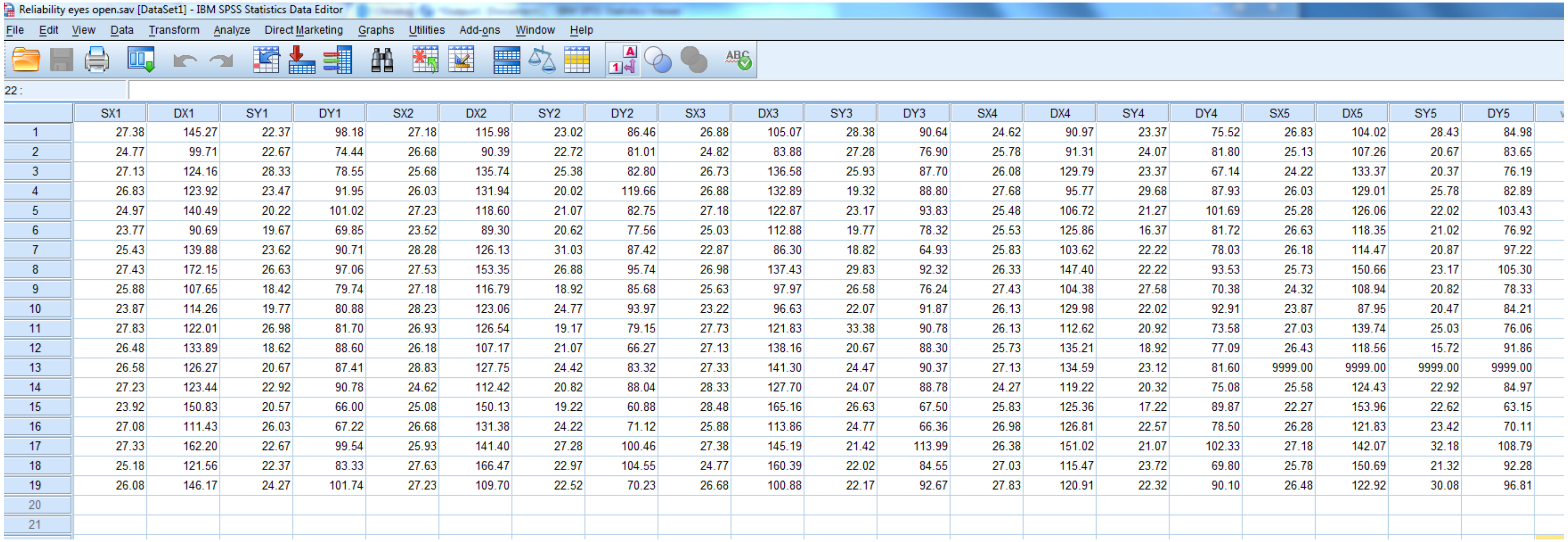
A	B	C	D	E	F ---> AL	
Stability export for measurement: _1eyesopen						
Patient name: Xxxx Xxxxxx						
Measurement done on 08/12/2008						
Interval	Begin (ms)	End (ms)	Begin (Frame)	End (Frame)	Area (cm²)	COF traveled way (mm)
1	0	3400	0	170	0.01	23.6
2	3400	6600	170	330	0.04	23.1
3	6600	10000	330	500	0.02	23.8
4	10000	13380	500	669	0	23.7
5	13380	16580	669	829	0.02	21.2
6	16580	19980	829	999	0.01	22.5
Frame	Time (ms)	Entire plate COF X (mm)	Entire plate COF Y (mm)	Entire plate	Entire plate COF	Left Selection
0	0	262.234	132.49	1673	0	111.052
1	20	261.067	133.114	1728	1.323	111.192
2	40	261.106	133.041	1729	0.082	111.193
3	60	261.078	133.021	1726	0.034	111.191
4	80	261.02	132.962	1727	0.083	111.163
5	100	261.024	132.81	1726	0.153	111.168
6	120	261.139	132.867	1723	0.129	111.128
7	140	261.176	132.854	1725	0.04	111.184
8	160	261.082	132.834	1722	0.097	111.157
9	180	260.731	132.884	1724	0.354	111.09
10	200	260.78	132.838	1725	0.068	111.089
11	220	260.812	132.913	1725	0.081	111.094
12	240	260.935	132.901	1727	0.123	111.093
13	260	260.962	132.933	1729	0.042	111.146
14	280	261.019	132.941	1728	0.058	111.14
15	300	261.234	132.891	1729	0.22	111.108
16	320	261.429	132.945	1726	0.202	111.136
17	340	261.467	133.015	1728	0.079	111.178
18	360	261.351	133.048	1728	0.121	111.206
19	380	261.365	132.886	1728	0.163	111.212
20	400	261.183	132.962	1726	0.198	111.236
21	420	261.136	132.976	1725	0.049	111.227
22	440	261.23	132.979	1725	0.094	111.248
23	460	261.279	133.021	1727	0.064	111.272
24	480	261.27	133.025	1726	0.01	111.25

Sway rate and distance travelled were extracted from the Footscan® roll-off using clustered logic functions created in Microsoft Excel. These calculate variables from the centre of pressure positions recorded from the RS Scanplate.	
Excel Logic function direction change identifier	=IF(OR(AND(B4<B5,B5>B6),AND(B4>B5,B5<B6)),1,0)
Excel Logic function incremental distance calculator	=SQRT((B5-B4)*(B5-B4))
	Direction changes are summed and divided by test duration to provide a sway rate (Hz)
	Incremental distances are summed to provide total accumulated distance (mm)

<-- Actual RS Scan International Footscan® plate roll-offs have 999 rows -->	**Entire plate COF X (mm)**	**Sway**	**Distance**	**Entire plate COF Y (mm)**	**Sway**	**Distance**
	262.234			132.49		
	261.067	1	1.167	133.114	1	0.624
	261.106	1	0.039	133.041	0	0.073
	261.078	0	0.028	133.021	0	0.02
	261.02	1	0.058	132.962	0	0.059
	261.024	0	0.004	132.81	1	0.152
	261.139	0	0.115	132.867	1	0.057
	261.176	1	0.037	132.854	0	0.013
	261.082	0	0.094	132.834	1	0.02
	260.731	1	0.351	132.884	1	0.05
	260.78	0	0.049	132.838	1	0.046
	260.812	0	0.032	132.913	1	0.075
	260.935	0	0.123	132.901	1	0.012
	260.962	0	0.027	132.933	0	0.032
	261.019	0	0.057	132.941	1	0.008
	261.234	0	0.215	132.891	1	0.05
	261.429	0	0.195	132.945	0	0.054
	261.467	1	0.038	133.015	0	0.07
	261.351	1	0.116	133.048	1	0.033
	261.365	1	0.014	132.886	1	0.162
	261.183	0	0.182	132.962	0	0.076
	261.136	1	0.047	132.976	0	0.014
	261.23	0	0.094	132.979	0	0.003
	261.279	1	0.049	133.021	0	0.042
	261.27	1	0.009	133.025	0	0.004
	261.427	0	0.157	133.087	1	0.062
	261.504	0	0.077	133.04	1	0.047
	261.55	1	0.046	133.059	1	0.019
	261.456	0	0.094	133.046	1	0.013
	261.409	1	0.047	133.069	1	0.023
	261.44	0	0.031	133.025	0	0.044
	261.445	0	0.005	132.968	0	0.057
		19.04762	**4.38**		**25**	**2.537**
		Sway X	**Dist X**		**Sway Y**	**Dist Y**

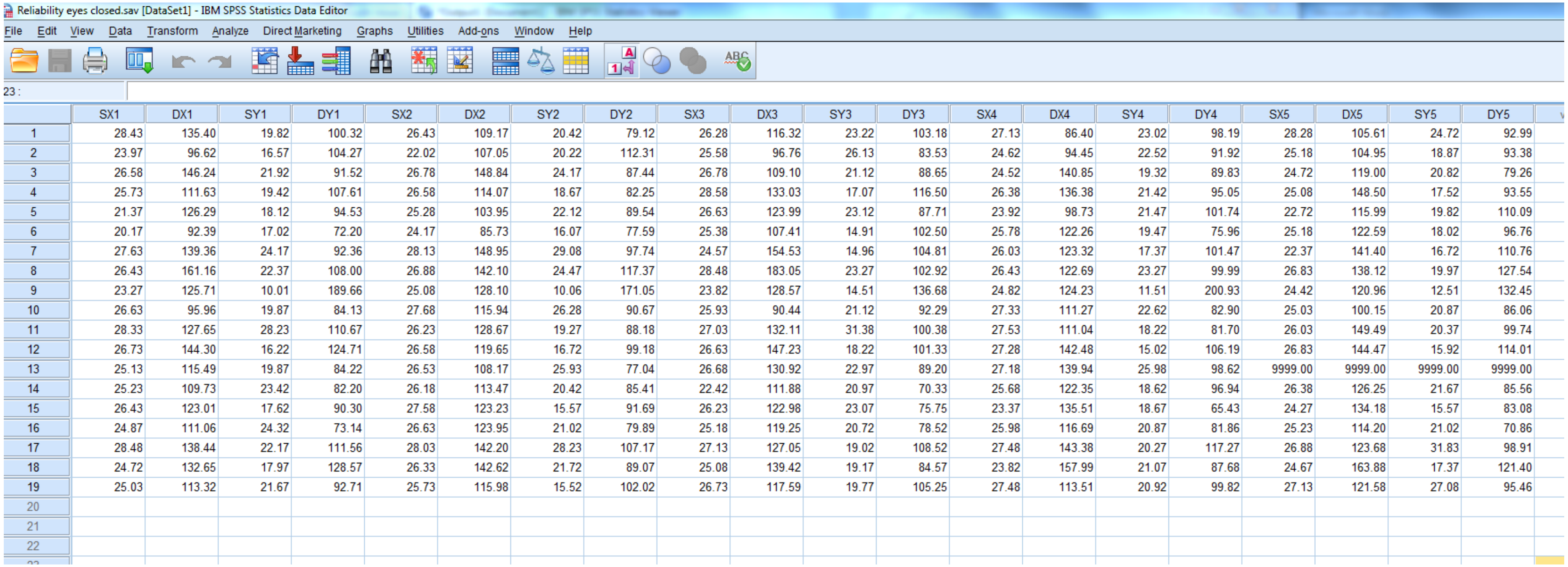
Appendix 4

RELIABILITY ANALYSIS

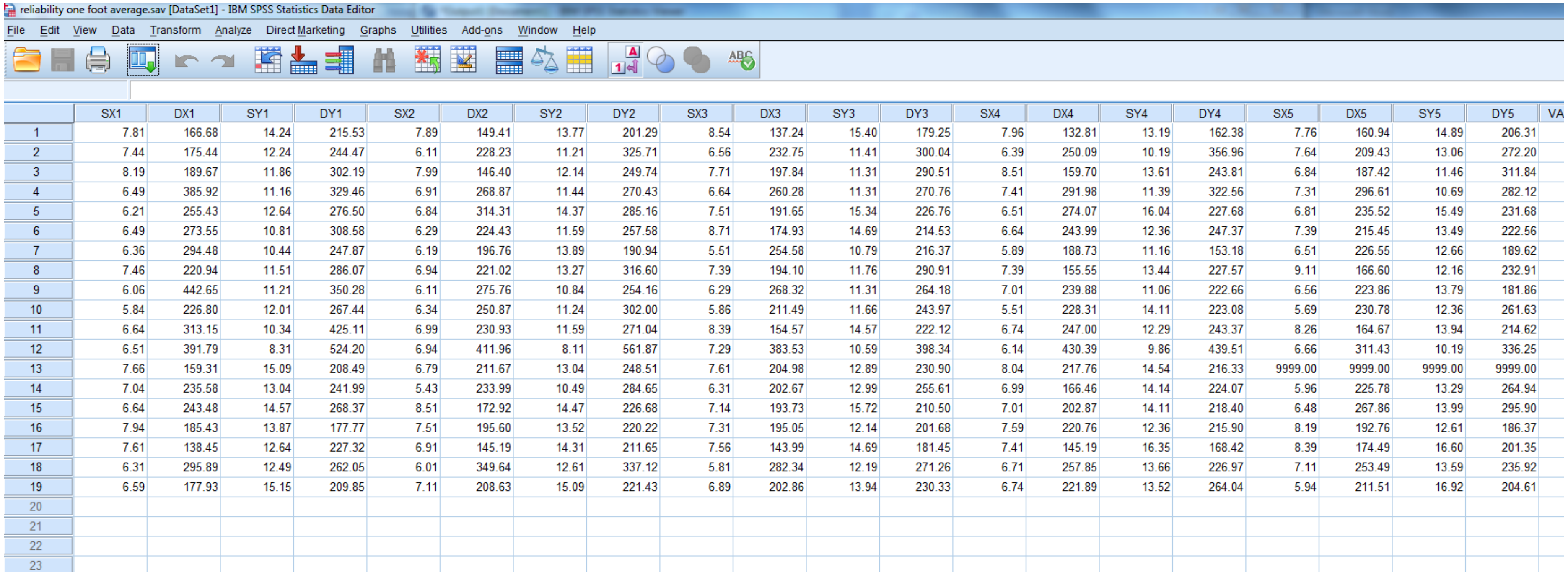


Reliability eyes open.sav [DataSet1] - IBM SPSS Statistics Data Editor

	SX1	DX1	SY1	DY1	SX2	DX2	SY2	DY2	SX3	DX3	SY3	DY3	SX4	DX4	SY4	DY4	SX5	DX5	SY5	DY5
1	27.38	145.27	22.37	98.18	27.18	115.98	23.02	86.46	26.88	105.07	28.38	90.64	24.62	90.97	23.37	75.52	26.83	104.02	28.43	84.98
2	24.77	99.71	22.67	74.44	26.68	90.39	22.72	81.01	24.82	83.88	27.28	76.90	25.78	91.31	24.07	81.80	25.13	107.26	20.67	83.65
3	27.13	124.16	28.33	78.55	25.68	135.74	25.38	82.80	26.73	136.58	25.93	87.70	26.08	129.79	23.37	67.14	24.22	133.37	20.37	76.19
4	26.83	123.92	23.47	91.95	26.03	131.94	20.02	119.66	26.88	132.89	19.32	88.80	27.68	95.77	29.68	87.93	26.03	129.01	25.78	82.89
5	24.97	140.49	20.22	101.02	27.23	118.60	21.07	82.75	27.18	122.87	23.17	93.83	25.48	106.72	21.27	101.69	25.28	126.06	22.02	103.43
6	23.77	90.69	19.67	69.85	23.52	89.30	20.62	77.56	25.03	112.88	19.77	78.32	25.53	125.86	16.37	81.72	26.63	118.35	21.02	76.92
7	25.43	139.88	23.62	90.71	28.28	126.13	31.03	87.42	22.87	86.30	18.82	64.93	25.83	103.62	22.22	78.03	26.18	114.47	20.87	97.22
8	27.43	172.15	26.63	97.06	27.53	153.35	26.88	95.74	26.98	137.43	29.83	92.32	26.33	147.40	22.22	93.53	25.73	150.66	23.17	105.30
9	25.88	107.65	18.42	79.74	27.18	116.79	18.92	85.68	25.63	97.97	26.58	76.24	27.43	104.38	27.58	70.38	24.32	108.94	20.82	78.33
10	23.87	114.26	19.77	80.88	28.23	123.06	24.77	93.97	23.22	96.63	22.07	91.87	26.13	129.98	22.02	92.91	23.87	87.95	20.47	84.21
11	27.83	122.01	26.98	81.70	26.93	126.54	19.17	79.15	27.73	121.83	33.38	90.78	26.13	112.62	20.92	73.58	27.03	139.74	25.03	76.06
12	26.48	133.89	18.62	88.60	26.18	107.17	21.07	66.27	27.13	138.16	20.67	88.30	25.73	135.21	18.92	77.09	26.43	118.56	15.72	91.86
13	26.58	126.27	20.67	87.41	28.83	127.75	24.42	83.32	27.33	141.30	24.47	90.37	27.13	134.59	23.12	81.60	9999.00	9999.00	9999.00	9999.00
14	27.23	123.44	22.92	90.78	24.62	112.42	20.82	88.04	28.33	127.70	24.07	88.78	24.27	119.22	20.32	75.08	25.58	124.43	22.92	84.97
15	23.92	150.83	20.57	66.00	25.08	150.13	19.22	60.88	28.48	165.16	26.63	67.50	25.83	125.36	17.22	89.87	22.27	153.96	22.62	63.15
16	27.08	111.43	26.03	67.22	26.68	131.38	24.22	71.12	25.88	113.86	24.77	66.36	26.98	126.81	22.57	78.50	26.28	121.83	23.42	70.11
17	27.33	162.20	22.67	99.54	25.93	141.40	27.28	100.46	27.38	145.19	21.42	113.99	26.38	151.02	21.07	102.33	27.18	142.07	32.18	108.79
18	25.18	121.56	22.37	83.33	27.63	166.47	22.97	104.55	24.77	160.39	22.02	84.55	27.03	115.47	23.72	69.80	25.78	150.69	21.32	92.28
19	26.08	146.17	24.27	101.74	27.23	109.70	22.52	70.23	26.68	100.88	22.17	92.67	27.83	120.91	22.32	90.10	26.48	122.92	30.08	96.81
20																				
21																				



	SX1	DX1	SY1	DY1	SX2	DX2	SY2	DY2	SX3	DX3	SY3	DY3	SX4	DX4	SY4	DY4	SX5	DX5	SY5	DY5
1	28.43	135.40	19.82	100.32	26.43	109.17	20.42	79.12	26.28	116.32	23.22	103.18	27.13	86.40	23.02	98.19	28.28	105.61	24.72	92.99
2	23.97	96.62	16.57	104.27	22.02	107.05	20.22	112.31	25.58	96.76	26.13	83.53	24.62	94.45	22.52	91.92	25.18	104.95	18.87	93.38
3	26.58	146.24	21.92	91.52	26.78	148.84	24.17	87.44	26.78	109.10	21.12	88.65	24.52	140.85	19.32	89.83	24.72	119.00	20.82	79.26
4	25.73	111.63	19.42	107.61	26.58	114.07	18.67	82.25	28.58	133.03	17.07	116.50	26.38	136.38	21.42	95.05	25.08	148.50	17.52	93.55
5	21.37	126.29	18.12	94.53	25.28	103.95	22.12	89.54	26.63	123.99	23.12	87.71	23.92	98.73	21.47	101.74	22.72	115.99	19.82	110.09
6	20.17	92.39	17.02	72.20	24.17	85.73	16.07	77.59	25.38	107.41	14.91	102.50	25.78	122.26	19.47	75.96	25.18	122.59	18.02	96.76
7	27.63	139.36	24.17	92.36	28.13	148.95	29.08	97.74	24.57	154.53	14.96	104.81	26.03	123.32	17.37	101.47	22.37	141.40	16.72	110.76
8	26.43	161.16	22.37	108.00	26.88	142.10	24.47	117.37	28.48	183.05	23.27	102.92	26.43	122.69	23.27	99.99	26.83	138.12	19.97	127.54
9	23.27	125.71	10.01	189.66	25.08	128.10	10.06	171.05	23.82	128.57	14.51	136.68	24.82	124.23	11.51	200.93	24.42	120.96	12.51	132.45
10	26.63	95.96	19.87	84.13	27.68	115.94	26.28	90.67	25.93	90.44	21.12	92.29	27.33	111.27	22.62	82.90	25.03	100.15	20.87	86.06
11	28.33	127.65	28.23	110.67	26.23	128.67	19.27	88.18	27.03	132.11	31.38	100.38	27.53	111.04	18.22	81.70	26.03	149.49	20.37	99.74
12	26.73	144.30	16.22	124.71	26.58	119.65	16.72	99.18	26.63	147.23	18.22	101.33	27.28	142.48	15.02	106.19	26.83	144.47	15.92	114.01
13	25.13	115.49	19.87	84.22	26.53	108.17	25.93	77.04	26.68	130.92	22.97	89.20	27.18	139.94	25.98	98.62	9999.00	9999.00	9999.00	9999.00
14	25.23	109.73	23.42	82.20	26.18	113.47	20.42	85.41	22.42	111.88	20.97	70.33	25.68	122.35	18.62	96.94	26.38	126.25	21.67	85.56
15	26.43	123.01	17.62	90.30	27.58	123.23	15.57	91.69	26.23	122.98	23.07	75.75	23.37	135.51	18.67	65.43	24.27	134.18	15.57	83.08
16	24.87	111.06	24.32	73.14	26.63	123.95	21.02	79.89	25.18	119.25	20.72	78.52	25.98	116.69	20.87	81.86	25.23	114.20	21.02	70.86
17	28.48	138.44	22.17	111.56	28.03	142.20	28.23	107.17	27.13	127.05	19.02	108.52	27.48	143.38	20.27	117.27	26.88	123.68	31.83	98.91
18	24.72	132.65	17.97	128.57	26.33	142.62	21.72	89.07	25.08	139.42	19.17	84.57	23.82	157.99	21.07	87.68	24.67	163.88	17.37	121.40
19	25.03	113.32	21.67	92.71	25.73	115.98	15.52	102.02	26.73	117.59	19.77	105.25	27.48	113.51	20.92	99.82	27.13	121.58	27.08	95.46
20																				
21																				
22																				



	SX1	DX1	SY1	DY1	SX2	DX2	SY2	DY2	SX3	DX3	SY3	DY3	SX4	DX4	SY4	DY4	SX5	DX5	SY5	DY5	VA
1	7.81	166.68	14.24	215.53	7.89	149.41	13.77	201.29	8.54	137.24	15.40	179.25	7.96	132.81	13.19	162.38	7.76	160.94	14.89	206.31	
2	7.44	175.44	12.24	244.47	6.11	228.23	11.21	325.71	6.56	232.75	11.41	300.04	6.39	250.09	10.19	356.96	7.64	209.43	13.06	272.20	
3	8.19	189.67	11.86	302.19	7.99	146.40	12.14	249.74	7.71	197.84	11.31	290.51	8.51	159.70	13.61	243.81	6.84	187.42	11.46	311.84	
4	6.49	385.92	11.16	329.46	6.91	268.87	11.44	270.43	6.64	260.28	11.31	270.76	7.41	291.98	11.39	322.56	7.31	296.61	10.69	282.12	
5	6.21	255.43	12.64	276.50	6.84	314.31	14.37	285.16	7.51	191.65	15.34	226.76	6.51	274.07	16.04	227.68	6.81	235.52	15.49	231.68	
6	6.49	273.55	10.81	308.58	6.29	224.43	11.59	257.58	8.71	174.93	14.69	214.53	6.64	243.99	12.36	247.37	7.39	215.45	13.49	222.56	
7	6.36	294.48	10.44	247.87	6.19	196.76	13.89	190.94	5.51	254.58	10.79	216.37	5.89	188.73	11.16	153.18	6.51	226.55	12.66	189.62	
8	7.46	220.94	11.51	286.07	6.94	221.02	13.27	316.60	7.39	194.10	11.76	290.91	7.39	155.55	13.44	227.57	9.11	166.60	12.16	232.91	
9	6.06	442.65	11.21	350.28	6.11	275.76	10.84	254.16	6.29	268.32	11.31	264.18	7.01	239.88	11.06	222.66	6.56	223.86	13.79	181.86	
10	5.84	226.80	12.01	267.44	6.34	250.87	11.24	302.00	5.86	211.49	11.66	243.97	5.51	228.31	14.11	223.08	5.69	230.78	12.36	261.63	
11	6.64	313.15	10.34	425.11	6.99	230.93	11.59	271.04	8.39	154.57	14.57	222.12	6.74	247.00	12.29	243.37	8.26	164.67	13.94	214.62	
12	6.51	391.79	8.31	524.20	6.94	411.96	8.11	561.87	7.29	383.53	10.59	398.34	6.14	430.39	9.86	439.51	6.66	311.43	10.19	336.25	
13	7.66	159.31	15.09	208.49	6.79	211.67	13.04	248.51	7.61	204.98	12.89	230.90	8.04	217.76	14.54	216.33	9999.00	9999.00	9999.00	9999.00	
14	7.04	235.58	13.04	241.99	5.43	233.99	10.49	284.65	6.31	202.67	12.99	255.61	6.99	166.46	14.14	224.07	5.96	225.78	13.29	264.94	
15	6.64	243.48	14.57	268.37	8.51	172.92	14.47	226.68	7.14	193.73	15.72	210.50	7.01	202.87	14.11	218.40	6.48	267.86	13.99	295.90	
16	7.94	185.43	13.87	177.77	7.51	195.60	13.52	220.22	7.31	195.05	12.14	201.68	7.59	220.76	12.36	215.90	8.19	192.76	12.61	186.37	
17	7.61	138.45	12.64	227.32	6.91	145.19	14.31	211.65	7.56	143.99	14.69	181.45	7.41	145.19	16.35	168.42	8.39	174.49	16.60	201.35	
18	6.31	295.89	12.49	262.05	6.01	349.64	12.61	337.12	5.81	282.34	12.19	271.26	6.71	257.85	13.66	226.97	7.11	253.49	13.59	235.92	
19	6.59	177.93	15.15	209.85	7.11	208.63	15.09	221.43	6.89	202.86	13.94	230.33	6.74	221.89	13.52	264.04	5.94	211.51	16.92	204.61	
20																					
21																					
22																					
23																					

EYES OPEN Reliability
Scale: swayx

Case Processing Summary

		N	%
Cases	Valid	18	94.7
	Excluded[a]	1	5.3
	Total	19	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.311	5

ANOVA

		Sum of Squares	df	Mean Square	F	Sig
Between People		38.211	17	2.248		
Within People	Between Items	8.177	4	2.044	1.320	.271
	Residual	105.315	68	1.549		
	Total	113.492	72	1.576		
Total		151.703	89	1.705		

Grand Mean = 26.1239

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.083[a]	-.056	.327	1.451	17	68	.141
Average Measures	.311[c]	-.364	.709	1.451	17	68	.141

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition-the between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Scale: distx

Case Processing Summary

		N	%
Cases	Valid	18	94.7
	Excluded[a]	1	5.3
	Total	19	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.847	5

ANOVA

		Sum of Squares	df	Mean Square	F	Sig
Between People		21649.401	17	1273.494		
Within People	Between Items	1238.216	4	309.554	1.588	.188
	Residual	13256.878	68	194.954		
	Total	14495.094	72	201.321		
Total		36144.495	89	406.118		

Grand Mean = 123.8728

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.525[a]	.315	.743	6.532	17	68	.000
Average Measures	.847[c]	.697	.935	6.532	17	68	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition-the between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Reliability
Scale: sway

Case Processing Summary

		N	%
Cases	Valid	18	94.7
	Excluded[a]	1	5.3
	Total	19	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.434	5

ANOVA

		Sum of Squares	df	Mean Square	F	Sig
Between People		313.834	17	18.461		
Within People	Between Items	41.358	4	10.339	.990	.419
	Residual	710.431	68	10.448		
	Total	751.789	72	10.442		
Total		1065.623	89	11.973		

Grand Mean = 23.0419

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.133[a]	-.022	.389	1.767	17	68	.051
Average Measures	.434[c]	-.120	.761	1.767	17	68	.051

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition-the between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Scale: disty

Case Processing Summary

		N	%
Cases	Valid	18	94.7
	Excluded[a]	1	5.3
	Total	19	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.816	5

ANOVA

		Sum of Squares	df	Mean Square	F	Sig
Between People		7366.594	17	433.329		
Within People	Between Items	152.517	4	38.129	.477	.752
	Residual	5432.323	68	79.887		
	Total	5584.841	72	77.567		
Total		12951.434	89	145.522		

Grand Mean = 85.0407

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.469[a]	.258	.703	5.424	17	68	.000
Average Measures	.816[c]	.635	.922	5.424	17	68	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition-the between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Descriptives

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
SX1	19	23.77	27.83	26.0603	1.32326
SX2	19	23.52	28.83	26.6635	1.31987
SX3	19	22.87	28.48	26.3105	1.56326
SX4	19	24.27	27.83	26.2183	.95479
SX5	18	22.27	27.18	25.6228	1.27065
SY1	19	18.42	28.33	22.6463	2.86892
SY2	19	18.92	31.03	22.9545	3.18649
SY3	19	18.82	33.38	24.2506	3.83599
SY4	19	16.37	29.68	22.2301	3.08585
SY5	18	15.72	32.18	23.1621	3.94351
DX1	19	90.69	172.15	129.2612	20.77969
DX2	19	89.30	166.47	124.9602	19.74206
DX3	19	83.88	165.16	122.4719	23.49606
DX4	19	90.97	151.02	119.3158	17.43389
DX5	18	87.95	153.96	125.2381	17.73722
DY1	19	66.00	101.74	85.7194	11.32619
DY2	19	60.88	119.66	85.1089	13.94017
DY3	19	64.93	113.99	85.5180	11.68512
DY4	19	67.14	102.33	82.5581	10.34771
DY5	18	63.15	108.79	86.5094	12.45931
Valid N (listwise)	18				

EYES CLOSED Reliability
Scale: sway x

Case Processing Summary

		N	%
Cases	Valid	18	94.7
	Excluded[a]	1	5.3
	Total	19	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.731	5

ANOVA

		Sum of Squares	df	Mean Square	F	Sig
Between People		113.880	17	6.699		
Within People	Between Items	8.336	4	2.084	1.156	.338
	Residual	122.633	68	1.803		
	Total	130.969	72	1.819		
Total		244.849	89	2.751		

Grand Mean = 25.8164

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.352[a]	.149	.609	3.715	17	68	.000
Average Measures	.731[c]	.467	.886	3.715	17	68	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition-the between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Scale: sway y

Case Processing Summary

		N	%
Cases	Valid	18	94.7
	Excluded[a]	1	5.3
	Total	19	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.762	5

ANOVA

		Sum of Squares	df	Mean Square	F	Sig
Between People		751.882	17	44.228		
Within People	Between Items	10.376	4	2.594	.247	.911
	Residual	714.657	68	10.510		
	Total	725.033	72	10.070		
Total		1476.915	89	16.595		

Grand Mean = 20.2113

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.391[a]	.184	.642	4.208	17	68	.000
Average Measures	.762[c]	.530	.900	4.208	17	68	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition-the between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Reliability
Scale: distance x

Case Processing Summary

		N	%
	Valid	18	94.7
Cases	Excluded[a]	1	5.3
	Total	19	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.855	5

ANOVA

		Sum of Squares	df	Mean Square	F	Sig
Between People		19000.003	17	1117.647		
	Between Items	308.628	4	77.157	.475	.754
Within People	Residual	11039.850	68	162.351		
	Total	11348.478	72	157.618		
Total		30348.481	89	340.994		

Grand Mean = 124.4863

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.541[a]	.331	.753	6.884	17	68	.000
Average Measures	.855[c]	.712	.939	6.884	17	68	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition-the between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Scale: distance y

Case Processing Summary

		N	%
Cases	Valid	18	94.7
	Excluded[a]	1	5.3
	Total	19	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.916	5

ANOVA

		Sum of Squares	df	Mean Square	F	Sig
Between People		32016.783	17	1883.340		
Within People	Between Items	480.712	4	120.178	.761	.555
	Residual	10745.060	68	158.016		
	Total	11225.772	72	155.914		
Total		43242.555	89	485.871		

Grand Mean = 99.0691

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.686[a]	.501	.845	11.919	17	68	.000
Average Measures	.916[c]	.834	.965	11.919	17	68	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition-the between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Descriptives

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
SX1	19	20.17	28.48	25.5334	2.23390
SX2	19	22.02	28.13	26.2526	1.42253
SX3	19	22.42	28.58	26.0576	1.47638
SX4	19	23.37	27.53	25.9338	1.38525
SX5	18	22.37	28.28	25.4004	1.51033
SY1	19	10.01	28.23	20.0411	3.95041
SY2	19	10.06	29.08	20.8393	4.85773
SY3	19	14.51	31.38	20.7760	4.10637
SY4	19	11.51	25.98	20.0859	3.22416
SY5	18	12.51	31.83	20.0367	4.46755
DX1	19	92.39	161.16	123.4941	18.55867
DX2	19	85.73	148.95	122.2027	17.00476
DX3	19	90.44	183.05	125.8748	21.07085
DX4	19	86.40	157.99	123.3394	18.43171
DX5	18	100.15	163.88	127.4988	17.35742
DY1	19	72.20	189.66	102.2454	26.22197
DY2	19	77.04	171.05	96.0377	21.53137
DY3	19	70.33	136.68	96.4523	15.67746
DY4	19	65.43	200.93	98.6031	27.46887
DY5	18	70.86	132.45	99.5477	16.82851
Valid N (listwise)	18				

Reliability 1ft
Scale: sway x

Case Processing Summary

		N	%
Cases	Valid	18	94.7
	Excluded[a]	1	5.3
	Total	19	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.821	5

ANOVA

		Sum of Squares	df	Mean Square	F	Sig
Between People		33.703	17	1.983		
Within People	Between Items	1.332	4	.333	.940	.446
	Residual	24.095	68	.354		
	Total	25.428	72	.353		
Total		59.131	89	.664		

Grand Mean = 6.9667

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.479[a]	.268	.710	5.595	17	68	.000
Average Measures	.821[c]	.646	.924	5.595	17	68	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition-the between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Scale: sway y

Case Processing Summary

		N	%
Cases	Valid	18	94.7
	Excluded[a]	1	5.3
	Total	19	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.890	5

ANOVA

		Sum of Squares	df	Mean Square	F	Sig
Between People		185.546	17	10.914		
Within People	Between Items	16.904	4	4.226	3.533	.011
	Residual	81.352	68	1.196		
	Total	98.256	72	1.365		
Total		283.803	89	3.189		

Grand Mean = 12.7563

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.619[a]	.419	.805	9.123	17	68	.000
Average Measures	.890[c]	.783	.954	9.123	17	68	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition-the between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Scale: sway y day 2

Case Processing Summary

		N	%
Cases	Valid	18	94.7
	Excluded[a]	1	5.3
	Total	19	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.872	4

ANOVA

		Sum of Squares	df	Mean Square	F	Sig
Between People		157.755	17	9.280		
Within People	Between Items	8.303	3	2.768	2.333	.085
	Residual	60.503	51	1.186		
	Total	68.806	54	1.274		
Total		226.561	71	3.191		

Grand Mean = 12.9109

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.630[a]	.413	.816	7.822	17	51	.000
Average Measures	.872[c]	.738	.947	7.822	17	51	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition-the between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Reliability
Scale: distance x

Case Processing Summary

		N	%
Cases	Valid	18	94.7
	Excluded[a]	1	5.3
	Total	19	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.914	5

ANOVA

		Sum of Squares	df	Mean Square	F	Sig
Between People		282625.131	17	16625.008		
Within People	Between Items	18807.994	4	4701.998	3.306	.016
	Residual	96706.787	68	1422.159		
	Total	115514.781	72	1604.372		
Total		398139.912	89	4473.482		

Grand Mean = 230.3618

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.681[a]	.495	.842	11.690	17	68	.000
Average Measures	.914[c]	.831	.964	11.690	17	68	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition-the between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Reliability
Scale: distance x day 2

Case Processing Summary

		N	%
Cases	Valid	18	94.7
	Excluded[a]	1	5.3
	Total	19	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.922	4

ANOVA

		Sum of Squares	df	Mean Square	F	Sig
Between People		207443.890	17	12202.582		
Within People	Between Items	3682.182	3	1227.394	1.286	.289
	Residual	48673.553	51	954.383		
	Total	52355.735	54	969.551		
Total		259799.624	71	3659.150		

Grand Mean = 223.8798

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.747[a]	.567	.881	12.786	17	51	.000
Average Measures	.922[c]	.840	.967	12.786	17	51	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition-the between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Scale: distance y

Case Processing Summary

		N	%
Cases	Valid	18	94.7
	Excluded[a]	1	5.3
	Total	19	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.907	5

ANOVA

		Sum of Squares	df	Mean Square	F	Sig
Between People		288414.074	17	16965.534		
Within People	Between Items	32237.614	4	8059.404	5.084	.001
	Residual	107804.441	68	1585.359		
	Total	140042.055	72	1945.029		
Total		428456.129	89	4814.114		

Grand Mean = 259.3586

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.660[a]	.468	.829	10.701	17	68	.000
Average Measures	.907[c]	.815	.960	10.701	17	68	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition-the between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Scale: distance y day 2

Case Processing Summary

		N	%
Cases	Valid	18	94.7
	Excluded[a]	1	5.3
	Total	19	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.908	4

ANOVA

		Sum of Squares	df	Mean Square	F	Sig
Between People		220134.315	17	12949.077		
Within People	Between Items	15115.191	3	5038.397	4.222	.010
	Residual	60862.818	51	1193.389		
	Total	75978.009	54	1407.000		
Total		296112.324	71	4170.596		

Grand Mean = 252.4620

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.711[a]	.518	.862	10.851	17	51	.000
Average Measures	.908[c]	.811	.962	10.851	17	51	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition-the between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Reliability
Scale: distance y day 3

Case Processing Summary

		N	%
Cases	Valid	18	94.7
	Excluded[a]	1	5.3
	Total	19	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.877	3

ANOVA

		Sum of Squares	df	Mean Square	F	Sig
Between People		131172.035	17	7716.002		
Within People	Between Items	518.855	2	259.427	.272	.763
	Residual	32394.068	34	952.767		
	Total	32912.923	36	914.248		
Total		164084.958	53	3095.943		

Grand Mean = 244.2416

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.703[a]	.473	.864	8.099	17	34	.000
Average Measures	.877[c]	.729	.950	8.099	17	34	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition-the between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Descriptives

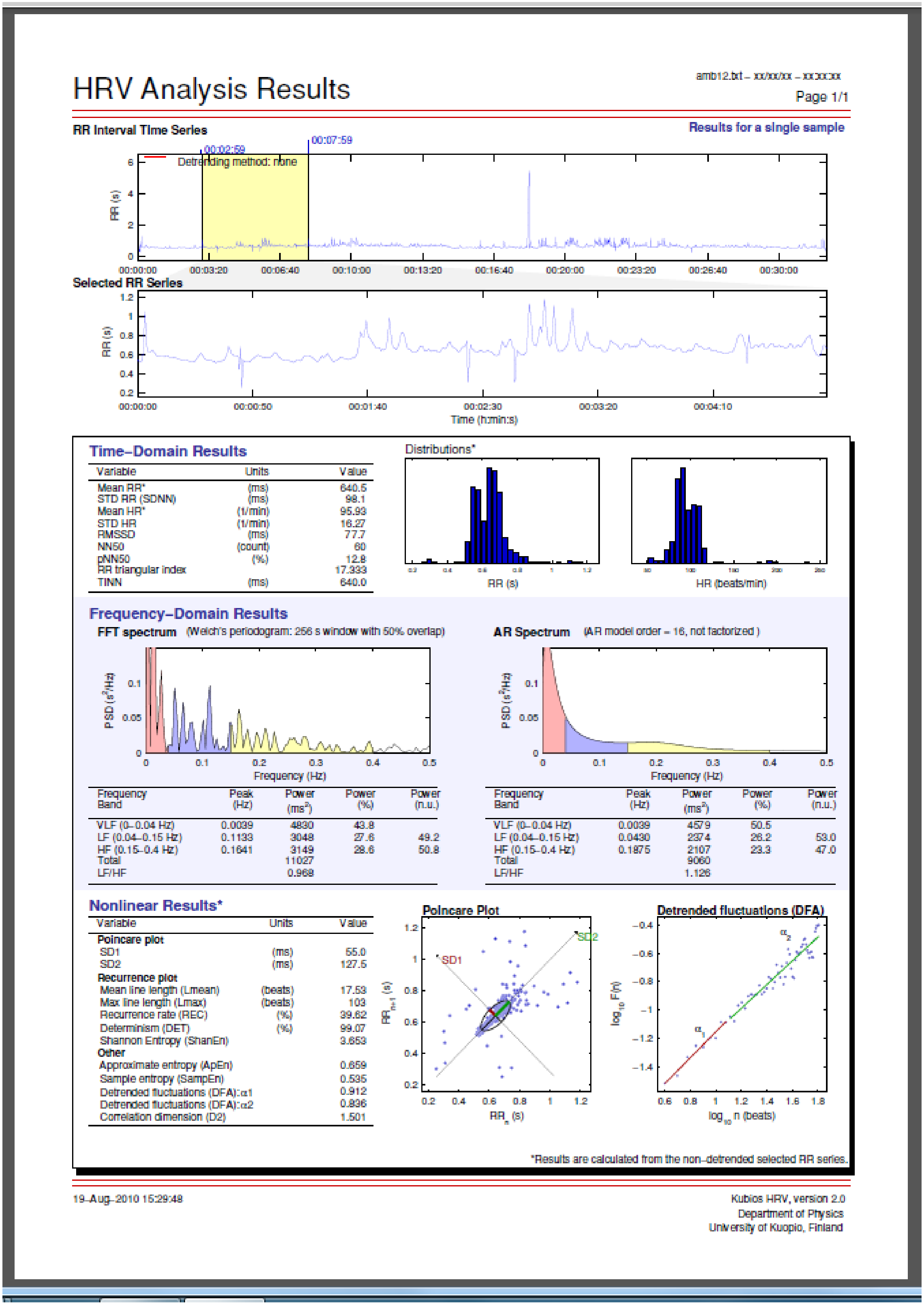
Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
SX1	19	5.84	8.19	6.9074	.70479
SX2	19	5.43	8.51	6.8295	.76371
SX3	19	5.51	8.71	7.1045	.91478
SX4	19	5.51	8.51	6.9755	.75613
SX5	18	5.69	9.11	7.1431	.94119
SY1	19	8.31	15.15	12.2934	1.77789
SY2	19	8.11	15.09	12.4695	1.74879
SY3	19	10.59	15.72	12.8761	1.73051
SY4	19	9.86	16.35	13.0179	1.77508
SY5	18	10.19	16.92	13.3967	1.80476
DX1	19	138.45	442.65	251.1855	85.67527
DX2	19	145.19	411.96	233.5024	68.91466
DX3	19	137.24	383.53	215.0982	57.05512
DX4	19	132.81	430.39	225.0118	67.13836
DX5	18	160.94	311.43	219.7283	43.09161
DY1	19	177.77	524.20	282.8155	82.00697
DY2	19	190.94	561.87	275.6171	81.03735
DY3	19	179.25	398.34	247.3379	51.04411
DY4	19	153.18	439.51	242.3266	67.68589
DY5	18	181.86	336.25	240.7025	45.50437
Valid N (listwise)	18				

Appendix 5

HEART RATE VARIABILITY STUDY 2

KUBIOS OUTPUT
And
SPSS ANALYSIS



HRV Analysis Results

amb12.txt – xx/xx/xx – xx:xx:xx

Page 1/1

Results for a single sample

Time–Domain Results

Variable	Units	Value
Mean RR*	(ms)	640.5
STD RR (SDNN)	(ms)	98.1
Mean HR*	(1/min)	95.93
STD HR	(1/min)	16.27
RMSSD	(ms)	77.7
NN50	(count)	60
pNN50	(%)	12.8
RR triangular index		17.333
TINN	(ms)	640.0

Frequency–Domain Results

FFT spectrum (Welch's periodogram: 256 s window with 50% overlap)

Frequency Band	Peak (Hz)	Power (ms^2)	Power (%)	Power (n.u.)
VLF (0–0.04 Hz)	0.0039	4830	43.8	
LF (0.04–0.15 Hz)	0.1133	3048	27.6	49.2
HF (0.15–0.4 Hz)	0.1641	3149	28.6	50.8
Total		11027		
LF/HF		0.968		

AR Spectrum (AR model order = 16, not factorized)

Frequency Band	Peak (Hz)	Power (ms^2)	Power (%)	Power (n.u.)
VLF (0–0.04 Hz)	0.0039	4579	50.5	
LF (0.04–0.15 Hz)	0.0430	2374	26.2	53.0
HF (0.15–0.4 Hz)	0.1875	2107	23.3	47.0
Total		9060		
LF/HF		1.126		

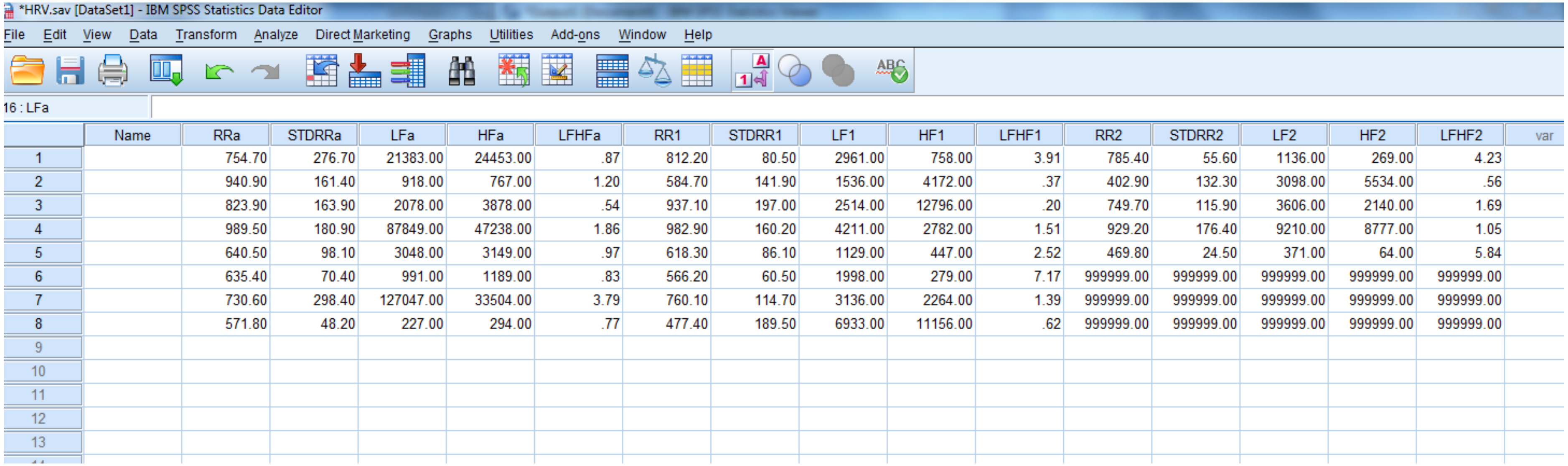
Nonlinear Results*

Variable	Units	Value
Poincare plot		
SD1	(ms)	55.0
SD2	(ms)	127.5
Recurrence plot		
Mean line length (Lmean)	(beats)	17.53
Max line length (Lmax)	(beats)	103
Recurrence rate (REC)	(%)	39.62
Determinism (DET)	(%)	99.07
Shannon Entropy (ShanEn)		3.653
Other		
Approximate entropy (ApEn)		0.659
Sample entropy (SampEn)		0.535
Detrended fluctuations (DFA):α1		0.912
Detrended fluctuations (DFA):α2		0.836
Correlation dimension (D2)		1.501

*Results are calculated from the non–detrended selected RR series.

19–Aug–2010 15:29:48

Kubios HRV, version 2.0
Department of Physics
University of Kuopio, Finland



	Name	RRa	STDRRa	LFa	HFa	LFHFa	RR1	STDRR1	LF1	HF1	LFHF1	RR2	STDRR2	LF2	HF2	LFHF2	var
1		754.70	276.70	21383.00	24453.00	.87	812.20	80.50	2961.00	758.00	3.91	785.40	55.60	1136.00	269.00	4.23	
2		940.90	161.40	918.00	767.00	1.20	584.70	141.90	1536.00	4172.00	.37	402.90	132.30	3098.00	5534.00	.56	
3		823.90	163.90	2078.00	3878.00	.54	937.10	197.00	2514.00	12796.00	.20	749.70	115.90	3606.00	2140.00	1.69	
4		989.50	180.90	87849.00	47238.00	1.86	982.90	160.20	4211.00	2782.00	1.51	929.20	176.40	9210.00	8777.00	1.05	
5		640.50	98.10	3048.00	3149.00	.97	618.30	86.10	1129.00	447.00	2.52	469.80	24.50	371.00	64.00	5.84	
6		635.40	70.40	991.00	1189.00	.83	566.20	60.50	1998.00	279.00	7.17	999999.00	999999.00	999999.00	999999.00	999999.00	
7		730.60	298.40	127047.00	33504.00	3.79	760.10	114.70	3136.00	2264.00	1.39	999999.00	999999.00	999999.00	999999.00	999999.00	
8		571.80	48.20	227.00	294.00	.77	477.40	189.50	6933.00	11156.00	.62	999999.00	999999.00	999999.00	999999.00	999999.00	
9																	
10																	
11																	
12																	
13																	

General Linear Model

Within-Subjects Factors

Measure	Temp	Dependent Variable
rr	1	RRa
	2	RR1
	3	RR2
stdrr	1	STDRRa
	2	STDRR1
	3	STDRR2
lf	1	LFa
	2	LF1
	3	LF2
hf	1	HFa
	2	HF1
	3	HF2
ratio	1	LFHFa
	2	LFHF1
	3	LFHF2

Mauchly's Test of Sphericity[b]

Within Subjects Effect	Measure	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Temp	rr	.249	4.171	2	.124	.571	.649	.500
	stdrr	.475	2.232	2	.328	.656	.848	.500
	lf	.008	14.474	2	.001	.502	.504	.500
	hf	.139	5.924	2	.052	.537	.576	.500
	ratio	.533	1.889	2	.389	.682	.913	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b. Design: Intercept
Within Subjects Design: Temp

Tests of Within-Subjects Effects

Univariate Tests

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Temp	rr	Sphericity Assumed	70928.265	2	35464.133	2.410	.152	.376	4.819	.351
		Greenhouse-Geisser	70928.265	1.142	62096.757	2.410	.189	.376	2.752	.244
		Huynh-Feldt	70928.265	1.299	54619.056	2.410	.182	.376	3.129	.265
		Lower-bound	70928.265	1.000	70928.265	2.410	.196	.376	2.410	.225
	stdrr	Sphericity Assumed	14258.452	2	7129.226	2.570	.137	.391	5.139	.372
		Greenhouse-Geisser	14258.452	1.312	10871.052	2.570	.168	.391	3.370	.281
		Huynh-Feldt	14258.452	1.695	8409.944	2.570	.150	.391	4.357	.333
		Lower-bound	14258.452	1.000	14258.452	2.570	.184	.391	2.570	.236
	lf	Sphericity Assumed	1.346E9	2	6.732E8	1.625	.256	.289	3.250	.249
		Greenhouse-Geisser	1.346E9	1.004	1.341E9	1.625	.271	.289	1.632	.168
		Huynh-Feldt	1.346E9	1.008	1.336E9	1.625	.271	.289	1.638	.169
		Lower-bound	1.346E9	1.000	1.346E9	1.625	.271	.289	1.625	.168
	hf	Sphericity Assumed	4.916E8	2	2.458E8	1.729	.238	.302	3.458	.263
		Greenhouse-Geisser	4.916E8	1.075	4.575E8	1.729	.258	.302	1.858	.183
		Huynh-Feldt	4.916E8	1.153	4.264E8	1.729	.256	.302	1.993	.190
		Lower-bound	4.916E8	1.000	4.916E8	1.729	.259	.302	1.729	.175
	ratio	Sphericity Assumed	6.400	2	3.200	1.732	.237	.302	3.464	.263
		Greenhouse-Geisser	6.400	1.363	4.695	1.732	.252	.302	2.361	.209
		Huynh-Feldt	6.400	1.826	3.504	1.732	.241	.302	3.163	.249
		Lower-bound	6.400	1.000	6.400	1.732	.259	.302	1.732	.176
Error(Temp)	rr	Sphericity	117747.141	8	14718.393					

		Assumed								
		Greenhouse-Geisser	117747.141	4.569	25771.516					
		Huynh-Feldt	117747.141	5.194	22668.106					
		Lower-bound	117747.141	4.000	29436.785					
	stdrr	Sphericity Assumed	22195.681	8	2774.460					
		Greenhouse-Geisser	22195.681	5.246	4230.656					
		Huynh-Feldt	22195.681	6.782	3272.873					
		Lower-bound	22195.681	4.000	5548.920					
	lf	Sphericity Assumed	3.314E9	8	4.142E8					
		Greenhouse-Geisser	3.314E9	4.016	8.251E8					
		Huynh-Feldt	3.314E9	4.032	8.218E8					
		Lower-bound	3.314E9	4.000	8.284E8					
	hf	Sphericity Assumed	1.137E9	8	1.422E8					
		Greenhouse-Geisser	1.137E9	4.298	2.646E8					
		Huynh-Feldt	1.137E9	4.612	2.466E8					
		Lower-bound	1.137E9	4.000	2.844E8					
	ratio	Sphericity Assumed	14.780	8	1.847					
		Greenhouse-Geisser	14.780	5.453	2.711					
		Huynh-Feldt	14.780	7.305	2.023					
		Lower-bound	14.780	4.000	3.695					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Source	Measure	Temp	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Temp	rr	Linear	66015.625	1	66015.625	2.686	.177	.402	2.686	.245
		Quadratic	4912.640	1	4912.640	1.011	.371	.202	1.011	.123
	stdrr	Linear	14160.169	1	14160.169	3.886	.120	.493	3.886	.328
		Quadratic	98.283	1	98.283	.052	.831	.013	.052	.054
	lf	Linear	9.576E8	1	9.576E8	1.632	.271	.290	1.632	.168
		Quadratic	3.888E8	1	3.888E8	1.608	.274	.287	1.608	.167
	hf	Linear	3.931E8	1	3.931E8	2.395	.197	.375	2.395	.224
		Quadratic	98496696.033	1	98496696.033	.819	.417	.170	.819	.109
	ratio	Linear	6.293	1	6.293	2.028	.228	.336	2.028	.197
		Quadratic	.106	1	.106	.180	.693	.043	.180	.063
Error(Temp)	rr	Linear	98317.730	4	24579.432					
		Quadratic	19429.411	4	4857.353					
	stdrr	Linear	14576.446	4	3644.111					
		Quadratic	7619.235	4	1904.809					
	lf	Linear	2.347E9	4	5.866E8					
		Quadratic	9.670E8	4	2.418E8					
	hf	Linear	6.565E8	4	1.641E8					
		Quadratic	4.809E8	4	1.202E8					
	ratio	Linear	12.415	4	3.104					
		Quadratic	2.365	4	.591					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

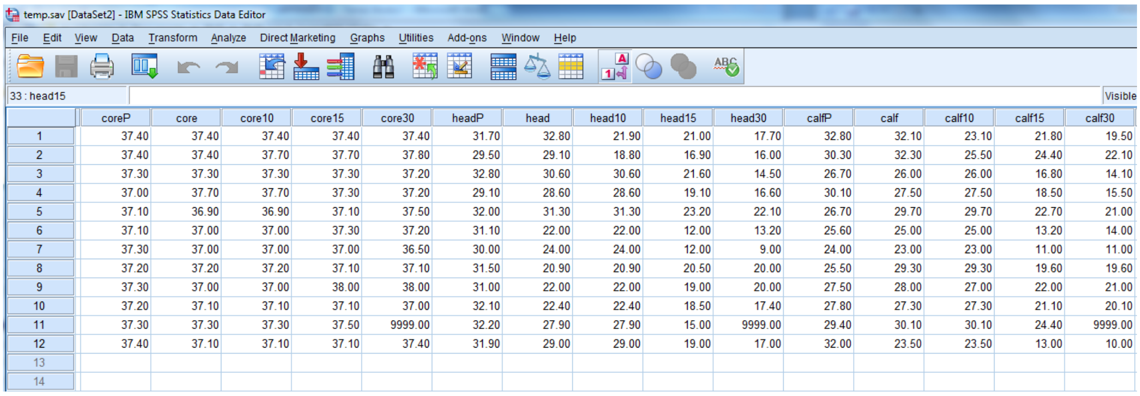
Transformed Variable:Average

Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	rr	8697015.393	1	8697015.393	119.638	.000	.968	119.638	1.000
	stdrr	280549.464	1	280549.464	58.853	.002	.936	58.853	1.000
	lf	1.403E9	1	1.403E9	2.469	.191	.382	2.469	.229
	hf	9.161E8	1	9.161E8	5.991	.071	.600	5.991	.462
	ratio	49.726	1	49.726	12.157	.025	.752	12.157	.742
Error	rr	290778.791	4	72694.698					
	stdrr	19067.663	4	4766.916					
	lf	2.272E9	4	5.680E8					
	hf	6.117E8	4	1.529E8					
	ratio	16.361	4	4.090					

a. Computed using alpha = .05

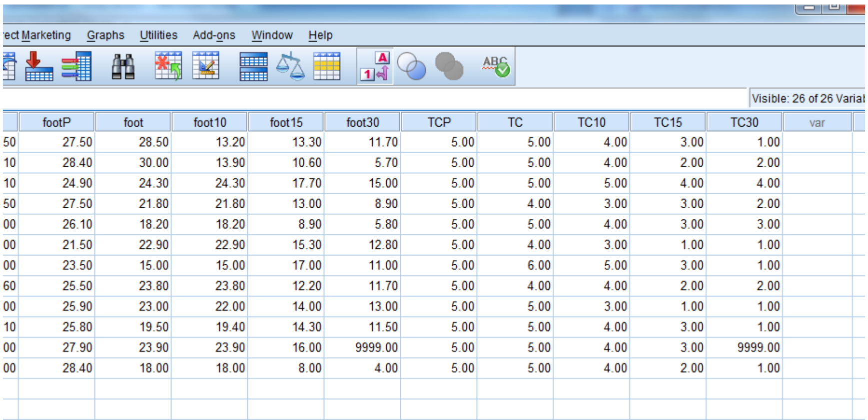
Appendix 6

BODY TEMPERATURE
STUDY 2



33 : head15

	coreP	core	core10	core15	core30	headP	head	head10	head15	head30	calfP	calf	calf10	calf15	calf30
1	37.40	37.40	37.40	37.40	37.40	31.70	32.80	21.90	21.00	17.70	32.80	32.10	23.10	21.80	19.50
2	37.40	37.40	37.70	37.70	37.80	29.50	29.10	18.80	16.90	16.00	30.30	32.30	25.50	24.40	22.10
3	37.30	37.30	37.30	37.30	37.20	32.80	30.60	30.60	21.60	14.50	26.70	26.00	26.00	16.80	14.10
4	37.00	37.70	37.70	37.30	37.20	29.10	28.60	28.60	19.10	16.60	30.10	27.50	27.50	18.50	15.50
5	37.10	36.90	36.90	37.10	37.50	32.00	31.30	31.30	23.20	22.10	26.70	29.70	29.70	22.70	21.00
6	37.10	37.00	37.00	37.30	37.20	31.10	22.00	22.00	12.00	13.20	25.60	25.00	25.00	13.20	14.00
7	37.30	37.00	37.00	37.00	36.50	30.00	24.00	24.00	12.00	9.00	24.00	23.00	23.00	11.00	11.00
8	37.20	37.20	37.20	37.10	37.10	31.50	20.90	20.90	20.50	20.00	25.50	29.30	29.30	19.60	19.60
9	37.30	37.00	37.00	38.00	38.00	31.00	22.00	22.00	19.00	20.00	27.50	28.00	27.00	22.00	21.00
10	37.20	37.10	37.10	37.10	37.00	32.10	22.40	22.40	18.50	17.40	27.80	27.30	27.30	21.10	20.10
11	37.30	37.30	37.30	37.50	9999.00	32.20	27.90	27.90	15.00	9999.00	29.40	30.10	30.10	24.40	9999.00
12	37.40	37.10	37.10	37.10	37.40	31.90	29.00	29.00	19.00	17.00	32.00	23.50	23.50	13.00	10.00
13															
14															



	footP	foot	foot10	foot15	foot30	TCP	TC	TC10	TC15	TC30	var
50	27.50	28.50	13.20	13.30	11.70	5.00	5.00	4.00	3.00	1.00	
10	28.40	30.00	13.90	10.60	5.70	5.00	5.00	4.00	2.00	2.00	
10	24.90	24.30	24.30	17.70	15.00	5.00	5.00	5.00	4.00	4.00	
50	27.50	21.80	21.80	13.00	8.90	5.00	4.00	3.00	3.00	2.00	
00	26.10	18.20	18.20	8.90	5.80	5.00	5.00	4.00	3.00	3.00	
00	21.50	22.90	22.90	15.30	12.80	5.00	4.00	3.00	1.00	1.00	
00	23.50	15.00	15.00	17.00	11.00	5.00	6.00	5.00	3.00	1.00	
60	25.50	23.80	23.80	12.20	11.70	5.00	4.00	4.00	2.00	2.00	
00	25.90	23.00	22.00	14.00	13.00	5.00	5.00	3.00	1.00	1.00	
10	25.80	19.50	19.40	14.30	11.50	5.00	5.00	4.00	3.00	1.00	
00	27.90	23.90	23.90	16.00	9999.00	5.00	5.00	4.00	3.00	9999.00	
00	28.40	18.00	18.00	8.00	4.00	5.00	5.00	4.00	2.00	1.00	

General Linear Model

Within-Subjects Factors

Measure	Time	Dependent Variable
coreT	1	coreP
	2	core
	3	core15
	4	core30
headT	1	headP
	2	head
	3	head15
	4	head30
calfT	1	calfP
	2	calf
	3	calf15
	4	calf30
footT	1	footP
	2	foot
	3	foot15
	4	foot30
comfortT	1	TCP
	2	TC
	3	TC15
	4	TC30

Mauchly's Test of Sphericity[a]

Within Subjects Effect	Measure	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Time	coreT	.427	7.423	5	.193	.642	.792	.333
	headT	.335	9.544	5	.091	.649	.803	.333
	calfT	.070	23.221	5	.000	.424	.457	.333
	footT	.184	14.775	5	.012	.621	.758	.333
	comfortT	.455	6.863	5	.234	.707	.903	.333

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Univariate Tests

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Time	coreT	Sphericity Assumed	.099	3	.033	.564	.643	.053	1.691	.152
		Greenhouse-Geisser	.099	1.926	.051	.564	.572	.053	1.086	.129
		Huynh-Feldt	.099	2.375	.042	.564	.605	.053	1.339	.139
		Lower-bound	.099	1.000	.099	.564	.470	.053	.564	.105
	headT	Sphericity Assumed	1540.813	3	513.604	68.228	.000	.872	204.683	1.000
		Greenhouse-Geisser	1540.813	1.946	791.915	68.228	.000	.872	132.749	1.000
		Huynh-Feldt	1540.813	2.409	639.619	68.228	.000	.872	164.357	1.000
		Lower-bound	1540.813	1.000	1540.813	68.228	.000	.872	68.228	1.000
	calfT	Sphericity Assumed	1120.217	3	373.406	68.746	.000	.873	206.238	1.000
		Greenhouse-Geisser	1120.217	1.271	881.506	68.746	.000	.873	87.362	1.000
		Huynh-Feldt	1120.217	1.372	816.326	68.746	.000	.873	94.338	1.000
		Lower-bound	1120.217	1.000	1120.217	68.746	.000	.873	68.746	1.000
	footT	Sphericity Assumed	1836.583	3	612.194	57.837	.000	.853	173.512	1.000
		Greenhouse-Geisser	1836.583	1.863	985.828	57.837	.000	.853	107.750	1.000
		Huynh-Feldt	1836.583	2.273	808.113	57.837	.000	.853	131.446	1.000
		Lower-bound	1836.583	1.000	1836.583	57.837	.000	.853	57.837	1.000
	comfortT	Sphericity Assumed	90.455	3	30.152	66.779	.000	.870	200.336	1.000
		Greenhouse-Geisser	90.455	2.122	42.634	66.779	.000	.870	141.681	1.000
		Huynh-Feldt	90.455	2.708	33.397	66.779	.000	.870	180.867	1.000
		Lower-bound	90.455	1.000	90.455	66.779	.000	.870	66.779	1.000

Error(Time)	coreT	Sphericity Assumed	1.754	30	.058					
		Greenhouse-Geisser	1.754	19.255	.091					
		Huynh-Feldt	1.754	23.755	.074					
		Lower-bound	1.754	10.000	.175					
	headT	Sphericity Assumed	225.834	30	7.528					
		Greenhouse-Geisser	225.834	19.457	11.607					
		Huynh-Feldt	225.834	24.090	9.375					
		Lower-bound	225.834	10.000	22.583					
	calfT	Sphericity Assumed	162.950	30	5.432					
		Greenhouse-Geisser	162.950	12.708	12.823					
		Huynh-Feldt	162.950	13.723	11.875					
		Lower-bound	162.950	10.000	16.295					
	footT	Sphericity Assumed	317.542	30	10.585					
		Greenhouse-Geisser	317.542	18.630	17.045					
		Huynh-Feldt	317.542	22.727	13.972					
		Lower-bound	317.542	10.000	31.754					
	comfortT	Sphericity Assumed	13.545	30	.452					
		Greenhouse-Geisser	13.545	21.217	.638					
		Huynh-Feldt	13.545	27.085	.500					
		Lower-bound	13.545	10.000	1.355					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Source	Measure	Time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Time	coreT	Linear	.044	1	.044	.443	.521	.042	.443	.093
		Quadratic	.006	1	.006	.153	.704	.015	.153	.065
		Cubic	.050	1	.050	1.250	.290	.111	1.250	.173
	headT	Linear	1463.892	1	1463.892	182.107	.000	.948	182.107	1.000
		Quadratic	21.420	1	21.420	2.421	.151	.195	2.421	.291
		Cubic	55.501	1	55.501	9.745	.011	.494	9.745	.803
	calfT	Linear	973.984	1	973.984	76.135	.000	.884	76.135	1.000
		Quadratic	2.700	1	2.700	1.247	.290	.111	1.247	.173
		Cubic	143.533	1	143.533	107.440	.000	.915	107.440	1.000
	footT	Linear	1760.826	1	1760.826	100.807	.000	.910	100.807	1.000
		Quadratic	1.051	1	1.051	.272	.613	.026	.272	.076
		Cubic	74.706	1	74.706	7.167	.023	.417	7.167	.675
	comfortT	Linear	81.618	1	81.618	120.349	.000	.923	120.349	1.000
		Quadratic	.818	1	.818	1.957	.192	.164	1.957	.245
		Cubic	8.018	1	8.018	31.056	.000	.756	31.056	.999
Error(Time)	coreT	Linear	.986	10	.099					
		Quadratic	.372	10	.037					
		Cubic	.396	10	.040					
	headT	Linear	80.386	10	8.039					
		Quadratic	88.492	10	8.849					
		Cubic	56.955	10	5.696					
	calfT	Linear	127.929	10	12.793					
		Quadratic	21.662	10	2.166					
		Cubic	13.359	10	1.336					
	footT	Linear	174.673	10	17.467					
		Quadratic	38.634	10	3.863					
		Cubic	104.235	10	10.424					
	comfortT	Linear	6.782	10	.678					
		Quadratic	4.182	10	.418					
		Cubic	2.582	10	.258					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

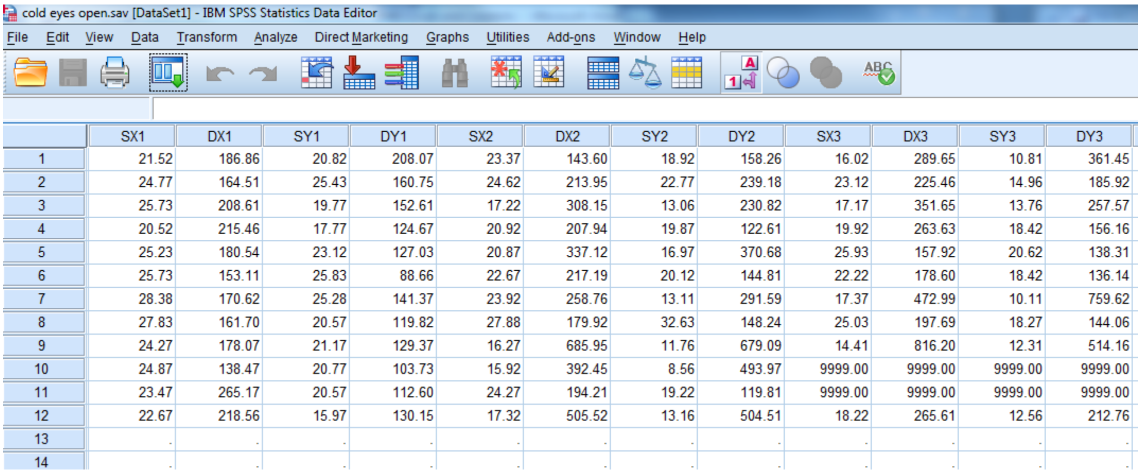
Transformed Variable: Average

Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	coreT	61090.006	1	61090.006	404083.020	.000	1.000	404083.020	1.000
	headT	23724.338	1	23724.338	993.714	.000	.990	993.714	1.000
	calfT	22941.411	1	22941.411	572.403	.000	.983	572.403	1.000
	footT	14019.390	1	14019.390	958.755	.000	.990	958.755	1.000
	comfortT	539.000	1	539.000	598.889	.000	.984	598.889	1.000
Error	coreT	1.512	10	.151					
	headT	238.744	10	23.874					
	calfT	400.791	10	40.079					
	footT	146.225	10	14.622					
	comfortT	9.000	10	.900					

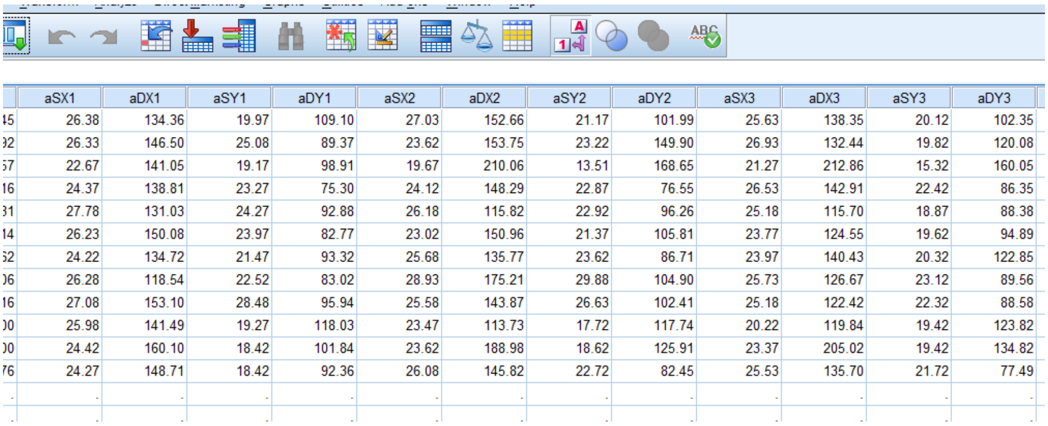
a. Computed using alpha = .05

Appendix 7

POSTURAL SWAY ANALYSIS
STUDY 2



	SX1	DX1	SY1	DY1	SX2	DX2	SY2	DY2	SX3	DX3	SY3	DY3
1	21.52	186.86	20.82	208.07	23.37	143.60	18.92	158.26	16.02	289.65	10.81	361.45
2	24.77	164.51	25.43	160.75	24.62	213.95	22.77	239.18	23.12	225.46	14.96	185.92
3	25.73	208.61	19.77	152.61	17.22	308.15	13.06	230.82	17.17	351.65	13.76	257.57
4	20.52	215.46	17.77	124.67	20.92	207.94	19.87	122.61	19.92	263.63	18.42	156.16
5	25.23	180.54	23.12	127.03	20.87	337.12	16.97	370.68	25.93	157.92	20.62	138.31
6	25.73	153.11	25.83	88.66	22.67	217.19	20.12	144.81	22.22	178.60	18.42	136.14
7	28.38	170.62	25.28	141.37	23.92	258.76	13.11	291.59	17.37	472.99	10.11	759.62
8	27.83	161.70	20.57	119.82	27.88	179.92	32.63	148.24	25.03	197.69	18.27	144.06
9	24.27	178.07	21.17	129.37	16.27	685.95	11.76	679.09	14.41	816.20	12.31	514.16
10	24.87	138.47	20.77	103.73	15.92	392.45	8.56	493.97	9999.00	9999.00	9999.00	9999.00
11	23.47	265.17	20.57	112.60	24.27	194.21	19.22	119.81	9999.00	9999.00	9999.00	9999.00
12	22.67	218.56	15.97	130.15	17.32	505.52	13.16	504.51	18.22	265.61	12.56	212.76
13	.	.	.	.	.	.	.	.	.	.	.	.
14	.	.	.	.	.	.	.	.	.	.	.	.



aSX1	aDX1	aSY1	aDY1	aSX2	aDX2	aSY2	aDY2	aSX3	aDX3	aSY3	aDY3
26.38	134.36	19.97	109.10	27.03	152.66	21.17	101.99	25.63	138.35	20.12	102.35
26.33	146.50	25.08	89.37	23.62	153.75	23.22	149.90	26.93	132.44	19.82	120.08
22.67	141.05	19.17	98.91	19.67	210.06	13.51	168.65	21.27	212.86	15.32	160.05
24.37	138.81	23.27	75.30	24.12	148.29	22.87	76.55	26.53	142.91	22.42	86.35
27.78	131.03	24.27	92.88	26.18	115.82	22.92	96.26	25.18	115.70	18.87	88.38
26.23	150.08	23.97	82.77	23.02	150.96	21.37	105.81	23.77	124.55	19.62	94.89
24.22	134.72	21.47	93.32	25.68	135.77	23.62	86.71	23.97	140.43	20.32	122.85
26.28	118.54	22.52	83.02	28.93	175.21	29.88	104.90	25.73	126.67	23.12	89.56
27.08	153.10	28.48	95.94	25.58	143.87	26.63	102.41	25.18	122.42	22.32	88.58
25.98	141.49	19.27	118.03	23.47	113.73	17.72	117.74	20.22	119.84	19.42	123.82
24.42	160.10	18.42	101.84	23.62	188.98	18.62	125.91	23.37	205.02	19.42	134.82
24.27	148.71	18.42	92.36	26.08	145.82	22.72	82.45	25.53	135.70	21.72	77.49
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.

General Linear Model

Within-Subjects Factors

Measure	time	condition	Dependent Variable
swayX	1	1	SX1
		2	aSX1
	2	1	SX2
		2	aSX2
	3	1	SX3
		2	aSX3
swayY	1	1	SY1
		2	aSY1
	2	1	SY2
		2	aSY2
	3	1	SY3
		2	aSY3
distancex	1	1	DX1
		2	aDX1
	2	1	DX2
		2	aDX2
	3	1	DX3
		2	aDX3
distanceY	1	1	DY1
		2	aDY1
	2	1	DY2
		2	aDY2
	3	1	DY3
		2	aDY3

Mauchly's Test of Sphericity[a]

Within Subjects Effect	Measure	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
time	swayX	.997	.027	2	.987	.997	1.000	.500
	swayY	.711	2.728	2	.256	.776	.907	.500
	distancex	.844	1.355	2	.508	.865	1.000	.500
	distanceY	.921	.656	2	.720	.927	1.000	.500
condition	swayX	1.000	.000	0	.	1.000	1.000	1.000
	swayY	1.000	.000	0	.	1.000	1.000	1.000
	distancex	1.000	.000	0	.	1.000	1.000	1.000
	distanceY	1.000	.000	0	.	1.000	1.000	1.000
time * condition	swayX	.975	.203	2	.904	.976	1.000	.500
	swayY	.979	.170	2	.918	.979	1.000	.500
	distancex	.839	1.402	2	.496	.861	1.000	.500
	distanceY	.996	.034	2	.983	.996	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: time + condition + time * condition

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Multivariate[a,b]

Within Subjects Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[e]
time	Pillai's Trace	.667	2.001	8.000	32.000	.078	.333	16.009	.716
	Wilks' Lambda	.423	2.014[c]	8.000	30.000	.079	.349	16.114	.712
	Hotelling's Trace	1.150	2.012	8.000	28.000	.082	.365	16.097	.703
	Roy's Largest Root	.918	3.670[d]	4.000	16.000	.026	.479	14.682	.761
condition	Pillai's Trace	.732	4.093[c]	4.000	6.000	.062	.732	16.370	.593
	Wilks' Lambda	.268	4.093[c]	4.000	6.000	.062	.732	16.370	.593
	Hotelling's Trace	2.728	4.093[c]	4.000	6.000	.062	.732	16.370	.593
	Roy's Largest Root	2.728	4.093[c]	4.000	6.000	.062	.732	16.370	.593
time * condition	Pillai's Trace	.547	1.507	8.000	32.000	.194	.274	12.055	.567
	Wilks' Lambda	.497	1.569[c]	8.000	30.000	.176	.295	12.553	.581
	Hotelling's Trace	.923	1.615	8.000	28.000	.165	.316	12.920	.587
	Roy's Largest Root	.813	3.253[d]	4.000	16.000	.039	.449	13.013	.703

a. Design: Intercept

Within Subjects Design: time + condition + time * condition

b. Tests are based on averaged variables.

c. Exact statistic

d. The statistic is an upper bound on F that yields a lower bound on the significance level.

e. Computed using alpha = .05

Univariate Tests

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
time	swayX	Sphericity Assumed	74.455	2	37.228	7.020	.006	.438	14.040	.878
		Greenhouse-Geisser	74.455	1.993	37.351	7.020	.006	.438	13.994	.877
		Huynh-Feldt	74.455	2.000	37.228	7.020	.006	.438	14.040	.878
		Lower-bound	74.455	1.000	74.455	7.020	.026	.438	7.020	.656
	swayY	Sphericity Assumed	200.485	2	100.242	6.868	.006	.433	13.736	.870
		Greenhouse-Geisser	200.485	1.552	129.204	6.868	.012	.433	10.657	.794
		Huynh-Feldt	200.485	1.815	110.475	6.868	.008	.433	12.463	.843
		Lower-bound	200.485	1.000	200.485	6.868	.028	.433	6.868	.646
	distancex	Sphericity Assumed	62201.264	2	31100.632	4.546	.025	.336	9.092	.698
		Greenhouse-Geisser	62201.264	1.730	35946.149	4.546	.032	.336	7.867	.648
		Huynh-Feldt	62201.264	2.000	31100.632	4.546	.025	.336	9.092	.698
		Lower-bound	62201.264	1.000	62201.264	4.546	.062	.336	4.546	.478
	distanceY	Sphericity Assumed	89293.459	2	44646.729	4.194	.032	.318	8.388	.661
		Greenhouse-Geisser	89293.459	1.854	48161.017	4.194	.036	.318	7.776	.635
		Huynh-Feldt	89293.459	2.000	44646.729	4.194	.032	.318	8.388	.661
		Lower-bound	89293.459	1.000	89293.459	4.194	.071	.318	4.194	.448

Error(time)	swayX	Sphericity Assumed	95.456	18	5.303					
		Greenhouse-Geisser	95.456	17.940	5.321					
		Huynh-Feldt	95.456	18.000	5.303					
		Lower-bound	95.456	9.000	10.606					
	swayY	Sphericity Assumed	262.726	18	14.596					
		Greenhouse-Geisser	262.726	13.965	18.813					
		Huynh-Feldt	262.726	16.333	16.086					
		Lower-bound	262.726	9.000	29.192					
	distancex	Sphericity Assumed	123137.421	18	6840.968					
		Greenhouse-Geisser	123137.421	15.574	7906.799					
		Huynh-Feldt	123137.421	18.000	6840.968					
		Lower-bound	123137.421	9.000	13681.936					
	distanceY	Sphericity Assumed	191623.286	18	10645.738					
		Greenhouse-Geisser	191623.286	16.687	11483.698					
		Huynh-Feldt	191623.286	18.000	10645.738					
		Lower-bound	191623.286	9.000	21291.476					

condition	swayX	Sphericity Assumed	147.562	1	147.562	13.976	.005	.608	13.976	.913
		Greenhouse-Geisser	147.562	1.000	147.562	13.976	.005	.608	13.976	.913
		Huynh-Feldt	147.562	1.000	147.562	13.976	.005	.608	13.976	.913
		Lower-bound	147.562	1.000	147.562	13.976	.005	.608	13.976	.913
	swayY	Sphericity Assumed	201.153	1	201.153	11.983	.007	.571	11.983	.868
		Greenhouse-Geisser	201.153	1.000	201.153	11.983	.007	.571	11.983	.868
		Huynh-Feldt	201.153	1.000	201.153	11.983	.007	.571	11.983	.868
		Lower-bound	201.153	1.000	201.153	11.983	.007	.571	11.983	.868
	distancex	Sphericity Assumed	239956.465	1	239956.465	12.250	.007	.576	12.250	.875
		Greenhouse-Geisser	239956.465	1.000	239956.465	12.250	.007	.576	12.250	.875
		Huynh-Feldt	239956.465	1.000	239956.465	12.250	.007	.576	12.250	.875
		Lower-bound	239956.465	1.000	239956.465	12.250	.007	.576	12.250	.875
	distanceY	Sphericity Assumed	282806.560	1	282806.560	15.720	.003	.636	15.720	.940
		Greenhouse-Geisser	282806.560	1.000	282806.560	15.720	.003	.636	15.720	.940
		Huynh-Feldt	282806.560	1.000	282806.560	15.720	.003	.636	15.720	.940
		Lower-bound	282806.560	1.000	282806.560	15.720	.003	.636	15.720	.940

Error(condition)	swayX	Sphericity Assumed	95.023	9	10.558					
		Greenhouse-Geisser	95.023	9.000	10.558					
		Huynh-Feldt	95.023	9.000	10.558					
		Lower-bound	95.023	9.000	10.558					
	swayY	Sphericity Assumed	151.075	9	16.786					
		Greenhouse-Geisser	151.075	9.000	16.786					
		Huynh-Feldt	151.075	9.000	16.786					
		Lower-bound	151.075	9.000	16.786					
	distancex	Sphericity Assumed	176293.143	9	19588.127					
		Greenhouse-Geisser	176293.143	9.000	19588.127					
		Huynh-Feldt	176293.143	9.000	19588.127					
		Lower-bound	176293.143	9.000	19588.127					
	distanceY	Sphericity Assumed	161909.170	9	17989.908					
		Greenhouse-Geisser	161909.170	9.000	17989.908					
		Huynh-Feldt	161909.170	9.000	17989.908					
		Lower-bound	161909.170	9.000	17989.908					

time * condition	swayX	Sphericity Assumed	43.631	2	21.815	6.302	.008	.412	12.604	.839
		Greenhouse-Geisser	43.631	1.951	22.362	6.302	.009	.412	12.296	.832
		Huynh-Feldt	43.631	2.000	21.815	6.302	.008	.412	12.604	.839
		Lower-bound	43.631	1.000	43.631	6.302	.033	.412	6.302	.610
	swayY	Sphericity Assumed	51.115	2	25.558	3.927	.038	.304	7.854	.630
		Greenhouse-Geisser	51.115	1.959	26.096	3.927	.040	.304	7.692	.623
		Huynh-Feldt	51.115	2.000	25.558	3.927	.038	.304	7.854	.630
		Lower-bound	51.115	1.000	51.115	3.927	.079	.304	3.927	.425
	distancex	Sphericity Assumed	53154.026	2	26577.013	3.437	.054	.276	6.874	.569
		Greenhouse-Geisser	53154.026	1.723	30849.705	3.437	.064	.276	5.922	.523
		Huynh-Feldt	53154.026	2.000	26577.013	3.437	.054	.276	6.874	.569
		Lower-bound	53154.026	1.000	53154.026	3.437	.097	.276	3.437	.381
	distanceY	Sphericity Assumed	61240.760	2	30620.380	3.044	.073	.253	6.088	.516
		Greenhouse-Geisser	61240.760	1.991	30751.325	3.044	.073	.253	6.062	.515
		Huynh-Feldt	61240.760	2.000	30620.380	3.044	.073	.253	6.088	.516
		Lower-bound	61240.760	1.000	61240.760	3.044	.115	.253	3.044	.345

Error(time*condition)	swayX	Sphericity Assumed	62.311	18	3.462					
		Greenhouse-Geisser	62.311	17.560	3.548					
		Huynh-Feldt	62.311	18.000	3.462					
		Lower-bound	62.311	9.000	6.923					
	swayY	Sphericity Assumed	117.151	18	6.508					
		Greenhouse-Geisser	117.151	17.629	6.646					
		Huynh-Feldt	117.151	18.000	6.508					
		Lower-bound	117.151	9.000	13.017					
	distancex	Sphericity Assumed	139191.684	18	7732.871					
		Greenhouse-Geisser	139191.684	15.507	8976.058					
		Huynh-Feldt	139191.684	18.000	7732.871					
		Lower-bound	139191.684	9.000	15465.743					
	distanceY	Sphericity Assumed	181057.562	18	10058.753					
		Greenhouse-Geisser	181057.562	17.923	10101.769					
		Huynh-Feldt	181057.562	18.000	10058.753					
		Lower-bound	181057.562	9.000	20117.507					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Source	Measure	time	condition	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
time	swayX	Linear		70.631	1	70.631	13.739	.005	.604	13.739	.908
		Quadratic		3.824	1	3.824	.700	.425	.072	.700	.117
	swayY	Linear		195.534	1	195.534	19.841	.002	.688	19.841	.976
		Quadratic		4.951	1	4.951	.256	.625	.028	.256	.074
	distancex	Linear		47366.673	1	47366.673	4.994	.052	.357	4.994	.514
		Quadratic		14834.592	1	14834.592	3.535	.093	.282	3.535	.390
	distanceY	Linear		64104.042	1	64104.042	6.257	.034	.410	6.257	.607
		Quadratic		25189.416	1	25189.416	2.280	.165	.202	2.280	.272
Error(time)	swayX	Linear		46.270	9	5.141					
		Quadratic		49.186	9	5.465					
	swayY	Linear		88.694	9	9.855					
		Quadratic		174.032	9	19.337					
	distancex	Linear		85370.858	9	9485.651					
		Quadratic		37766.563	9	4196.285					
	distanceY	Linear		92201.701	9	10244.633					
		Quadratic		99421.585	9	11046.843					

condition	swayX		Linear	147.562	1	147.562	13.976	.005	.608	13.976	.913
	swayY		Linear	201.153	1	201.153	11.983	.007	.571	11.983	.868
	distancex		Linear	239956.465	1	239956.465	12.250	.007	.576	12.250	.875
	distanceY		Linear	282806.560	1	282806.560	15.720	.003	.636	15.720	.940
Error(condition)	swayX		Linear	95.023	9	10.558					
	swayY		Linear	151.075	9	16.786					
	distancex		Linear	176293.143	9	19588.127					
	distanceY		Linear	161909.170	9	17989.908					
time * condition	swayX	Linear	Linear	42.728	1	42.728	10.657	.010	.542	10.657	.827
		Quadratic	Linear	.903	1	.903	.310	.591	.033	.310	.079
	swayY	Linear	Linear	45.140	1	45.140	7.020	.026	.438	7.020	.656
		Quadratic	Linear	5.975	1	5.975	.907	.366	.092	.907	.137
	distancex	Linear	Linear	48041.048	1	48041.048	4.642	.060	.340	4.642	.486
		Quadratic	Linear	5112.978	1	5112.978	.999	.344	.100	.999	.146
	distanceY	Linear	Linear	46650.539	1	46650.539	4.756	.057	.346	4.756	.495
		Quadratic	Linear	14590.221	1	14590.221	1.415	.265	.136	1.415	.187
Error(time*condition)	swayX	Linear	Linear	36.085	9	4.009					
		Quadratic	Linear	26.226	9	2.914					
	swayY	Linear	Linear	57.875	9	6.431					
		Quadratic	Linear	59.276	9	6.586					
	distancex	Linear	Linear	93149.490	9	10349.943					
		Quadratic	Linear	46042.194	9	5115.799					
	distanceY	Linear	Linear	88270.508	9	9807.834					
		Quadratic	Linear	92787.054	9	10309.673					

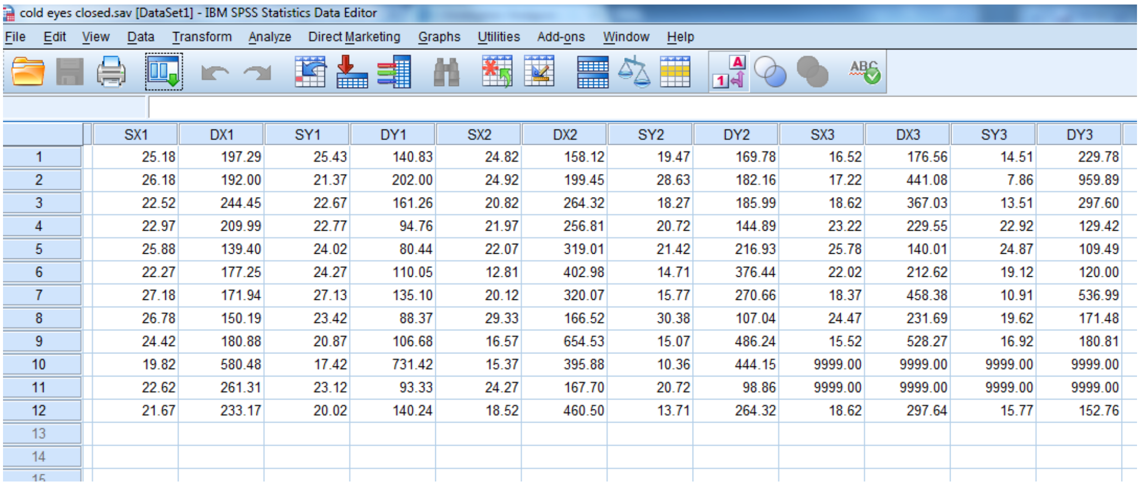
a. Computed using alpha = .05

Tests of Between-Subjects Effects

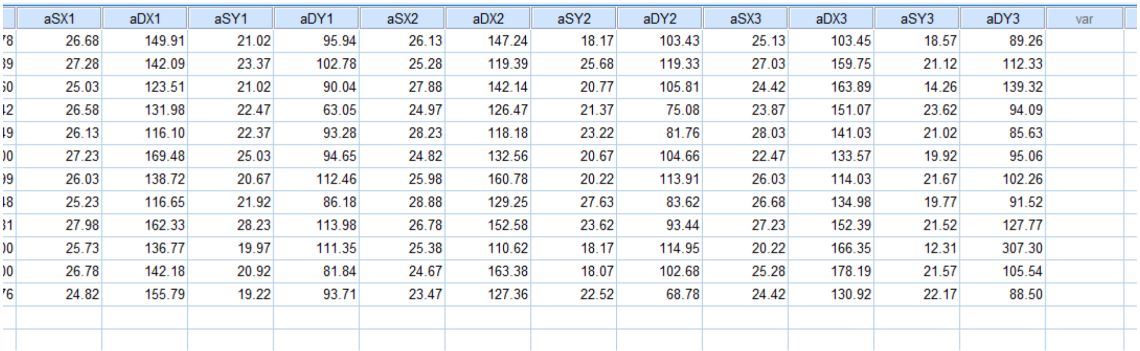
Transformed Variable: Average

Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	swayX	33432.532	1	33432.532	1725.632	.000	.995	1725.632	1.000
	swayY	24262.979	1	24262.979	654.648	.000	.986	654.648	1.000
	distancex	2577843.939	1	2577843.939	126.818	.000	.934	126.818	1.000
	distanceY	1719612.947	1	1719612.947	94.130	.000	.913	94.130	1.000
Error	swayX	174.367	9	19.374					
	swayY	333.564	9	37.063					
	distancex	182943.541	9	20327.060					
	distanceY	164416.622	9	18268.514					

a. Computed using alpha = .05



	SX1	DX1	SY1	DY1	SX2	DX2	SY2	DY2	SX3	DX3	SY3	DY3
1	25.18	197.29	25.43	140.83	24.82	158.12	19.47	169.78	16.52	176.56	14.51	229.78
2	26.18	192.00	21.37	202.00	24.92	199.45	28.63	182.16	17.22	441.08	7.86	959.89
3	22.52	244.45	22.67	161.26	20.82	264.32	18.27	185.99	18.62	367.03	13.51	297.60
4	22.97	209.99	22.77	94.76	21.97	256.81	20.72	144.89	23.22	229.55	22.92	129.42
5	25.88	139.40	24.02	80.44	22.07	319.01	21.42	216.93	25.78	140.01	24.87	109.49
6	22.27	177.25	24.27	110.05	12.81	402.98	14.71	376.44	22.02	212.62	19.12	120.00
7	27.18	171.94	27.13	135.10	20.12	320.07	15.77	270.66	18.37	458.38	10.91	536.99
8	26.78	150.19	23.42	88.37	29.33	166.52	30.38	107.04	24.47	231.69	19.62	171.48
9	24.42	180.88	20.87	106.68	16.57	654.53	15.07	486.24	15.52	528.27	16.92	180.81
10	19.82	580.48	17.42	731.42	15.37	395.88	10.36	444.15	9999.00	9999.00	9999.00	9999.00
11	22.62	261.31	23.12	93.33	24.27	167.70	20.72	98.86	9999.00	9999.00	9999.00	9999.00
12	21.67	233.17	20.02	140.24	18.52	460.50	13.71	264.32	18.62	297.64	15.77	152.76
13												
14												
15												



aSX1	aDX1	aSY1	aDY1	aSX2	aDX2	aSY2	aDY2	aSX3	aDX3	aSY3	aDY3	var
26.68	149.91	21.02	95.94	26.13	147.24	18.17	103.43	25.13	103.45	18.57	89.26	
27.28	142.09	23.37	102.78	25.28	119.39	25.68	119.33	27.03	159.75	21.12	112.33	
25.03	123.51	21.02	90.04	27.88	142.14	20.77	105.81	24.42	163.89	14.26	139.32	
26.58	131.98	22.47	63.05	24.97	126.47	21.37	75.08	23.87	151.07	23.62	94.09	
26.13	116.10	22.37	93.28	28.23	118.18	23.22	81.76	28.03	141.03	21.02	85.63	
27.23	169.48	25.03	94.65	24.82	132.56	20.67	104.66	22.47	133.57	19.92	95.06	
26.03	138.72	20.67	112.46	25.98	160.78	20.22	113.91	26.03	114.03	21.67	102.26	
25.23	116.65	21.92	86.18	28.88	129.25	27.63	83.62	26.68	134.98	19.77	91.52	
27.98	162.33	28.23	113.98	26.78	152.58	23.62	93.44	27.23	152.39	21.52	127.77	
25.73	136.77	19.97	111.35	25.38	110.62	18.17	114.95	20.22	166.35	12.31	307.30	
26.78	142.18	20.92	81.84	24.67	163.38	18.07	102.68	25.28	178.19	21.57	105.54	
24.82	155.79	19.22	93.71	23.47	127.36	22.52	68.78	24.42	130.92	22.17	88.50	

General Linear Model

Within-Subjects Factors

Measure	time	condition	Dependent Variable
swayX	1	1	SX1
		2	aSX1
	2	1	SX2
		2	aSX2
	3	1	SX3
		2	aSX3
swayY	1	1	SY1
		2	aSY1
	2	1	SY2
		2	aSY2
	3	1	SY3
		2	aSY3
distanceX	1	1	DX1
		2	aDX1
	2	1	DX2
		2	aDX2
	3	1	DX3
		2	aDX3
distanceY	1	1	DY1
		2	aDY1
	2	1	DY2
		2	aDY2
	3	1	DY3
		2	aDY3

Mauchly's Test of Sphericity[a]

Within Subjects Effect	Measure	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
time	swayX	.928	.598	2	.741	.933	1.000	.500
	swayY	.805	1.733	2	.420	.837	1.000	.500
	distanceX	.977	.186	2	.911	.978	1.000	.500
	distanceY	.314	9.256	2	.010	.593	.631	.500
condition	swayX	1.000	.000	0	.	1.000	1.000	1.000
	swayY	1.000	.000	0	.	1.000	1.000	1.000
	distanceX	1.000	.000	0	.	1.000	1.000	1.000
	distanceY	1.000	.000	0	.	1.000	1.000	1.000
time * condition	swayX	.635	3.638	2	.162	.732	.839	.500
	swayY	.847	1.331	2	.514	.867	1.000	.500
	distanceX	.946	.441	2	.802	.949	1.000	.500
	distanceY	.346	8.501	2	.014	.604	.647	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: time + condition + time * condition

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Multivariate[a,b]

Within Subjects Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[e]
time	Pillai's Trace	.689	2.101	8.000	32.000	.065	.344	16.805	.742
	Wilks' Lambda	.424	2.011[c]	8.000	30.000	.079	.349	16.090	.712
	Hotelling's Trace	1.095	1.916	8.000	28.000	.097	.354	15.332	.678
	Roy's Largest Root	.734	2.935[d]	4.000	16.000	.054	.423	11.740	.652
condition	Pillai's Trace	.947	26.761[c]	4.000	6.000	.001	.947	107.045	1.000
	Wilks' Lambda	.053	26.761[c]	4.000	6.000	.001	.947	107.045	1.000
	Hotelling's Trace	17.841	26.761[c]	4.000	6.000	.001	.947	107.045	1.000
	Roy's Largest Root	17.841	26.761[c]	4.000	6.000	.001	.947	107.045	1.000
time * condition	Pillai's Trace	.472	1.237	8.000	32.000	.310	.236	9.896	.471
	Wilks' Lambda	.556	1.279[c]	8.000	30.000	.291	.254	10.235	.480
	Hotelling's Trace	.748	1.309	8.000	28.000	.280	.272	10.469	.483
	Roy's Largest Root	.672	2.688[d]	4.000	16.000	.069	.402	10.751	.609

a. Design: Intercept

Within Subjects Design: time + condition + time * condition

b. Tests are based on averaged variables.

c. Exact statistic

d. The statistic is an upper bound on F that yields a lower bound on the significance level.

e. Computed using alpha = .05

Univariate Tests

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
time	swayX	Sphericity Assumed	70.373	2	35.187	6.060	.010	.402	12.121	.824
		Greenhouse-Geisser	70.373	1.866	37.722	6.060	.012	.402	11.306	.802
		Huynh-Feldt	70.373	2.000	35.187	6.060	.010	.402	12.121	.824
		Lower-bound	70.373	1.000	70.373	6.060	.036	.402	6.060	.593
	swayY	Sphericity Assumed	194.436	2	97.218	5.243	.016	.368	10.485	.763
		Greenhouse-Geisser	194.436	1.674	116.155	5.243	.023	.368	8.776	.702
		Huynh-Feldt	194.436	2.000	97.218	5.243	.016	.368	10.485	.763
		Lower-bound	194.436	1.000	194.436	5.243	.048	.368	5.243	.533
	distance X	Sphericity Assumed	49005.988	2	24502.994	4.616	.024	.339	9.231	.705
		Greenhouse-Geisser	49005.988	1.955	25065.698	4.616	.025	.339	9.024	.697
		Huynh-Feldt	49005.988	2.000	24502.994	4.616	.024	.339	9.231	.705
		Lower-bound	49005.988	1.000	49005.988	4.616	.060	.339	4.616	.483
	distance Y	Sphericity Assumed	75833.887	2	37916.943	2.812	.087	.238	5.623	.483
		Greenhouse-Geisser	75833.887	1.187	63912.205	2.812	.119	.238	3.336	.356
		Huynh-Feldt	75833.887	1.263	60061.461	2.812	.116	.238	3.550	.369
		Lower-bound	75833.887	1.000	75833.887	2.812	.128	.238	2.812	.323

Error(time)	swayX	Sphericity Assumed	104.509	18	5.806					
		Greenhouse-Geisser	104.509	16.790	6.224					
		Huynh-Feldt	104.509	18.000	5.806					
		Lower-bound	104.509	9.000	11.612					
	swayY	Sphericity Assumed	333.795	18	18.544					
		Greenhouse-Geisser	333.795	15.065	22.156					
		Huynh-Feldt	333.795	18.000	18.544					
		Lower-bound	333.795	9.000	37.088					
	distanceX	Sphericity Assumed	95555.518	18	5308.640					
		Greenhouse-Geisser	95555.518	17.596	5430.551					
		Huynh-Feldt	95555.518	18.000	5308.640					
		Lower-bound	95555.518	9.000	10617.280					
	distanceY	Sphericity Assumed	242739.862	18	13485.548					
		Greenhouse-Geisser	242739.862	10.679	22731.028					
		Huynh-Feldt	242739.862	11.363	21361.472					
		Lower-bound	242739.862	9.000	26971.096					

condition	swayX	Sphericity Assumed	253.477	1	253.477	34.328	.000	.792	34.328	.999
		Greenhouse-Geisser	253.477	1.000	253.477	34.328	.000	.792	34.328	.999
		Huynh-Feldt	253.477	1.000	253.477	34.328	.000	.792	34.328	.999
		Lower-bound	253.477	1.000	253.477	34.328	.000	.792	34.328	.999
	swayY	Sphericity Assumed	53.594	1	53.594	4.602	.061	.338	4.602	.482
		Greenhouse-Geisser	53.594	1.000	53.594	4.602	.061	.338	4.602	.482
		Huynh-Feldt	53.594	1.000	53.594	4.602	.061	.338	4.602	.482
		Lower-bound	53.594	1.000	53.594	4.602	.061	.338	4.602	.482
	distanceX	Sphericity Assumed	271232.848	1	271232.848	31.109	.000	.776	31.109	.998
		Greenhouse-Geisser	271232.848	1.000	271232.848	31.109	.000	.776	31.109	.998
		Huynh-Feldt	271232.848	1.000	271232.848	31.109	.000	.776	31.109	.998
		Lower-bound	271232.848	1.000	271232.848	31.109	.000	.776	31.109	.998
	distanceY	Sphericity Assumed	219707.454	1	219707.454	17.647	.002	.662	17.647	.961
		Greenhouse-Geisser	219707.454	1.000	219707.454	17.647	.002	.662	17.647	.961
		Huynh-Feldt	219707.454	1.000	219707.454	17.647	.002	.662	17.647	.961
		Lower-bound	219707.454	1.000	219707.454	17.647	.002	.662	17.647	.961

Error(condition)	swayX	Sphericity Assumed	66.456	9	7.384					
		Greenhouse-Geisser	66.456	9.000	7.384					
		Huynh-Feldt	66.456	9.000	7.384					
		Lower-bound	66.456	9.000	7.384					
	swayY	Sphericity Assumed	104.822	9	11.647					
		Greenhouse-Geisser	104.822	9.000	11.647					
		Huynh-Feldt	104.822	9.000	11.647					
		Lower-bound	104.822	9.000	11.647					
	distanceX	Sphericity Assumed	78470.312	9	8718.924					
		Greenhouse-Geisser	78470.312	9.000	8718.924					
		Huynh-Feldt	78470.312	9.000	8718.924					
		Lower-bound	78470.312	9.000	8718.924					
	distanceY	Sphericity Assumed	112050.183	9	12450.020					
		Greenhouse-Geisser	112050.183	9.000	12450.020					
		Huynh-Feldt	112050.183	9.000	12450.020					
		Lower-bound	112050.183	9.000	12450.020					

time * condition	swayX	Sphericity Assumed	40.840	2	20.420	3.634	.047	.288	7.267	.594
		Greenhouse-Geisser	40.840	1.465	27.881	3.634	.066	.288	5.323	.498
		Huynh-Feldt	40.840	1.679	24.331	3.634	.058	.288	6.099	.538
		Lower-bound	40.840	1.000	40.840	3.634	.089	.288	3.634	.399
	swayY	Sphericity Assumed	52.542	2	26.271	2.889	.082	.243	5.778	.494
		Greenhouse-Geisser	52.542	1.734	30.298	2.889	.091	.243	5.010	.454
		Huynh-Feldt	52.542	2.000	26.271	2.889	.082	.243	5.778	.494
		Lower-bound	52.542	1.000	52.542	2.889	.123	.243	2.889	.330
	distanceX	Sphericity Assumed	55341.784	2	27670.892	4.949	.019	.355	9.897	.737
		Greenhouse-Geisser	55341.784	1.898	29154.779	4.949	.021	.355	9.394	.719
		Huynh-Feldt	55341.784	2.000	27670.892	4.949	.019	.355	9.897	.737
		Lower-bound	55341.784	1.000	55341.784	4.949	.053	.355	4.949	.510
	distanceY	Sphericity Assumed	64449.845	2	32224.923	2.205	.139	.197	4.411	.391
		Greenhouse-Geisser	64449.845	1.209	53314.271	2.205	.165	.197	2.666	.293
		Huynh-Feldt	64449.845	1.295	49772.419	2.205	.162	.197	2.856	.304
		Lower-bound	64449.845	1.000	64449.845	2.205	.172	.197	2.205	.265

Error(time*condition)	swayX	Sphericity Assumed	101.155	18	5.620					
		Greenhouse-Geisser	101.155	13.183	7.673					
		Huynh-Feldt	101.155	15.107	6.696					
		Lower-bound	101.155	9.000	11.239					
	swayY	Sphericity Assumed	163.677	18	9.093					
		Greenhouse-Geisser	163.677	15.607	10.487					
		Huynh-Feldt	163.677	18.000	9.093					
		Lower-bound	163.677	9.000	18.186					
	distanceX	Sphericity Assumed	100646.958	18	5591.498					
		Greenhouse-Geisser	100646.958	17.084	5891.349					
		Huynh-Feldt	100646.958	18.000	5591.498					
		Lower-bound	100646.958	9.000	11182.995					
	distanceY	Sphericity Assumed	263003.980	18	14611.332					
		Greenhouse-Geisser	263003.980	10.880	24173.604					
		Huynh-Feldt	263003.980	11.654	22567.668					
		Lower-bound	263003.980	9.000	29222.664					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Source	Measure	time	condition	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
time	swayX	Linear		68.519	1	68.519	16.108	.003	.642	16.108	.945
		Quadratic		1.854	1	1.854	.252	.628	.027	.252	.074
	swayY	Linear		192.009	1	192.009	17.197	.002	.656	17.197	.957
		Quadratic		2.427	1	2.427	.094	.767	.010	.094	.059
	distanceX	Linear		33918.335	1	33918.335	7.509	.023	.455	7.509	.685
		Quadratic		15087.652	1	15087.652	2.473	.150	.216	2.473	.291
	distanceY	Linear		72945.008	1	72945.008	5.126	.050	.363	5.126	.524
		Quadratic		2888.879	1	2888.879	.227	.645	.025	.227	.071
Error(time)	swayX	Linear		38.284	9	4.254					
		Quadratic		66.225	9	7.358					
	swayY	Linear		100.489	9	11.165					
		Quadratic		233.306	9	25.923					
	distanceX	Linear		40654.700	9	4517.189					
		Quadratic		54900.818	9	6100.091					
	distanceY	Linear		128078.178	9	14230.909					
		Quadratic		114661.684	9	12740.187					

condition	swayX		Linear	253.477	1	253.477	34.328	.000	.792	34.328	.999
	swayY		Linear	53.594	1	53.594	4.602	.061	.338	4.602	.482
	distanceX		Linear	271232.848	1	271232.848	31.109	.000	.776	31.109	.998
	distanceY		Linear	219707.454	1	219707.454	17.647	.002	.662	17.647	.961
Error(condition)	swayX		Linear	66.456	9	7.384					
	swayY		Linear	104.822	9	11.647					
	distanceX		Linear	78470.312	9	8718.924					
	distanceY		Linear	112050.183	9	12450.020					
time * condition	swayX	Linear	Linear	34.294	1	34.294	6.223	.034	.409	6.223	.604
		Quadratic	Linear	6.546	1	6.546	1.143	.313	.113	1.143	.160
	swayY	Linear	Linear	49.050	1	49.050	4.741	.057	.345	4.741	.494
		Quadratic	Linear	3.492	1	3.492	.445	.521	.047	.445	.092
	distanceX	Linear	Linear	36466.200	1	36466.200	8.349	.018	.481	8.349	.730
		Quadratic	Linear	18875.585	1	18875.585	2.770	.130	.235	2.770	.319
	distanceY	Linear	Linear	59971.007	1	59971.007	4.167	.072	.316	4.167	.446
		Quadratic	Linear	4478.838	1	4478.838	.302	.596	.032	.302	.078

Error(time*condition)	swayX	Linear	Linear	49.597	9	5.511					
		Quadratic	Linear	51.558	9	5.729					
	swayY	Linear	Linear	93.118	9	10.346					
		Quadratic	Linear	70.560	9	7.840					
	distanceX	Linear	Linear	39308.108	9	4367.568					
		Quadratic	Linear	61338.850	9	6815.428					
	distanceY	Linear	Linear	129531.609	9	14392.401					
		Quadratic	Linear	133472.371	9	14830.263					

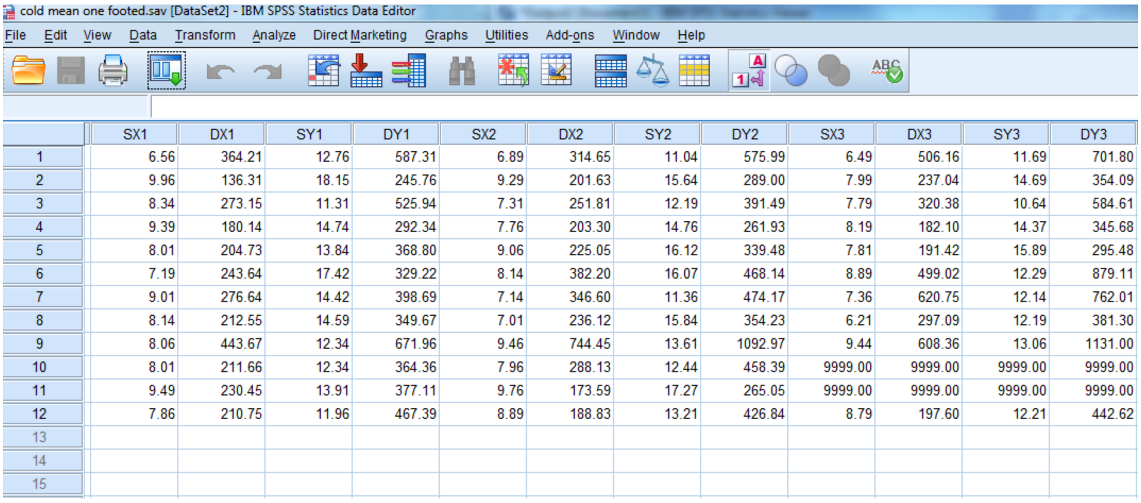
a. Computed using alpha = .05

Tests of Between-Subjects Effects

Transformed Variable: Average

Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	swayX	34465.890	1	34465.890	2258.011	.000	.996	2258.011	1.000
	swayY	25999.975	1	25999.975	1365.084	.000	.993	1365.084	1.000
	distanceX	2533513.746	1	2533513.746	202.382	.000	.957	202.382	1.000
	distanceY	1495938.916	1	1495938.916	80.609	.000	.900	80.609	1.000
Error	swayX	137.374	9	15.264					
	swayY	171.418	9	19.046					
	distanceX	112666.109	9	12518.457					
	distanceY	167020.927	9	18557.881					

a. Computed using alpha = .05



	SX1	DX1	SY1	DY1	SX2	DX2	SY2	DY2	SX3	DX3	SY3	DY3
1	6.56	364.21	12.76	587.31	6.89	314.65	11.04	575.99	6.49	506.16	11.69	701.80
2	9.96	136.31	18.15	245.76	9.29	201.63	15.64	289.00	7.99	237.04	14.69	354.09
3	8.34	273.15	11.31	525.94	7.31	251.81	12.19	391.49	7.79	320.38	10.64	584.61
4	9.39	180.14	14.74	292.34	7.76	203.30	14.76	261.93	8.19	182.10	14.37	345.68
5	8.01	204.73	13.84	368.80	9.06	225.05	16.12	339.48	7.81	191.42	15.89	295.48
6	7.19	243.64	17.42	329.22	8.14	382.20	16.07	468.14	8.89	499.02	12.29	879.11
7	9.01	276.64	14.42	398.69	7.14	346.60	11.36	474.17	7.36	620.75	12.14	762.01
8	8.14	212.55	14.59	349.67	7.01	236.12	15.84	354.23	6.21	297.09	12.19	381.30
9	8.06	443.67	12.34	671.96	9.46	744.45	13.61	1092.97	9.44	608.36	13.06	1131.00
10	8.01	211.66	12.34	364.36	7.96	288.13	12.44	458.39	9999.00	9999.00	9999.00	9999.00
11	9.49	230.45	13.91	377.11	9.76	173.59	17.27	265.05	9999.00	9999.00	9999.00	9999.00
12	7.86	210.75	11.96	467.39	8.89	188.83	13.21	426.84	8.79	197.60	12.21	442.62
13												
14												
15												

aSX1	aDX1	aSY1	aDY1	aSX2	aDX2	aSY2	aDY2	aSX3	aDX3	aSY3	aDY3	filter_$
6.59	337.11	10.39	591.77	6.01	278.69	11.21	443.69	6.39	357.50	11.56	513.42	.
6.61	182.27	14.79	331.59	7.84	161.85	14.59	244.73	7.21	152.55	13.19	239.68	.
7.69	189.24	12.49	332.56	7.81	174.09	12.71	294.64	7.06	167.52	13.09	256.94	.
9.14	123.15	15.72	174.70	9.06	111.59	17.40	183.85	10.41	108.56	18.90	163.46	.
8.81	185.55	14.64	312.10	8.21	150.03	14.37	284.38	8.89	120.53	15.07	232.20	.
8.81	137.31	13.94	294.90	6.81	159.59	14.17	275.07	7.69	154.38	15.12	273.01	.
7.04	248.54	13.76	308.94	7.79	201.70	14.92	297.36	7.59	272.87	12.96	397.58	.
7.64	209.21	12.66	342.60	8.16	231.92	11.89	395.87	7.94	179.50	11.69	314.23	.
6.99	422.13	11.19	807.14	7.84	362.17	10.11	722.38	7.89	311.10	11.04	605.75	.
5.76	311.41	12.11	422.70	6.39	254.62	11.39	381.59	6.24	340.85	10.69	517.88	.
7.91	194.75	12.41	307.31	7.56	243.33	12.51	355.10	7.91	245.57	13.91	391.15	.
7.39	333.53	11.16	625.89	6.79	301.96	9.81	577.01	7.06	238.38	11.99	434.13	.

General Linear Model

Within-Subjects Factors

Measure	condition	time	Dependent Variable
swayx	1	1	SX1
		2	SX2
		3	SX3
	2	1	aSX1
		2	aSX2
		3	aSX3
swayy	1	1	SY1
		2	SY2
		3	SY3
	2	1	aSY1
		2	aSY2
		3	aSY3
distx	1	1	DX1
		2	DX2
		3	DX3
	2	1	aDX1
		2	aDX2
		3	aDX3
disty	1	1	DY1
		2	DY2
		3	DY3
	2	1	aDY1
		2	aDY2
		3	aDY3

Mauchly's Test of Sphericity[a]

Within Subjects Effect	Measure	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	swayx	1.000	.000	0	.	1.000	1.000	1.000
	swayy	1.000	.000	0	.	1.000	1.000	1.000
	distx	1.000	.000	0	.	1.000	1.000	1.000
	disty	1.000	.000	0	.	1.000	1.000	1.000
time	swayx	.994	.052	2	.975	.994	1.000	.500
	swayy	.440	6.568	2	.037	.641	.701	.500
	distx	.784	1.942	2	.379	.823	.983	.500
	disty	.714	2.692	2	.260	.778	.910	.500
condition * time	swayx	.477	5.914	2	.052	.657	.724	.500
	swayy	.961	.320	2	.852	.962	1.000	.500
	distx	.903	.814	2	.666	.912	1.000	.500
	disty	.561	4.618	2	.099	.695	.782	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: condition + time + condition * time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Univariate Tests

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	swayx	Sphericity Assumed	2.119	1	2.119	1.505	.251	.143	1.505	.196
		Greenhouse-Geisser	2.119	1.000	2.119	1.505	.251	.143	1.505	.196
		Huynh-Feldt	2.119	1.000	2.119	1.505	.251	.143	1.505	.196
		Lower-bound	2.119	1.000	2.119	1.505	.251	.143	1.505	.196
	swayy	Sphericity Assumed	3.281	1	3.281	.762	.406	.078	.762	.123
		Greenhouse-Geisser	3.281	1.000	3.281	.762	.406	.078	.762	.123
		Huynh-Feldt	3.281	1.000	3.281	.762	.406	.078	.762	.123
		Lower-bound	3.281	1.000	3.281	.762	.406	.078	.762	.123
	distx	Sphericity Assumed	124746.552	1	124746.552	8.562	.017	.488	8.562	.741
		Greenhouse-Geisser	124746.552	1.000	124746.552	8.562	.017	.488	8.562	.741
		Huynh-Feldt	124746.552	1.000	124746.552	8.562	.017	.488	8.562	.741
		Lower-bound	124746.552	1.000	124746.552	8.562	.017	.488	8.562	.741
	disty	Sphericity Assumed	206209.334	1	206209.334	9.389	.013	.511	9.389	.778
		Greenhouse-Geisser	206209.334	1.000	206209.334	9.389	.013	.511	9.389	.778
		Huynh-Feldt	206209.334	1.000	206209.334	9.389	.013	.511	9.389	.778
		Lower-bound	206209.334	1.000	206209.334	9.389	.013	.511	9.389	.778

Error(condition)	swayx	Sphericity Assumed	12.671	9	1.408					
		Greenhouse-Geisser	12.671	9.000	1.408					
		Huynh-Feldt	12.671	9.000	1.408					
		Lower-bound	12.671	9.000	1.408					
	swayy	Sphericity Assumed	38.768	9	4.308					
		Greenhouse-Geisser	38.768	9.000	4.308					
		Huynh-Feldt	38.768	9.000	4.308					
		Lower-bound	38.768	9.000	4.308					
	distx	Sphericity Assumed	131131.026	9	14570.114					
		Greenhouse-Geisser	131131.026	9.000	14570.114					
		Huynh-Feldt	131131.026	9.000	14570.114					
		Lower-bound	131131.026	9.000	14570.114					
	disty	Sphericity Assumed	197664.904	9	21962.767					
		Greenhouse-Geisser	197664.904	9.000	21962.767					
		Huynh-Feldt	197664.904	9.000	21962.767					
		Lower-bound	197664.904	9.000	21962.767					

time	swayx	Sphericity Assumed	.141	2	.071	.215	.809	.023	.430	.079
		Greenhouse-Geisser	.141	1.987	.071	.215	.807	.023	.427	.078
		Huynh-Feldt	.141	2.000	.071	.215	.809	.023	.430	.079
		Lower-bound	.141	1.000	.141	.215	.654	.023	.215	.070
	swayy	Sphericity Assumed	2.115	2	1.057	.939	.409	.094	1.878	.187
		Greenhouse-Geisser	2.115	1.282	1.650	.939	.377	.094	1.204	.154
		Huynh-Feldt	2.115	1.402	1.508	.939	.384	.094	1.317	.160
		Lower-bound	2.115	1.000	2.115	.939	.358	.094	.939	.140
	distx	Sphericity Assumed	16633.007	2	8316.503	1.718	.208	.160	3.435	.313
		Greenhouse-Geisser	16633.007	1.645	10109.204	1.718	.214	.160	2.826	.280
		Huynh-Feldt	16633.007	1.965	8463.810	1.718	.208	.160	3.376	.310
		Lower-bound	16633.007	1.000	16633.007	1.718	.222	.160	1.718	.217
	disty	Sphericity Assumed	28971.799	2	14485.900	1.455	.260	.139	2.910	.270
		Greenhouse-Geisser	28971.799	1.555	18625.600	1.455	.262	.139	2.263	.236
		Huynh-Feldt	28971.799	1.821	15911.752	1.455	.261	.139	2.649	.257
		Lower-bound	28971.799	1.000	28971.799	1.455	.259	.139	1.455	.191

Error(time)	swayx	Sphericity Assumed	5.911	18	.328					
		Greenhouse-Geisser	5.911	17.885	.330					
		Huynh-Feldt	5.911	18.000	.328					
		Lower-bound	5.911	9.000	.657					
	swayy	Sphericity Assumed	20.266	18	1.126					
		Greenhouse-Geisser	20.266	11.538	1.756					
		Huynh-Feldt	20.266	12.618	1.606					
		Lower-bound	20.266	9.000	2.252					
	distx	Sphericity Assumed	87151.666	18	4841.759					
		Greenhouse-Geisser	87151.666	14.808	5885.446					
		Huynh-Feldt	87151.666	17.687	4927.519					
		Lower-bound	87151.666	9.000	9683.518					
	disty	Sphericity Assumed	179228.033	18	9957.113					
		Greenhouse-Geisser	179228.033	13.999	12802.601					
		Huynh-Feldt	179228.033	16.387	10937.195					
		Lower-bound	179228.033	9.000	19914.226					

condition * time	swayx	Sphericity Assumed	.681	2	.341	.539	.592	.057	1.078	.125
		Greenhouse-Geisser	.681	1.314	.519	.539	.524	.057	.708	.109
		Huynh-Feldt	.681	1.449	.470	.539	.540	.057	.781	.113
		Lower-bound	.681	1.000	.681	.539	.481	.057	.539	.101
	swayy	Sphericity Assumed	7.773	2	3.887	2.905	.081	.244	5.811	.496
		Greenhouse-Geisser	7.773	1.924	4.039	2.905	.083	.244	5.591	.485
		Huynh-Feldt	7.773	2.000	3.887	2.905	.081	.244	5.811	.496
		Lower-bound	7.773	1.000	7.773	2.905	.122	.244	2.905	.332
	distx	Sphericity Assumed	50539.533	2	25269.767	10.401	.001	.536	20.802	.970
		Greenhouse-Geisser	50539.533	1.824	27714.576	10.401	.001	.536	18.967	.959
		Huynh-Feldt	50539.533	2.000	25269.767	10.401	.001	.536	20.802	.970
		Lower-bound	50539.533	1.000	50539.533	10.401	.010	.536	10.401	.818
	disty	Sphericity Assumed	139540.446	2	69770.223	9.316	.002	.509	18.633	.953
		Greenhouse-Geisser	139540.446	1.390	100368.865	9.316	.006	.509	12.952	.875
		Huynh-Feldt	139540.446	1.564	89211.582	9.316	.004	.509	14.572	.904
		Lower-bound	139540.446	1.000	139540.446	9.316	.014	.509	9.316	.775

Error(condition*time)	swayx	Sphericity Assumed	11.374	18	.632					
		Greenhouse-Geisser	11.374	11.822	.962					
		Huynh-Feldt	11.374	13.039	.872					
		Lower-bound	11.374	9.000	1.264					
	swayy	Sphericity Assumed	24.080	18	1.338					
		Greenhouse-Geisser	24.080	17.320	1.390					
		Huynh-Feldt	24.080	18.000	1.338					
		Lower-bound	24.080	9.000	2.676					
	distx	Sphericity Assumed	43732.005	18	2429.556					
		Greenhouse-Geisser	43732.005	16.412	2664.612					
		Huynh-Feldt	43732.005	18.000	2429.556					
		Lower-bound	43732.005	9.000	4859.112					
	disty	Sphericity Assumed	134801.458	18	7488.970					
		Greenhouse-Geisser	134801.458	12.512	10773.355					
		Huynh-Feldt	134801.458	14.077	9575.759					
		Lower-bound	134801.458	9.000	14977.940					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Source	Measure	condition	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	swayx	Linear		2.119	1	2.119	1.505	.251	.143	1.505	.196
	swayy	Linear		3.281	1	3.281	.762	.406	.078	.762	.123
	distx	Linear		124746.552	1	124746.552	8.562	.017	.488	8.562	.741
	disty	Linear		206209.334	1	206209.334	9.389	.013	.511	9.389	.778
Error(condition)	swayx	Linear		12.671	9	1.408					
	swayy	Linear		38.768	9	4.308					
	distx	Linear		131131.026	9	14570.114					
	disty	Linear		197664.904	9	21962.767					
time	swayx		Linear	.116	1	.116	.330	.580	.035	.330	.081
			Quadratic	.026	1	.026	.083	.779	.009	.083	.058
	swayy		Linear	1.815	1	1.815	.927	.361	.093	.927	.139
			Quadratic	.300	1	.300	1.018	.339	.102	1.018	.148
	distx		Linear	16362.632	1	16362.632	2.938	.121	.246	2.938	.335
			Quadratic	270.375	1	270.375	.066	.803	.007	.066	.056
	disty		Linear	22505.773	1	22505.773	1.519	.249	.144	1.519	.197
			Quadratic	6466.026	1	6466.026	1.269	.289	.124	1.269	.172

Error(time)	swayx		Linear	3.156	9	.351					
			Quadratic	2.755	9	.306					
	swayy		Linear	17.614	9	1.957					
			Quadratic	2.652	9	.295					
	distx		Linear	50123.407	9	5569.267					
			Quadratic	37028.259	9	4114.251					
	disty		Linear	133353.795	9	14817.088					
			Quadratic	45874.238	9	5097.138					
condition * time	swayx	Linear	Linear	.625	1	.625	.752	.408	.077	.752	.122
			Quadratic	.056	1	.056	.130	.727	.014	.130	.062
	swayy	Linear	Linear	6.577	1	6.577	5.352	.046	.373	5.352	.542
			Quadratic	1.196	1	1.196	.827	.387	.084	.827	.129
	distx	Linear	Linear	50358.538	1	50358.538	19.513	.002	.684	19.513	.974
			Quadratic	180.995	1	180.995	.079	.784	.009	.079	.057
	disty	Linear	Linear	136001.661	1	136001.661	11.505	.008	.561	11.505	.854
			Quadratic	3538.785	1	3538.785	1.121	.317	.111	1.121	.158
Error(condition*time)	swayx	Linear	Linear	7.478	9	.831					
			Quadratic	3.896	9	.433					
	swayy	Linear	Linear	11.061	9	1.229					
			Quadratic	13.019	9	1.447					
	distx	Linear	Linear	23227.326	9	2580.814					
			Quadratic	20504.679	9	2278.298					
	disty	Linear	Linear	106388.031	9	11820.892					
			Quadratic	28413.427	9	3157.047					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Transformed Variable: Average

Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	swayx	3735.521	1	3735.521	1405.431	.000	.994	1405.431	1.000
	swayy	10851.729	1	10851.729	647.730	.000	.986	647.730	1.000
	distx	4194824.989	1	4194824.989	69.368	.000	.885	69.368	1.000
	disty	11319104.540	1	11319104.540	62.638	.000	.874	62.638	1.000
Error	swayx	23.921	9	2.658					
	swayy	150.781	9	16.753					
	distx	544252.231	9	60472.470					
	disty	1626364.674	9	180707.186					

a. Computed using alpha = .05

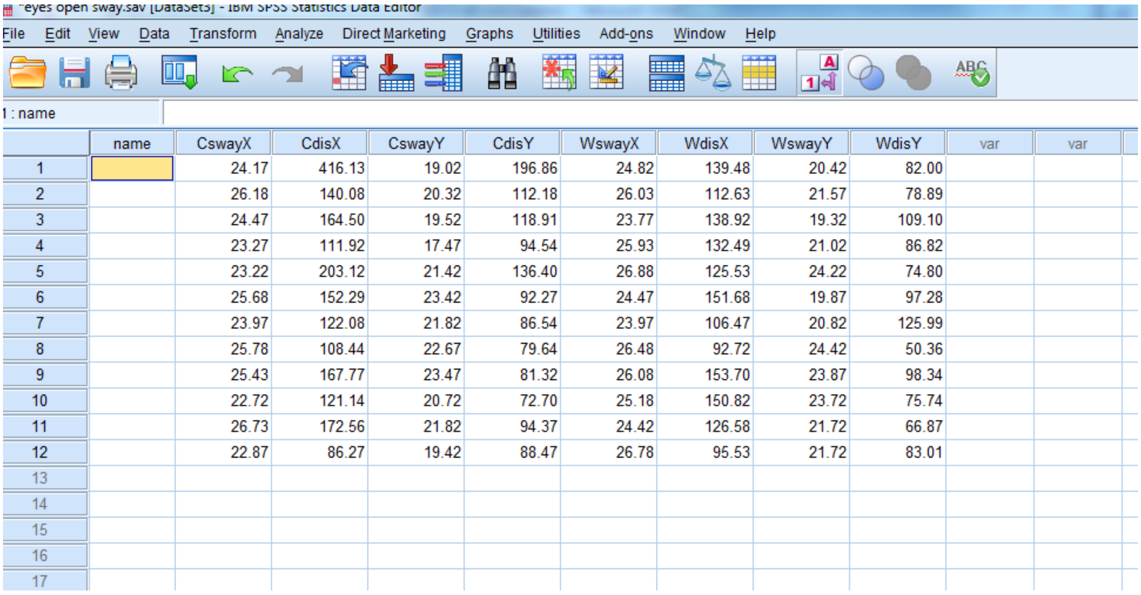
Descriptives

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
SX1	12	6.56	9.96	8.3329	.97918
DX1	12	136.31	443.67	248.9879	83.38068
SY1	12	11.31	18.15	13.9796	2.09882
DY1	12	245.76	671.96	414.8771	125.22276
SX2	12	6.89	9.76	8.2204	1.03262
DX2	12	173.59	744.45	296.3621	155.51918
SY2	12	11.04	17.27	14.1271	2.09262
DY2	12	261.93	1092.97	449.8054	223.83313
SX3	10	6.21	9.44	7.8925	1.02028
DX3	10	182.10	620.75	365.9895	175.46506
SY3	10	10.64	15.89	12.9140	1.59413
DY3	10	295.48	1131.00	587.7660	276.02322
aSX1	12	5.76	9.14	7.5288	1.02104
aDX1	12	123.15	422.13	239.5133	91.74408
aSY1	12	10.39	15.72	12.9367	1.64364
aDY1	12	174.70	807.14	404.3475	179.08586
aSX2	12	6.01	9.06	7.5204	.86468
aDX2	12	111.59	362.17	219.2925	72.84877
aSY2	12	9.81	17.40	12.9204	2.22686
aDY2	12	183.85	722.38	371.3038	151.08760
aSX3	12	6.24	10.41	7.6871	1.12120
aDX3	12	108.56	357.50	220.7746	85.89160
aSY3	12	10.69	18.90	13.2638	2.28788
aDY3	12	163.46	605.75	361.6158	136.98833
Valid N (listwise)	10				

Appendix 8

POSTURAL SWAY ANALYSIS STUDY 3



	name	CswayX	CdisX	CswayY	CdisY	WswayX	WdisX	WswayY	WdisY	var	var
1		24.17	416.13	19.02	196.86	24.82	139.48	20.42	82.00		
2		26.18	140.08	20.32	112.18	26.03	112.63	21.57	78.89		
3		24.47	164.50	19.52	118.91	23.77	138.92	19.32	109.10		
4		23.27	111.92	17.47	94.54	25.93	132.49	21.02	86.82		
5		23.22	203.12	21.42	136.40	26.88	125.53	24.22	74.80		
6		25.68	152.29	23.42	92.27	24.47	151.68	19.87	97.28		
7		23.97	122.08	21.82	86.54	23.97	106.47	20.82	125.99		
8		25.78	108.44	22.67	79.64	26.48	92.72	24.42	50.36		
9		25.43	167.77	23.47	81.32	26.08	153.70	23.87	98.34		
10		22.72	121.14	20.72	72.70	25.18	150.82	23.72	75.74		
11		26.73	172.56	21.82	94.37	24.42	126.58	21.72	66.87		
12		22.87	86.27	19.42	88.47	26.78	95.53	21.72	83.01		
13											
14											
15											
16											
17											

General Linear Model

Within-Subjects Factors

Measure	condition	Dependent Variable
swayx	1	CswayX
	2	WswayX
swayy	1	CswayY
	2	WswayY
distx	1	CdisX
	2	WdisX
disty	1	CdisY
	2	WdisY

Mauchly's Test of Sphericity[a]

Within Subjects Effect	Measure	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	swayx	1.000	.000	0	.	1.000	1.000	1.000
	swayy	1.000	.000	0	.	1.000	1.000	1.000
	distx	1.000	.000	0	.	1.000	1.000	1.000
	disty	1.000	.000	0	.	1.000	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: condition

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Univariate Tests

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	swayx	Sphericity Assumed	4.429	1	4.429	2.355	.153	.176	2.355	.289
		Greenhouse-Geisser	4.429	1.000	4.429	2.355	.153	.176	2.355	.289
		Huynh-Feldt	4.429	1.000	4.429	2.355	.153	.176	2.355	.289
		Lower-bound	4.429	1.000	4.429	2.355	.153	.176	2.355	.289
	swayy	Sphericity Assumed	5.618	1	5.618	2.809	.122	.203	2.809	.334
		Greenhouse-Geisser	5.618	1.000	5.618	2.809	.122	.203	2.809	.334
		Huynh-Feldt	5.618	1.000	5.618	2.809	.122	.203	2.809	.334
		Lower-bound	5.618	1.000	5.618	2.809	.122	.203	2.809	.334
	distx	Sphericity Assumed	8057.393	1	8057.393	2.461	.145	.183	2.461	.299
		Greenhouse-Geisser	8057.393	1.000	8057.393	2.461	.145	.183	2.461	.299
		Huynh-Feldt	8057.393	1.000	8057.393	2.461	.145	.183	2.461	.299
		Lower-bound	8057.393	1.000	8057.393	2.461	.145	.183	2.461	.299
	disty	Sphericity Assumed	2109.581	1	2109.581	2.643	.132	.194	2.643	.318
		Greenhouse-Geisser	2109.581	1.000	2109.581	2.643	.132	.194	2.643	.318
		Huynh-Feldt	2109.581	1.000	2109.581	2.643	.132	.194	2.643	.318
		Lower-bound	2109.581	1.000	2109.581	2.643	.132	.194	2.643	.318

Error(condition)	swayx	Sphericity Assumed	20.688	11	1.881					
		Greenhouse-Geisser	20.688	11.000	1.881					
		Huynh-Feldt	20.688	11.000	1.881					
		Lower-bound	20.688	11.000	1.881					
	swayy	Sphericity Assumed	22.002	11	2.000					
		Greenhouse-Geisser	22.002	11.000	2.000					
		Huynh-Feldt	22.002	11.000	2.000					
		Lower-bound	22.002	11.000	2.000					
	distx	Sphericity Assumed	36019.298	11	3274.482					
		Greenhouse-Geisser	36019.298	11.000	3274.482					
		Huynh-Feldt	36019.298	11.000	3274.482					
		Lower-bound	36019.298	11.000	3274.482					
	disty	Sphericity Assumed	8778.338	11	798.031					
		Greenhouse-Geisser	8778.338	11.000	798.031					
		Huynh-Feldt	8778.338	11.000	798.031					
		Lower-bound	8778.338	11.000	798.031					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Source	Measure	condition	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	swayx	Linear	4.429	1	4.429	2.355	.153	.176	2.355	.289
	swayy	Linear	5.618	1	5.618	2.809	.122	.203	2.809	.334
	distx	Linear	8057.393	1	8057.393	2.461	.145	.183	2.461	.299
	disty	Linear	2109.581	1	2109.581	2.643	.132	.194	2.643	.318
Error(condition)	swayx	Linear	20.688	11	1.881					
	swayy	Linear	22.002	11	2.000					
	distx	Linear	36019.298	11	3274.482					
	disty	Linear	8778.338	11	798.031					

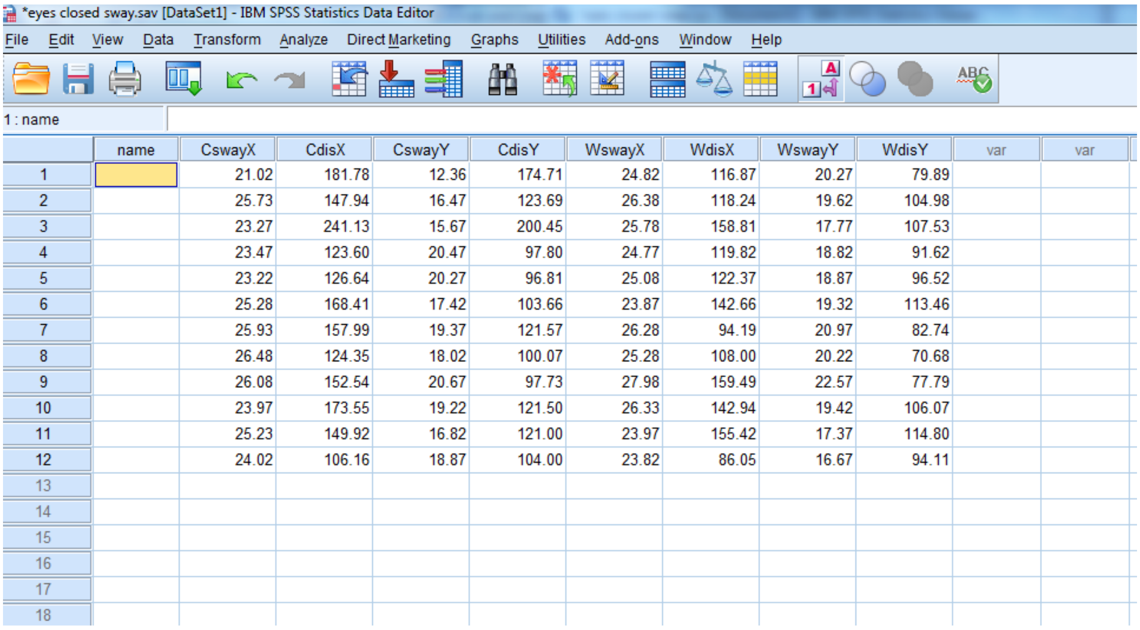
a. Computed using alpha = .05

Tests of Between-Subjects Effects

Transformed Variable: Average

Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	swayx	14964.985	1	14964.985	12212.664	.000	.999	12212.664	1.000
	swayy	11000.193	1	11000.193	2422.169	.000	.995	2422.169	1.000
	distx	508327.850	1	508327.850	111.110	.000	.910	111.110	1.000
	disty	217243.247	1	217243.247	281.532	.000	.962	281.532	1.000
Error	swayx	13.479	11	1.225					
	swayy	49.956	11	4.541					
	distx	50325.020	11	4575.002					
	disty	8488.105	11	771.646					

a. Computed using alpha = .05



	name	CswayX	CdisX	CswayY	CdisY	WswayX	WdisX	WswayY	WdisY	var	var
1		21.02	181.78	12.36	174.71	24.82	116.87	20.27	79.89		
2		25.73	147.94	16.47	123.69	26.38	118.24	19.62	104.98		
3		23.27	241.13	15.67	200.45	25.78	158.81	17.77	107.53		
4		23.47	123.60	20.47	97.80	24.77	119.82	18.82	91.62		
5		23.22	126.64	20.27	96.81	25.08	122.37	18.87	96.52		
6		25.28	168.41	17.42	103.66	23.87	142.66	19.32	113.46		
7		25.93	157.99	19.37	121.57	26.28	94.19	20.97	82.74		
8		26.48	124.35	18.02	100.07	25.28	108.00	20.22	70.68		
9		26.08	152.54	20.67	97.73	27.98	159.49	22.57	77.79		
10		23.97	173.55	19.22	121.50	26.33	142.94	19.42	106.07		
11		25.23	149.92	16.82	121.00	23.97	155.42	17.37	114.80		
12		24.02	106.16	18.87	104.00	23.82	86.05	16.67	94.11		
13											
14											
15											
16											
17											
18											

General Linear Model

Within-Subjects Factors

Measure	condition	Dependent Variable
swayx	1	CswayX
	2	WswayX
swayy	1	CswayY
	2	WswayY
distx	1	CdisX
	2	WdisX
disty	1	CdisY
	2	WdisY

Mauchly's Test of Sphericity[a]

Within Subjects Effect	Measure	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	swayx	1.000	.000	0	.	1.000	1.000	1.000
	swayy	1.000	.000	0	.	1.000	1.000	1.000
	distx	1.000	.000	0	.	1.000	1.000	1.000
	disty	1.000	.000	0	.	1.000	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: condition

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Univariate Tests

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	swayx	Sphericity Assumed	4.735	1	4.735	3.351	.094	.233	3.351	.387
		Greenhouse-Geisser	4.735	1.000	4.735	3.351	.094	.233	3.351	.387
		Huynh-Feldt	4.735	1.000	4.735	3.351	.094	.233	3.351	.387
		Lower-bound	4.735	1.000	4.735	3.351	.094	.233	3.351	.387
	swayy	Sphericity Assumed	11.025	1	11.025	3.055	.108	.217	3.055	.358
		Greenhouse-Geisser	11.025	1.000	11.025	3.055	.108	.217	3.055	.358
		Huynh-Feldt	11.025	1.000	11.025	3.055	.108	.217	3.055	.358
		Lower-bound	11.025	1.000	11.025	3.055	.108	.217	3.055	.358
	distx	Sphericity Assumed	4514.457	1	4514.457	10.683	.007	.493	10.683	.845
		Greenhouse-Geisser	4514.457	1.000	4514.457	10.683	.007	.493	10.683	.845
		Huynh-Feldt	4514.457	1.000	4514.457	10.683	.007	.493	10.683	.845
		Lower-bound	4514.457	1.000	4514.457	10.683	.007	.493	10.683	.845
	disty	Sphericity Assumed	4342.064	1	4342.064	7.600	.019	.409	7.600	.709
		Greenhouse-Geisser	4342.064	1.000	4342.064	7.600	.019	.409	7.600	.709
		Huynh-Feldt	4342.064	1.000	4342.064	7.600	.019	.409	7.600	.709
		Lower-bound	4342.064	1.000	4342.064	7.600	.019	.409	7.600	.709

Error(condition)	swayx	Sphericity Assumed	15.546	11	1.413					
		Greenhouse-Geisser	15.546	11.000	1.413					
		Huynh-Feldt	15.546	11.000	1.413					
		Lower-bound	15.546	11.000	1.413					
	swayy	Sphericity Assumed	39.690	11	3.608					
		Greenhouse-Geisser	39.690	11.000	3.608					
		Huynh-Feldt	39.690	11.000	3.608					
		Lower-bound	39.690	11.000	3.608					
	distx	Sphericity Assumed	4648.312	11	422.574					
		Greenhouse-Geisser	4648.312	11.000	422.574					
		Huynh-Feldt	4648.312	11.000	422.574					
		Lower-bound	4648.312	11.000	422.574					
	disty	Sphericity Assumed	6284.710	11	571.337					
		Greenhouse-Geisser	6284.710	11.000	571.337					
		Huynh-Feldt	6284.710	11.000	571.337					
		Lower-bound	6284.710	11.000	571.337					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Source	Measure	condition	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	swayx	Linear	4.735	1	4.735	3.351	.094	.233	3.351	.387
	swayy	Linear	11.025	1	11.025	3.055	.108	.217	3.055	.358
	distx	Linear	4514.457	1	4514.457	10.683	.007	.493	10.683	.845
	disty	Linear	4342.064	1	4342.064	7.600	.019	.409	7.600	.709
Error(condition)	swayx	Linear	15.546	11	1.413					
	swayy	Linear	39.690	11	3.608					
	distx	Linear	4648.312	11	422.574					
	disty	Linear	6284.710	11	571.337					

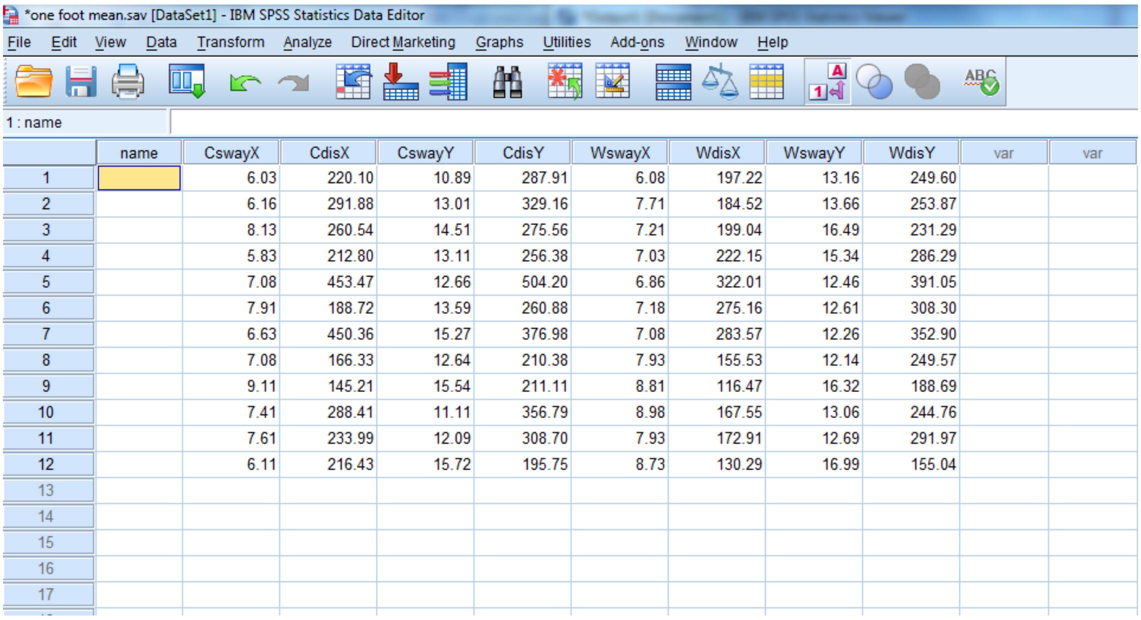
a. Computed using alpha = .05

Tests of Between-Subjects Effects

Transformed Variable: Average

Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	swayx	14902.561	1	14902.561	5588.343	.000	.998	5588.343	1.000
	swayy	8343.917	1	8343.917	1732.998	.000	.994	1732.998	1.000
	distx	475686.892	1	475686.892	327.961	.000	.968	327.961	1.000
	disty	282348.929	1	282348.929	388.474	.000	.972	388.474	1.000
Error	swayx	29.334	11	2.667					
	swayy	52.962	11	4.815					
	distx	15954.825	11	1450.439					
	disty	7994.969	11	726.815					

a. Computed using alpha = .05



	name	CswayX	CdisX	CswayY	CdisY	WswayX	WdisX	WswayY	WdisY	var	var
1		6.03	220.10	10.89	287.91	6.08	197.22	13.16	249.60		
2		6.16	291.88	13.01	329.16	7.71	184.52	13.66	253.87		
3		8.13	260.54	14.51	275.56	7.21	199.04	16.49	231.29		
4		5.83	212.80	13.11	256.38	7.03	222.15	15.34	286.29		
5		7.08	453.47	12.66	504.20	6.86	322.01	12.46	391.05		
6		7.91	188.72	13.59	260.88	7.18	275.16	12.61	308.30		
7		6.63	450.36	15.27	376.98	7.08	283.57	12.26	352.90		
8		7.08	166.33	12.64	210.38	7.93	155.53	12.14	249.57		
9		9.11	145.21	15.54	211.11	8.81	116.47	16.32	188.69		
10		7.41	288.41	11.11	356.79	8.98	167.55	13.06	244.76		
11		7.61	233.99	12.09	308.70	7.93	172.91	12.69	291.97		
12		6.11	216.43	15.72	195.75	8.73	130.29	16.99	155.04		
13											
14											
15											
16											
17											

General Linear Model

Within-Subjects Factors

Measure	condition	Dependent Variable
swayx	1	CswayX
	2	WswayX
swayy	1	CswayY
	2	WswayY
distx	1	CdisX
	2	WdisX
disty	1	CdisY
	2	WdisY

Mauchly's Test of Sphericity[a]

Within Subjects Effect	Measure	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	swayx	1.000	.000	0	.	1.000	1.000	1.000
	swayy	1.000	.000	0	.	1.000	1.000	1.000
	distx	1.000	.000	0	.	1.000	1.000	1.000
	disty	1.000	.000	0	.	1.000	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: condition

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Univariate Tests

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	swayx	Sphericity Assumed	1.737	1	1.737	3.100	.106	.220	3.100	.363
		Greenhouse-Geisser	1.737	1.000	1.737	3.100	.106	.220	3.100	.363
		Huynh-Feldt	1.737	1.000	1.737	3.100	.106	.220	3.100	.363
		Lower-bound	1.737	1.000	1.737	3.100	.106	.220	3.100	.363
	swayy	Sphericity Assumed	2.075	1	2.075	1.691	.220	.133	1.691	.221
		Greenhouse-Geisser	2.075	1.000	2.075	1.691	.220	.133	1.691	.221
		Huynh-Feldt	2.075	1.000	2.075	1.691	.220	.133	1.691	.221
		Lower-bound	2.075	1.000	2.075	1.691	.220	.133	1.691	.221
	distx	Sphericity Assumed	20523.176	1	20523.176	8.338	.015	.431	8.338	.748
		Greenhouse-Geisser	20523.176	1.000	20523.176	8.338	.015	.431	8.338	.748
		Huynh-Feldt	20523.176	1.000	20523.176	8.338	.015	.431	8.338	.748
		Lower-bound	20523.176	1.000	20523.176	8.338	.015	.431	8.338	.748
	disty	Sphericity Assumed	5720.196	1	5720.196	4.098	.068	.271	4.098	.455
		Greenhouse-Geisser	5720.196	1.000	5720.196	4.098	.068	.271	4.098	.455
		Huynh-Feldt	5720.196	1.000	5720.196	4.098	.068	.271	4.098	.455
		Lower-bound	5720.196	1.000	5720.196	4.098	.068	.271	4.098	.455

Error(condition)	swayx	Sphericity Assumed	6.163	11	.560					
		Greenhouse-Geisser	6.163	11.000	.560					
		Huynh-Feldt	6.163	11.000	.560					
		Lower-bound	6.163	11.000	.560					
	swayy	Sphericity Assumed	13.495	11	1.227					
		Greenhouse-Geisser	13.495	11.000	1.227					
		Huynh-Feldt	13.495	11.000	1.227					
		Lower-bound	13.495	11.000	1.227					
	distx	Sphericity Assumed	27073.932	11	2461.267					
		Greenhouse-Geisser	27073.932	11.000	2461.267					
		Huynh-Feldt	27073.932	11.000	2461.267					
		Lower-bound	27073.932	11.000	2461.267					
	disty	Sphericity Assumed	15356.028	11	1396.003					
		Greenhouse-Geisser	15356.028	11.000	1396.003					
		Huynh-Feldt	15356.028	11.000	1396.003					
		Lower-bound	15356.028	11.000	1396.003					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Source	Measure	condition	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	swayx	Linear	1.737	1	1.737	3.100	.106	.220	3.100	.363
	swayy	Linear	2.075	1	2.075	1.691	.220	.133	1.691	.221
	distx	Linear	20523.176	1	20523.176	8.338	.015	.431	8.338	.748
	disty	Linear	5720.196	1	5720.196	4.098	.068	.271	4.098	.455
Error(condition)	swayx	Linear	6.163	11	.560					
	swayy	Linear	13.495	11	1.227					
	distx	Linear	27073.932	11	2461.267					
	disty	Linear	15356.028	11	1396.003					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

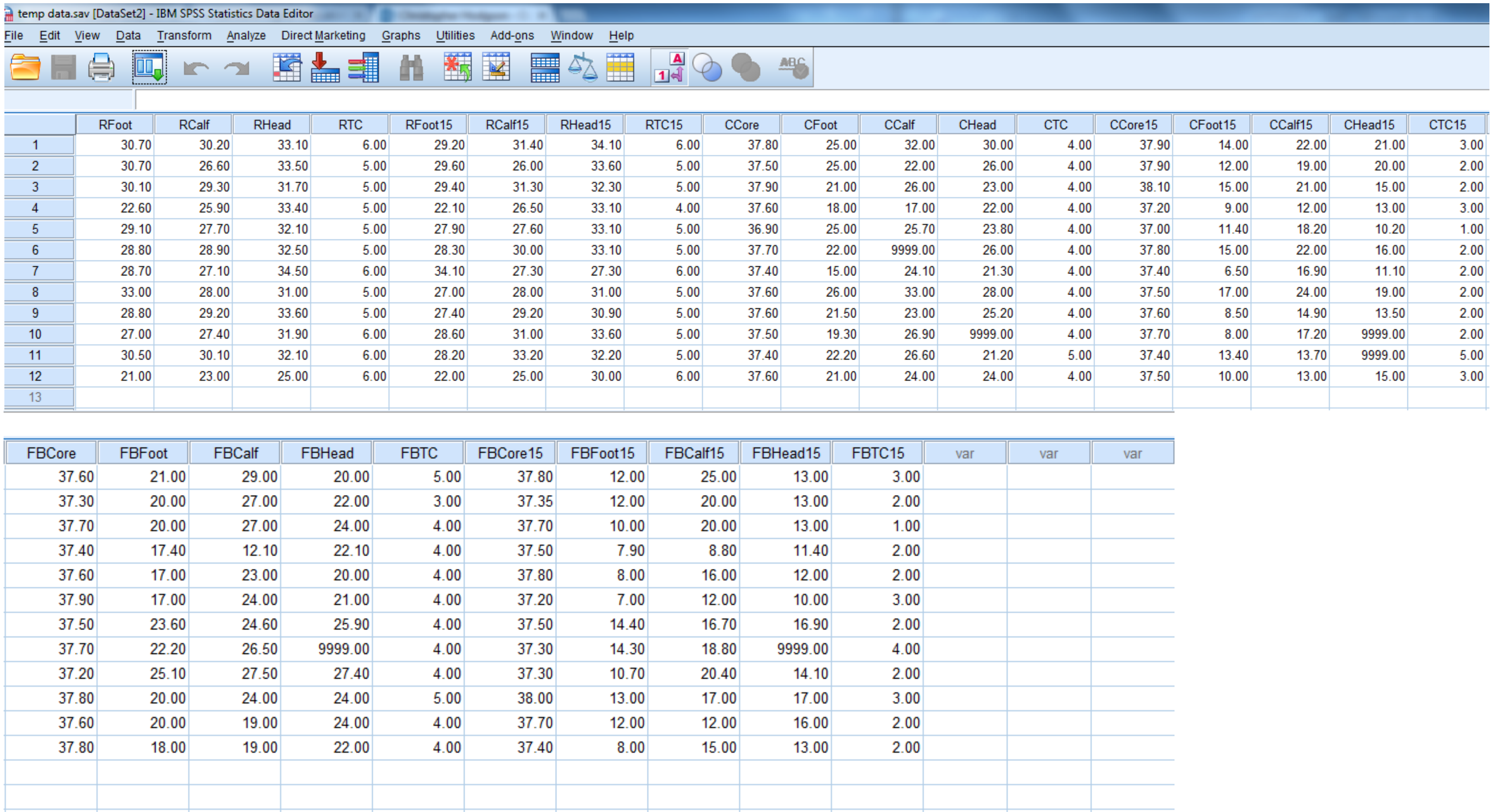
Transformed Variable: Average

Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	swayx	1299.874	1	1299.874	1062.211	.000	.990	1062.211	1.000
	swayy	4464.299	1	4464.299	939.513	.000	.988	939.513	1.000
	distx	1285588.794	1	1285588.794	112.554	.000	.911	112.554	1.000
	disty	1913717.216	1	1913717.216	184.618	.000	.944	184.618	1.000
Error	swayx	13.461	11	1.224					
	swayy	52.269	11	4.752					
	distx	125641.436	11	11421.949					
	disty	114024.146	11	10365.831					

a. Computed using alpha = .05

Appendix 9

BODY TEMPERATURE STUDY 4



	RFoot	RCalf	RHead	RTC	RFoot15	RCalf15	RHead15	RTC15	CCore	CFoot	CCalf	CHead	CTC	CCore15	CFoot15	CCalf15	CHead15	CTC15
1	30.70	30.20	33.10	6.00	29.20	31.40	34.10	6.00	37.80	25.00	32.00	30.00	4.00	37.90	14.00	22.00	21.00	3.00
2	30.70	26.60	33.50	5.00	29.60	26.00	33.60	5.00	37.50	25.00	22.00	26.00	4.00	37.90	12.00	19.00	20.00	2.00
3	30.10	29.30	31.70	5.00	29.40	31.30	32.30	5.00	37.90	21.00	26.00	23.00	4.00	38.10	15.00	21.00	15.00	2.00
4	22.60	25.90	33.40	5.00	22.10	26.50	33.10	4.00	37.60	18.00	17.00	22.00	4.00	37.20	9.00	12.00	13.00	3.00
5	29.10	27.70	32.10	5.00	27.90	27.60	33.10	5.00	36.90	25.00	25.70	23.80	4.00	37.00	11.40	18.20	10.20	1.00
6	28.80	28.90	32.50	5.00	28.30	30.00	33.10	5.00	37.70	22.00	9999.00	26.00	4.00	37.80	15.00	22.00	16.00	2.00
7	28.70	27.10	34.50	6.00	34.10	27.30	27.30	6.00	37.40	15.00	24.10	21.30	4.00	37.40	6.50	16.90	11.10	2.00
8	33.00	28.00	31.00	5.00	27.00	28.00	31.00	5.00	37.60	26.00	33.00	28.00	4.00	37.50	17.00	24.00	19.00	2.00
9	28.80	29.20	33.60	5.00	27.40	29.20	30.90	5.00	37.60	21.50	23.00	25.20	4.00	37.60	8.50	14.90	13.50	2.00
10	27.00	27.40	31.90	6.00	28.60	31.00	33.60	5.00	37.50	19.30	26.90	9999.00	4.00	37.70	8.00	17.20	9999.00	2.00
11	30.50	30.10	32.10	6.00	28.20	33.20	32.20	5.00	37.40	22.20	26.60	21.20	5.00	37.40	13.40	13.70	9999.00	5.00
12	21.00	23.00	25.00	6.00	22.00	25.00	30.00	6.00	37.60	21.00	24.00	24.00	4.00	37.50	10.00	13.00	15.00	3.00
13																		

FBCore	FBFoot	FBCalf	FBHead	FBTC	FBCore15	FBFoot15	FBCalf15	FBHead15	FBTC15	var	var	var
37.60	21.00	29.00	20.00	5.00	37.80	12.00	25.00	13.00	3.00			
37.30	20.00	27.00	22.00	3.00	37.35	12.00	20.00	13.00	2.00			
37.70	20.00	27.00	24.00	4.00	37.70	10.00	20.00	13.00	1.00			
37.40	17.40	12.10	22.10	4.00	37.50	7.90	8.80	11.40	2.00			
37.60	17.00	23.00	20.00	4.00	37.80	8.00	16.00	12.00	2.00			
37.90	17.00	24.00	21.00	4.00	37.20	7.00	12.00	10.00	3.00			
37.50	23.60	24.60	25.90	4.00	37.50	14.40	16.70	16.90	2.00			
37.70	22.20	26.50	9999.00	4.00	37.30	14.30	18.80	9999.00	4.00			
37.20	25.10	27.50	27.40	4.00	37.30	10.70	20.40	14.10	2.00			
37.80	20.00	24.00	24.00	5.00	38.00	13.00	17.00	17.00	3.00			
37.60	20.00	19.00	24.00	4.00	37.70	12.00	12.00	16.00	2.00			
37.80	18.00	19.00	22.00	4.00	37.40	8.00	15.00	13.00	2.00			

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

condition	time	Dependent Variable
1	1	RFoot
	2	RFoot15
2	1	CFoot
	2	CFoot15
3	1	FBFoot
	2	FBFoot15

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	.736	3.065	2	.216	.791	.902	.500
time	1.000	.000	0	.	1.000	1.000	1.000
condition * time	.953	.477	2	.788	.956	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: condition + time + condition * time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Sphericity Assumed	2340.634	2	1170.317	96.933	.000	.898	193.866	1.000
	Greenhouse-Geisser	2340.634	1.582	1479.264	96.933	.000	.898	153.377	1.000
	Huynh-Feldt	2340.634	1.804	1297.621	96.933	.000	.898	174.847	1.000
	Lower-bound	2340.634	1.000	2340.634	96.933	.000	.898	96.933	1.000
Error(condition)	Sphericity Assumed	265.616	22	12.073					
	Greenhouse-Geisser	265.616	17.405	15.261					
	Huynh-Feldt	265.616	19.842	13.387					
	Lower-bound	265.616	11.000	24.147					
time	Sphericity Assumed	802.669	1	802.669	270.195	.000	.961	270.195	1.000
	Greenhouse-Geisser	802.669	1.000	802.669	270.195	.000	.961	270.195	1.000
	Huynh-Feldt	802.669	1.000	802.669	270.195	.000	.961	270.195	1.000
	Lower-bound	802.669	1.000	802.669	270.195	.000	.961	270.195	1.000
Error(time)	Sphericity Assumed	32.678	11	2.971					
	Greenhouse-Geisser	32.678	11.000	2.971					
	Huynh-Feldt	32.678	11.000	2.971					
	Lower-bound	32.678	11.000	2.971					
condition * time	Sphericity Assumed	334.218	2	167.109	63.533	.000	.852	127.067	1.000
	Greenhouse-Geisser	334.218	1.911	174.891	63.533	.000	.852	121.413	1.000
	Huynh-Feldt	334.218	2.000	167.109	63.533	.000	.852	127.067	1.000
	Lower-bound	334.218	1.000	334.218	63.533	.000	.852	63.533	1.000
Error(condition*time)	Sphericity Assumed	57.866	22	2.630					
	Greenhouse-Geisser	57.866	21.021	2.753					
	Huynh-Feldt	57.866	22.000	2.630					
	Lower-bound	57.866	11.000	5.261					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	condition	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Linear		1927.867	1	1927.867	308.067	.000	.966	308.067	1.000
	Quadratic		412.767	1	412.767	23.074	.001	.677	23.074	.992
Error(condition)	Linear		68.837	11	6.258					
	Quadratic		196.778	11	17.889					
time		Linear	802.669	1	802.669	270.195	.000	.961	270.195	1.000
Error(time)		Linear	32.678	11	2.971					
condition * time	Linear	Linear	228.813	1	228.813	83.615	.000	.884	83.615	1.000
	Quadratic	Linear	105.404	1	105.404	41.761	.000	.792	41.761	1.000
Error(condition*time)	Linear	Linear	30.102	11	2.737					
	Quadratic	Linear	27.764	11	2.524					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	29048.534	1	29048.534	1171.629	.000	.991	1171.629	1.000
Error	272.726	11	24.793					

a. Computed using alpha = .05

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

condition	time	Dependent Variable
1	1	RCalf
	2	RCalf15
2	1	CCalf
	2	CCalf15
3	1	FBCalf
	2	FBCalf15

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	.860	1.357	2	.507	.877	1.000	.500
time	1.000	.000	0	.	1.000	1.000	1.000
condition * time	.596	4.657	2	.097	.712	.797	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: condition + time + condition * time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Sphericity Assumed	795.434	2	397.717	28.483	.000	.740	56.965	1.000
	Greenhouse-Geisser	795.434	1.754	453.371	28.483	.000	.740	49.973	1.000
	Huynh-Feldt	795.434	2.000	397.717	28.483	.000	.740	56.965	1.000
	Lower-bound	795.434	1.000	795.434	28.483	.000	.740	28.483	.998
Error(condition)	Sphericity Assumed	279.269	20	13.963					
	Greenhouse-Geisser	279.269	17.545	15.917					
	Huynh-Feldt	279.269	20.000	13.963					
	Lower-bound	279.269	10.000	27.927					
time	Sphericity Assumed	320.321	1	320.321	235.772	.000	.959	235.772	1.000
	Greenhouse-Geisser	320.321	1.000	320.321	235.772	.000	.959	235.772	1.000
	Huynh-Feldt	320.321	1.000	320.321	235.772	.000	.959	235.772	1.000
	Lower-bound	320.321	1.000	320.321	235.772	.000	.959	235.772	1.000
Error(time)	Sphericity Assumed	13.586	10	1.359					
	Greenhouse-Geisser	13.586	10.000	1.359					
	Huynh-Feldt	13.586	10.000	1.359					
	Lower-bound	13.586	10.000	1.359					
condition * time	Sphericity Assumed	257.841	2	128.921	49.355	.000	.832	98.710	1.000
	Greenhouse-Geisser	257.841	1.425	180.996	49.355	.000	.832	70.310	1.000
	Huynh-Feldt	257.841	1.594	161.745	49.355	.000	.832	78.678	1.000
	Lower-bound	257.841	1.000	257.841	49.355	.000	.832	49.355	1.000
Error(condition*time)	Sphericity Assumed	52.242	20	2.612					
	Greenhouse-Geisser	52.242	14.246	3.667					
	Huynh-Feldt	52.242	15.941	3.277					
	Lower-bound	52.242	10.000	5.224					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	condition	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Linear		677.063	1	677.063	35.533	.000	.780	35.533	1.000
	Quadratic		118.371	1	118.371	13.341	.004	.572	13.341	.907
Error(condition)	Linear		190.542	10	19.054					
	Quadratic		88.727	10	8.873					
time		Linear	320.321	1	320.321	235.772	.000	.959	235.772	1.000
Error(time)		Linear	13.586	10	1.359					
condition * time	Linear	Linear	149.114	1	149.114	145.316	.000	.936	145.316	1.000
	Quadratic	Linear	108.728	1	108.728	25.899	.000	.721	25.899	.995
Error(condition*time)	Linear	Linear	10.261	10	1.026					
	Quadratic	Linear	41.981	10	4.198					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	36008.039	1	36008.039	643.038	.000	.985	643.038	1.000
Error	559.968	10	55.997					

a. Computed using alpha = .05

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

condition	time	Dependent Variable
1	1	RHead
	2	RHead15
2	1	CHead
	2	CHead15
3	1	FBHead
	2	FBHead15

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	.781	1.730	2	.421	.820	1.000	.500
time	1.000	.000	0	.	1.000	1.000	1.000
condition * time	.912	.643	2	.725	.919	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: condition + time + condition * time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Sphericity Assumed	2140.480	2	1070.240	88.410	.000	.917	176.820	1.000
	Greenhouse-Geisser	2140.480	1.641	1304.582	88.410	.000	.917	145.058	1.000
	Huynh-Feldt	2140.480	2.000	1070.240	88.410	.000	.917	176.820	1.000
	Lower-bound	2140.480	1.000	2140.480	88.410	.000	.917	88.410	1.000
Error(condition)	Sphericity Assumed	193.686	16	12.105					
	Greenhouse-Geisser	193.686	13.126	14.756					
	Huynh-Feldt	193.686	16.000	12.105					
	Lower-bound	193.686	8.000	24.211					
time	Sphericity Assumed	576.240	1	576.240	136.996	.000	.945	136.996	1.000
	Greenhouse-Geisser	576.240	1.000	576.240	136.996	.000	.945	136.996	1.000
	Huynh-Feldt	576.240	1.000	576.240	136.996	.000	.945	136.996	1.000
	Lower-bound	576.240	1.000	576.240	136.996	.000	.945	136.996	1.000
Error(time)	Sphericity Assumed	33.650	8	4.206					
	Greenhouse-Geisser	33.650	8.000	4.206					
	Huynh-Feldt	33.650	8.000	4.206					
	Lower-bound	33.650	8.000	4.206					
condition * time	Sphericity Assumed	269.863	2	134.932	50.375	.000	.863	100.750	1.000
	Greenhouse-Geisser	269.863	1.839	146.778	50.375	.000	.863	92.619	1.000
	Huynh-Feldt	269.863	2.000	134.932	50.375	.000	.863	100.750	1.000
	Lower-bound	269.863	1.000	269.863	50.375	.000	.863	50.375	1.000
Error(condition*time)	Sphericity Assumed	42.857	16	2.679					
	Greenhouse-Geisser	42.857	14.709	2.914					
	Huynh-Feldt	42.857	16.000	2.679					
	Lower-bound	42.857	8.000	5.357					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	condition	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Linear		1821.867	1	1821.867	182.197	.000	.958	182.197	1.000
	Quadratic		318.613	1	318.613	22.420	.001	.737	22.420	.984
Error(condition)	Linear		79.996	8	9.999					
	Quadratic		113.691	8	14.211					
time		Linear	576.240	1	576.240	136.996	.000	.945	136.996	1.000
Error(time)		Linear	33.650	8	4.206					
condition * time	Linear	Linear	205.922	1	205.922	70.855	.000	.899	70.855	1.000
	Quadratic	Linear	63.941	1	63.941	26.089	.001	.765	26.089	.993
Error(condition*time)	Linear	Linear	23.250	8	2.906					
	Quadratic	Linear	19.607	8	2.451					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	29111.379	1	29111.379	3145.271	.000	.997	3145.271	1.000
Error	74.045	8	9.256					

a. Computed using alpha = .05

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

condition	time	Dependent Variable
1	1	RTC
	2	RTC15
2	1	CTC
	2	CTC15
3	1	FBTC
	2	FBTC15

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	.882	1.261	2	.532	.894	1.000	.500
time	1.000	.000	0	.	1.000	1.000	1.000
condition * time	.832	1.834	2	.400	.856	.999	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: condition + time + condition * time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power^{a}
condition	Sphericity Assumed	68.083	2	34.042	64.655	.000	.855	129.309	1.000
	Greenhouse-Geisser	68.083	1.788	38.075	64.655	.000	.855	115.612	1.000
	Huynh-Feldt	68.083	2.000	34.042	64.655	.000	.855	129.309	1.000
	Lower-bound	68.083	1.000	68.083	64.655	.000	.855	64.655	1.000
Error(condition)	Sphericity Assumed	11.583	22	.527					
	Greenhouse-Geisser	11.583	19.670	.589					
	Huynh-Feldt	11.583	22.000	.527					
	Lower-bound	11.583	11.000	1.053					
time	Sphericity Assumed	26.889	1	26.889	166.375	.000	.938	166.375	1.000
	Greenhouse-Geisser	26.889	1.000	26.889	166.375	.000	.938	166.375	1.000
	Huynh-Feldt	26.889	1.000	26.889	166.375	.000	.938	166.375	1.000
	Lower-bound	26.889	1.000	26.889	166.375	.000	.938	166.375	1.000
Error(time)	Sphericity Assumed	1.778	11	.162					
	Greenhouse-Geisser	1.778	11.000	.162					
	Huynh-Feldt	1.778	11.000	.162					
	Lower-bound	1.778	11.000	.162					
condition * time	Sphericity Assumed	8.528	2	4.264	16.158	.000	.595	32.316	.999
	Greenhouse-Geisser	8.528	1.713	4.979	16.158	.000	.595	27.677	.996
	Huynh-Feldt	8.528	1.998	4.268	16.158	.000	.595	32.282	.999
	Lower-bound	8.528	1.000	8.528	16.158	.002	.595	16.158	.954
Error(condition*time)	Sphericity Assumed	5.806	22	.264					
	Greenhouse-Geisser	5.806	18.842	.308					
	Huynh-Feldt	5.806	21.977	.264					
	Lower-bound	5.806	11.000	.528					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	condition	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Linear		52.083	1	52.083	129.717	.000	.922	129.717	1.000
	Quadratic		16.000	1	16.000	24.558	.000	.691	24.558	.994
Error(condition)	Linear		4.417	11	.402					
	Quadratic		7.167	11	.652					
time		Linear	26.889	1	26.889	166.375	.000	.938	166.375	1.000
Error(time)		Linear	1.778	11	.162					
condition * time	Linear	Linear	6.750	1	6.750	42.429	.000	.794	42.429	1.000
	Quadratic	Linear	1.778	1	1.778	4.822	.050	.305	4.822	.517
Error(condition*time)	Linear	Linear	1.750	11	.159					
	Quadratic	Linear	4.056	11	.369					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	1104.500	1	1104.500	1375.415	.000	.992	1375.415	1.000
Error	8.833	11	.803					

a. Computed using alpha = .05

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

condition	time	Dependent Variable
1	1	CCore
	2	CCore15
2	1	FBCore
	2	FBCore15

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	1.000	.000	0	.	1.000	1.000	1.000
time	1.000	.000	0	.	1.000	1.000	1.000
condition * time	1.000	.000	0	.	1.000	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: condition + time + condition * time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Sphericity Assumed	.000	1	.000	.004	.948	.000	.004	.050
	Greenhouse-Geisser	.000	1.000	.000	.004	.948	.000	.004	.050
	Huynh-Feldt	.000	1.000	.000	.004	.948	.000	.004	.050
	Lower-bound	.000	1.000	.000	.004	.948	.000	.004	.050
Error(condition)	Sphericity Assumed	1.148	11	.104					
	Greenhouse-Geisser	1.148	11.000	.104					
	Huynh-Feldt	1.148	11.000	.104					
	Lower-bound	1.148	11.000	.104					
time	Sphericity Assumed	5.208E-005	1	5.208E-005	.001	.970	.000	.001	.050
	Greenhouse-Geisser	5.208E-005	1.000	5.208E-005	.001	.970	.000	.001	.050
	Huynh-Feldt	5.208E-005	1.000	5.208E-005	.001	.970	.000	.001	.050
	Lower-bound	5.208E-005	1.000	5.208E-005	.001	.970	.000	.001	.050
Error(time)	Sphericity Assumed	.388	11	.035					
	Greenhouse-Geisser	.388	11.000	.035					
	Huynh-Feldt	.388	11.000	.035					
	Lower-bound	.388	11.000	.035					
condition * time	Sphericity Assumed	.023	1	.023	.856	.375	.072	.856	.135
	Greenhouse-Geisser	.023	1.000	.023	.856	.375	.072	.856	.135
	Huynh-Feldt	.023	1.000	.023	.856	.375	.072	.856	.135
	Lower-bound	.023	1.000	.023	.856	.375	.072	.856	.135
Error(condition*time)	Sphericity Assumed	.295	11	.027					
	Greenhouse-Geisser	.295	11.000	.027					
	Huynh-Feldt	.295	11.000	.027					

	Lower-bound	.295	11.000	.027					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	condition	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Linear		.000	1	.000	.004	.948	.000	.004	.050
Error(condition)	Linear		1.148	11	.104					
time		Linear	5.208E-005	1	5.208E-005	.001	.970	.000	.001	.050
Error(time)		Linear	.388	11	.035					
condition * time	Linear	Linear	.023	1	.023	.856	.375	.072	.856	.135
Error(condition*time)	Linear	Linear	.295	11	.027					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1

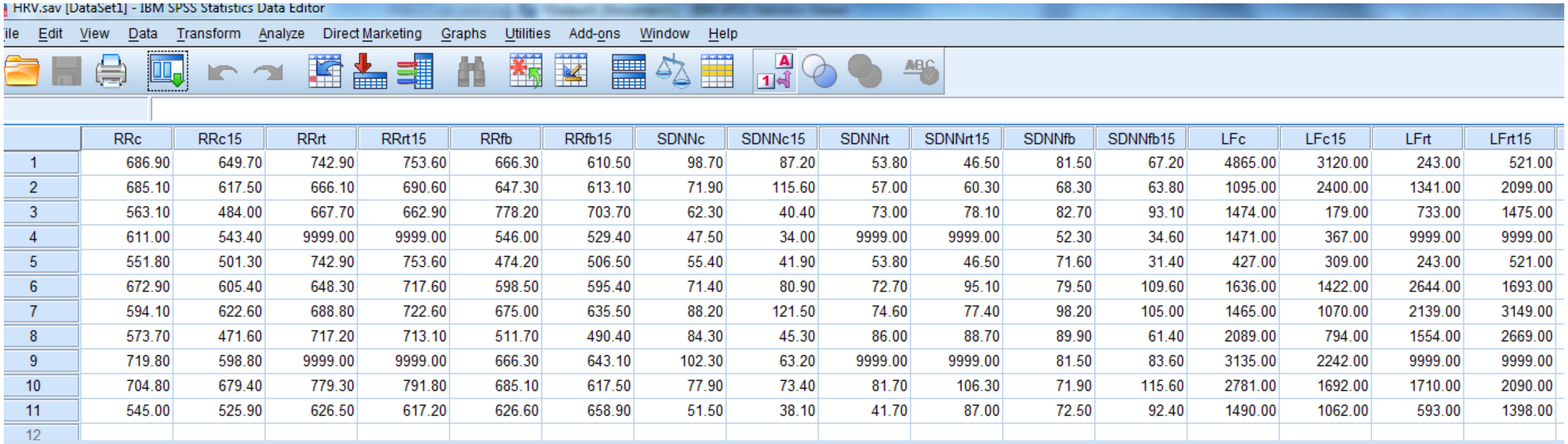
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	67736.457	1	67736.457	658561.877	.000	1.000	658561.877	1.000
Error	1.131	11	.103					

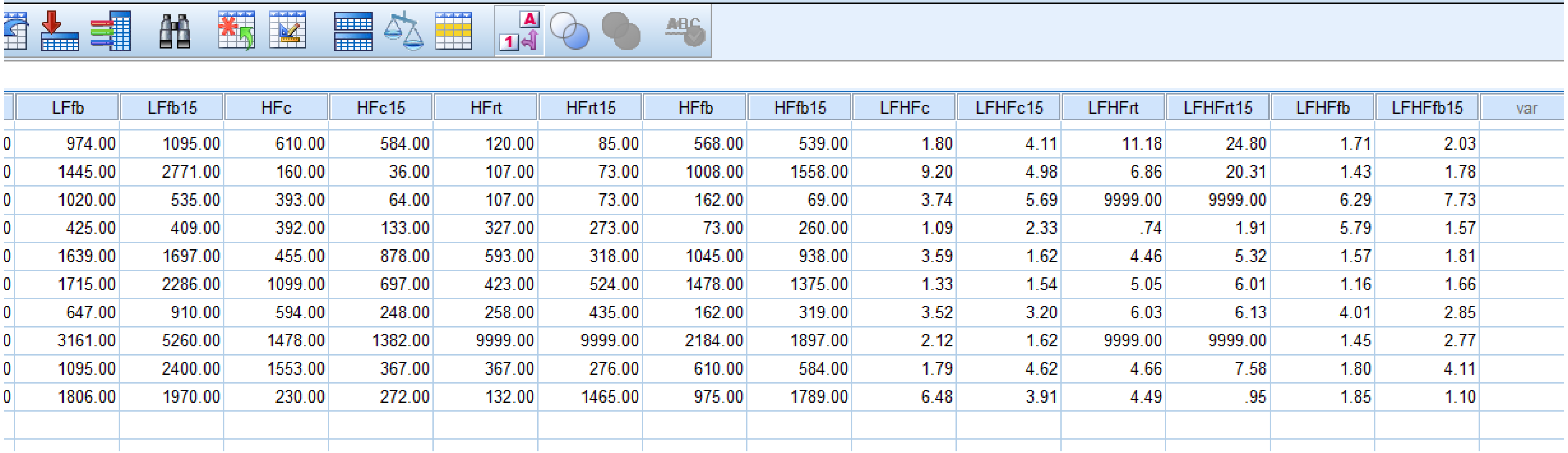
a. Computed using alpha = .05

Appendix 10

HEART
RATE VARIABILITY
STUDY 4



	RRc	RRc15	RRrt	RRrt15	RRfb	RRfb15	SDNNc	SDNNc15	SDNNrt	SDNNrt15	SDNNfb	SDNNfb15	LFc	LFc15	LFrt	LFrt15
1	686.90	649.70	742.90	753.60	666.30	610.50	98.70	87.20	53.80	46.50	81.50	67.20	4865.00	3120.00	243.00	521.00
2	685.10	617.50	666.10	690.60	647.30	613.10	71.90	115.60	57.00	60.30	68.30	63.80	1095.00	2400.00	1341.00	2099.00
3	563.10	484.00	667.70	662.90	778.20	703.70	62.30	40.40	73.00	78.10	82.70	93.10	1474.00	179.00	733.00	1475.00
4	611.00	543.40	9999.00	9999.00	546.00	529.40	47.50	34.00	9999.00	9999.00	52.30	34.60	1471.00	367.00	9999.00	9999.00
5	551.80	501.30	742.90	753.60	474.20	506.50	55.40	41.90	53.80	46.50	71.60	31.40	427.00	309.00	243.00	521.00
6	672.90	605.40	648.30	717.60	598.50	595.40	71.40	80.90	72.70	95.10	79.50	109.60	1636.00	1422.00	2644.00	1693.00
7	594.10	622.60	688.80	722.60	675.00	635.50	88.20	121.50	74.60	77.40	98.20	105.00	1465.00	1070.00	2139.00	3149.00
8	573.70	471.60	717.20	713.10	511.70	490.40	84.30	45.30	86.00	88.70	89.90	61.40	2089.00	794.00	1554.00	2669.00
9	719.80	598.80	9999.00	9999.00	666.30	643.10	102.30	63.20	9999.00	9999.00	81.50	83.60	3135.00	2242.00	9999.00	9999.00
10	704.80	679.40	779.30	791.80	685.10	617.50	77.90	73.40	81.70	106.30	71.90	115.60	2781.00	1692.00	1710.00	2090.00
11	545.00	525.90	626.50	617.20	626.60	658.90	51.50	38.10	41.70	87.00	72.50	92.40	1490.00	1062.00	593.00	1398.00
12																



	LFfb	LFfb15	HFc	HFc15	HFrt	HFrt15	HFfb	HFfb15	LFHFc	LFHFc15	LFHFrt	LFHFrt15	LFHFfb	LFHFfb15	var
0	974.00	1095.00	610.00	584.00	120.00	85.00	568.00	539.00	1.80	4.11	11.18	24.80	1.71	2.03	
0	1445.00	2771.00	160.00	36.00	107.00	73.00	1008.00	1558.00	9.20	4.98	6.86	20.31	1.43	1.78	
0	1020.00	535.00	393.00	64.00	107.00	73.00	162.00	69.00	3.74	5.69	9999.00	9999.00	6.29	7.73	
0	425.00	409.00	392.00	133.00	327.00	273.00	73.00	260.00	1.09	2.33	.74	1.91	5.79	1.57	
0	1639.00	1697.00	455.00	878.00	593.00	318.00	1045.00	938.00	3.59	1.62	4.46	5.32	1.57	1.81	
0	1715.00	2286.00	1099.00	697.00	423.00	524.00	1478.00	1375.00	1.33	1.54	5.05	6.01	1.16	1.66	
0	647.00	910.00	594.00	248.00	258.00	435.00	162.00	319.00	3.52	3.20	6.03	6.13	4.01	2.85	
0	3161.00	5260.00	1478.00	1382.00	9999.00	9999.00	2184.00	1897.00	2.12	1.62	9999.00	9999.00	1.45	2.77	
0	1095.00	2400.00	1553.00	367.00	367.00	276.00	610.00	584.00	1.79	4.62	4.66	7.58	1.80	4.11	
0	1806.00	1970.00	230.00	272.00	132.00	1465.00	975.00	1789.00	6.48	3.91	4.49	.95	1.85	1.10	

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

condition	time	Dependent Variable
1	1	RRc
	2	RRc15
2	1	RRrt
	2	RRrt15
3	1	RRfb
	2	RRfb15

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	.733	2.178	2	.336	.789	.950	.500
time	1.000	.000	0	.	1.000	1.000	1.000
condition * time	.903	.713	2	.700	.912	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: condition + time + condition * time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Sphericity Assumed	122010.583	2	61005.291	7.855	.004	.495	15.710	.906
	Greenhouse-Geisser	122010.583	1.578	77320.663	7.855	.009	.495	12.395	.842
	Huynh-Feldt	122010.583	1.900	64216.100	7.855	.005	.495	14.924	.894
	Lower-bound	122010.583	1.000	122010.583	7.855	.023	.495	7.855	.691
Error(condition)	Sphericity Assumed	124266.254	16	7766.641					
	Greenhouse-Geisser	124266.254	12.624	9843.766					
	Huynh-Feldt	124266.254	15.200	8175.412					
	Lower-bound	124266.254	8.000	15533.282					
time	Sphericity Assumed	4780.845	1	4780.845	7.065	.029	.469	7.065	.645
	Greenhouse-Geisser	4780.845	1.000	4780.845	7.065	.029	.469	7.065	.645
	Huynh-Feldt	4780.845	1.000	4780.845	7.065	.029	.469	7.065	.645
	Lower-bound	4780.845	1.000	4780.845	7.065	.029	.469	7.065	.645
Error(time)	Sphericity Assumed	5413.927	8	676.741					
	Greenhouse-Geisser	5413.927	8.000	676.741					
	Huynh-Feldt	5413.927	8.000	676.741					
	Lower-bound	5413.927	8.000	676.741					
condition * time	Sphericity Assumed	9134.758	2	4567.379	7.911	.004	.497	15.822	.908
	Greenhouse-Geisser	9134.758	1.823	5009.777	7.911	.006	.497	14.425	.885
	Huynh-Feldt	9134.758	2.000	4567.379	7.911	.004	.497	15.822	.908
	Lower-bound	9134.758	1.000	9134.758	7.911	.023	.497	7.911	.694
Error(condition*time)	Sphericity Assumed	9237.325	16	577.333					
	Greenhouse-Geisser	9237.325	14.587	633.254					
	Huynh-Feldt	9237.325	16.000	577.333					
	Lower-bound	9237.325	8.000	1154.666					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	condition	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Linear		3592.004	1	3592.004	.449	.522	.053	.449	.091
	Quadratic		118418.578	1	118418.578	15.705	.004	.663	15.705	.933
Error(condition)	Linear		63945.356	8	7993.169					
	Quadratic		60320.899	8	7540.112					
time		Linear	4780.845	1	4780.845	7.065	.029	.469	7.065	.645
Error(time)		Linear	5413.927	8	676.741					
condition * time	Linear	Linear	988.054	1	988.054	1.311	.285	.141	1.311	.173
	Quadratic	Linear	8146.704	1	8146.704	20.303	.002	.717	20.303	.975
Error(condition*time)	Linear	Linear	6027.276	8	753.409					
	Quadratic	Linear	3210.050	8	401.256					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	22082446.622	1	22082446.622	1932.156	.000	.996	1932.156	1.000
Error	91431.316	8	11428.914					

a. Computed using alpha = .05

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

condition	time	Dependent Variable
1	1	SDNNc
	2	SDNNc15
2	1	SDNNrt
	2	SDNNrt15
3	1	SDNNfb
	2	SDNNfb15

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	.466	5.342	2	.069	.652	.727	.500
time	1.000	.000	0	.	1.000	1.000	1.000
condition * time	.667	2.836	2	.242	.750	.885	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: condition + time + condition * time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Sphericity Assumed	996.958	2	498.479	1.090	.360	.120	2.180	.208
	Greenhouse-Geisser	996.958	1.304	764.584	1.090	.341	.120	1.422	.170
	Huynh-Feldt	996.958	1.454	685.721	1.090	.346	.120	1.585	.178
	Lower-bound	996.958	1.000	996.958	1.090	.327	.120	1.090	.152
Error(condition)	Sphericity Assumed	7315.639	16	457.227					
	Greenhouse-Geisser	7315.639	10.431	701.310					
	Huynh-Feldt	7315.639	11.631	628.975					
	Lower-bound	7315.639	8.000	914.455					
time	Sphericity Assumed	176.765	1	176.765	.382	.554	.046	.382	.085
	Greenhouse-Geisser	176.765	1.000	176.765	.382	.554	.046	.382	.085
	Huynh-Feldt	176.765	1.000	176.765	.382	.554	.046	.382	.085
	Lower-bound	176.765	1.000	176.765	.382	.554	.046	.382	.085
Error(time)	Sphericity Assumed	3706.727	8	463.341					
	Greenhouse-Geisser	3706.727	8.000	463.341					
	Huynh-Feldt	3706.727	8.000	463.341					
	Lower-bound	3706.727	8.000	463.341					
condition * time	Sphericity Assumed	336.425	2	168.212	.825	.456	.094	1.651	.167
	Greenhouse-Geisser	336.425	1.500	224.253	.825	.429	.094	1.238	.148
	Huynh-Feldt	336.425	1.770	190.117	.825	.445	.094	1.461	.158
	Lower-bound	336.425	1.000	336.425	.825	.390	.094	.825	.127
Error(condition*time)	Sphericity Assumed	3260.339	16	203.771					
	Greenhouse-Geisser	3260.339	12.002	271.658					
	Huynh-Feldt	3260.339	14.157	230.307					
	Lower-bound	3260.339	8.000	407.542					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	condition	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Linear		622.502	1	622.502	1.231	.300	.133	1.231	.165
	Quadratic		374.456	1	374.456	.916	.366	.103	.916	.135
Error(condition)	Linear		4046.750	8	505.844					
	Quadratic		3268.889	8	408.611					
time		Linear	176.765	1	176.765	.382	.554	.046	.382	.085
Error(time)		Linear	3706.727	8	463.341					
condition * time	Linear	Linear	46.014	1	46.014	.172	.689	.021	.172	.066
	Quadratic	Linear	290.411	1	290.411	2.079	.187	.206	2.079	.247
Error(condition*time)	Linear	Linear	2143.049	8	267.881					
	Quadratic	Linear	1117.290	8	139.661					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	302506.276	1	302506.276	289.094	.000	.973	289.094	1.000
Error	8371.163	8	1046.395					

a. Computed using alpha = .05

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

condition	time	Dependent Variable
1	1	LFc
	2	LFc15
2	1	LFrt
	2	LFrt15
3	1	LFfb
	2	LFfb15

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	.695	2.545	2	.280	.766	.912	.500
time	1.000	.000	0	.	1.000	1.000	1.000
condition * time	.941	.424	2	.809	.945	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
 Within Subjects Design: condition + time + condition * time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Sphericity Assumed	184974.111	2	92487.056	.072	.931	.009	.144	.059
	Greenhouse-Geisser	184974.111	1.533	120678.388	.072	.887	.009	.110	.058
	Huynh-Feldt	184974.111	1.824	101420.936	.072	.917	.009	.131	.059
	Lower-bound	184974.111	1.000	184974.111	.072	.795	.009	.072	.057
Error(condition)	Sphericity Assumed	20539432.889	16	1283714.556					
	Greenhouse-Geisser	20539432.889	12.262	1675008.484					
	Huynh-Feldt	20539432.889	14.591	1407716.265					
	Lower-bound	20539432.889	8.000	2567429.111					
time	Sphericity Assumed	22652.519	1	22652.519	.056	.819	.007	.056	.055
	Greenhouse-Geisser	22652.519	1.000	22652.519	.056	.819	.007	.056	.055
	Huynh-Feldt	22652.519	1.000	22652.519	.056	.819	.007	.056	.055
	Lower-bound	22652.519	1.000	22652.519	.056	.819	.007	.056	.055
Error(time)	Sphericity Assumed	3231578.815	8	403947.352					
	Greenhouse-Geisser	3231578.815	8.000	403947.352					
	Huynh-Feldt	3231578.815	8.000	403947.352					
	Lower-bound	3231578.815	8.000	403947.352					
condition * time	Sphericity Assumed	2820043.370	2	1410021.685	4.504	.028	.360	9.008	.684
	Greenhouse-Geisser	2820043.370	1.889	1492816.196	4.504	.031	.360	8.508	.664
	Huynh-Feldt	2820043.370	2.000	1410021.685	4.504	.028	.360	9.008	.684
	Lower-bound	2820043.370	1.000	2820043.370	4.504	.067	.360	4.504	.463
Error(condition*time)	Sphericity Assumed	5008922.296	16	313057.644					
	Greenhouse-Geisser	5008922.296	15.113	331439.953					
	Huynh-Feldt	5008922.296	16.000	313057.644					
	Lower-bound	5008922.296	8.000	626115.287					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	condition	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Linear		70313.361	1	70313.361	.083	.780	.010	.083	.058
	Quadratic		114660.750	1	114660.750	.066	.803	.008	.066	.056
Error(condition)	Linear		6737567.889	8	842195.986					
	Quadratic		13801865.000	8	1725233.125					
time		Linear	22652.519	1	22652.519	.056	.819	.007	.056	.055
Error(time)		Linear	3231578.815	8	403947.352					
condition * time	Linear	Linear	1455642.250	1	1455642.250	3.887	.084	.327	3.887	.411
	Quadratic	Linear	1364401.120	1	1364401.120	5.421	.048	.404	5.421	.534
Error(condition*time)	Linear	Linear	2995565.000	8	374445.625					
	Quadratic	Linear	2013357.296	8	251669.662					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	130554690.667	1	130554690.667	76.860	.000	.906	76.860	1.000
Error	13588897.333	8	1698612.167					

a. Computed using alpha = .05

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

condition	time	Dependent Variable
1	1	HFc
	2	HFc15
2	1	HFrt
	2	HFrt15
3	1	HFfb
	2	HFfb15

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	.734	2.470	2	.291	.790	.930	.500
time	1.000	.000	0	.	1.000	1.000	1.000
condition * time	.717	2.657	2	.265	.780	.913	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: condition + time + condition * time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Sphericity Assumed	2599782.033	2	1299891.017	2.797	.088	.237	5.594	.481
	Greenhouse-Geisser	2599782.033	1.580	1645237.126	2.797	.103	.237	4.420	.418
	Huynh-Feldt	2599782.033	1.860	1397629.409	2.797	.092	.237	5.203	.460
	Lower-bound	2599782.033	1.000	2599782.033	2.797	.129	.237	2.797	.322
Error(condition)	Sphericity Assumed	8365035.967	18	464724.220					
	Greenhouse-Geisser	8365035.967	14.222	588188.957					
	Huynh-Feldt	8365035.967	16.741	499666.687					
	Lower-bound	8365035.967	9.000	929448.441					
time	Sphericity Assumed	24766.017	1	24766.017	.149	.709	.016	.149	.064
	Greenhouse-Geisser	24766.017	1.000	24766.017	.149	.709	.016	.149	.064
	Huynh-Feldt	24766.017	1.000	24766.017	.149	.709	.016	.149	.064
	Lower-bound	24766.017	1.000	24766.017	.149	.709	.016	.149	.064
Error(time)	Sphericity Assumed	1499008.483	9	166556.498					
	Greenhouse-Geisser	1499008.483	9.000	166556.498					
	Huynh-Feldt	1499008.483	9.000	166556.498					
	Lower-bound	1499008.483	9.000	166556.498					
condition * time	Sphericity Assumed	224731.233	2	112365.617	.941	.409	.095	1.882	.187
	Greenhouse-Geisser	224731.233	1.559	144122.054	.941	.391	.095	1.467	.168
	Huynh-Feldt	224731.233	1.827	123014.815	.941	.402	.095	1.719	.180
	Lower-bound	224731.233	1.000	224731.233	.941	.357	.095	.941	.140
Error(condition*time)	Sphericity Assumed	2149814.767	18	119434.154					
	Greenhouse-Geisser	2149814.767	14.034	153188.280					
	Huynh-Feldt	2149814.767	16.442	130753.257					
	Lower-bound	2149814.767	9.000	238868.307					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	condition	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Linear		105987.025	1	105987.025	.192	.671	.021	.192	.068
	Quadratic		2493795.008	1	2493795.008	6.585	.030	.423	6.585	.628
Error(condition)	Linear		4956898.725	9	550766.525					
	Quadratic		3408137.242	9	378681.916					
time		Linear	24766.017	1	24766.017	.149	.709	.016	.149	.064
Error(time)		Linear	1499008.483	9	166556.498					
condition * time	Linear	Linear	69139.225	1	69139.225	.378	.554	.040	.378	.086
	Quadratic	Linear	155592.008	1	155592.008	2.780	.130	.236	2.780	.320
Error(condition*time)	Linear	Linear	1646117.525	9	182901.947					
	Quadratic	Linear	503697.242	9	55966.360					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	22775984.817	1	22775984.817	25.384	.001	.738	25.384	.994
Error	8075375.683	9	897263.965					

a. Computed using alpha = .05

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

condition	time	Dependent Variable
1	1	LFHFc
	2	LFHFc15
2	1	LFHFrt
	2	LFHFrt15
3	1	LFHFfb
	2	LFHFfb15

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	.354	7.274	2	.026	.607	.658	.500
time	1.000	.000	0	.	1.000	1.000	1.000
condition * time	.493	4.955	2	.084	.663	.745	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: condition + time + condition * time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Sphericity Assumed	190.506	2	95.253	4.298	.032	.350	8.597	.662
	Greenhouse-Geisser	190.506	1.215	156.808	4.298	.060	.350	5.222	.500
	Huynh-Feldt	190.506	1.317	144.682	4.298	.056	.350	5.660	.524
	Lower-bound	190.506	1.000	190.506	4.298	.072	.350	4.298	.446
Error(condition)	Sphericity Assumed	354.560	16	22.160					
	Greenhouse-Geisser	354.560	9.719	36.480					
	Huynh-Feldt	354.560	10.534	33.659					
	Lower-bound	354.560	8.000	44.320					
time	Sphericity Assumed	12.561	1	12.561	1.496	.256	.158	1.496	.191
	Greenhouse-Geisser	12.561	1.000	12.561	1.496	.256	.158	1.496	.191
	Huynh-Feldt	12.561	1.000	12.561	1.496	.256	.158	1.496	.191
	Lower-bound	12.561	1.000	12.561	1.496	.256	.158	1.496	.191
Error(time)	Sphericity Assumed	67.185	8	8.398					
	Greenhouse-Geisser	67.185	8.000	8.398					
	Huynh-Feldt	67.185	8.000	8.398					
	Lower-bound	67.185	8.000	8.398					
condition * time	Sphericity Assumed	40.540	2	20.270	2.922	.083	.268	5.844	.490
	Greenhouse-Geisser	40.540	1.327	30.554	2.922	.110	.268	3.877	.383
	Huynh-Feldt	40.540	1.490	27.212	2.922	.103	.268	4.353	.411
	Lower-bound	40.540	1.000	40.540	2.922	.126	.268	2.922	.325
Error(condition*time)	Sphericity Assumed	110.990	16	6.937					
	Greenhouse-Geisser	110.990	10.615	10.456					
	Huynh-Feldt	110.990	11.918	9.313					
	Lower-bound	110.990	8.000	13.874					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	condition	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Linear		8.926	1	8.926	1.737	.224	.178	1.737	.214
	Quadratic		181.580	1	181.580	4.634	.064	.367	4.634	.474
Error(condition)	Linear		41.113	8	5.139					
	Quadratic		313.447	8	39.181					
time		Linear	12.561	1	12.561	1.496	.256	.158	1.496	.191
Error(time)		Linear	67.185	8	8.398					
condition * time	Linear	Linear	.102	1	.102	.049	.831	.006	.049	.054
	Quadratic	Linear	40.439	1	40.439	3.430	.101	.300	3.430	.371
Error(condition*time)	Linear	Linear	16.681	8	2.085					
	Quadratic	Linear	94.309	8	11.789					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1

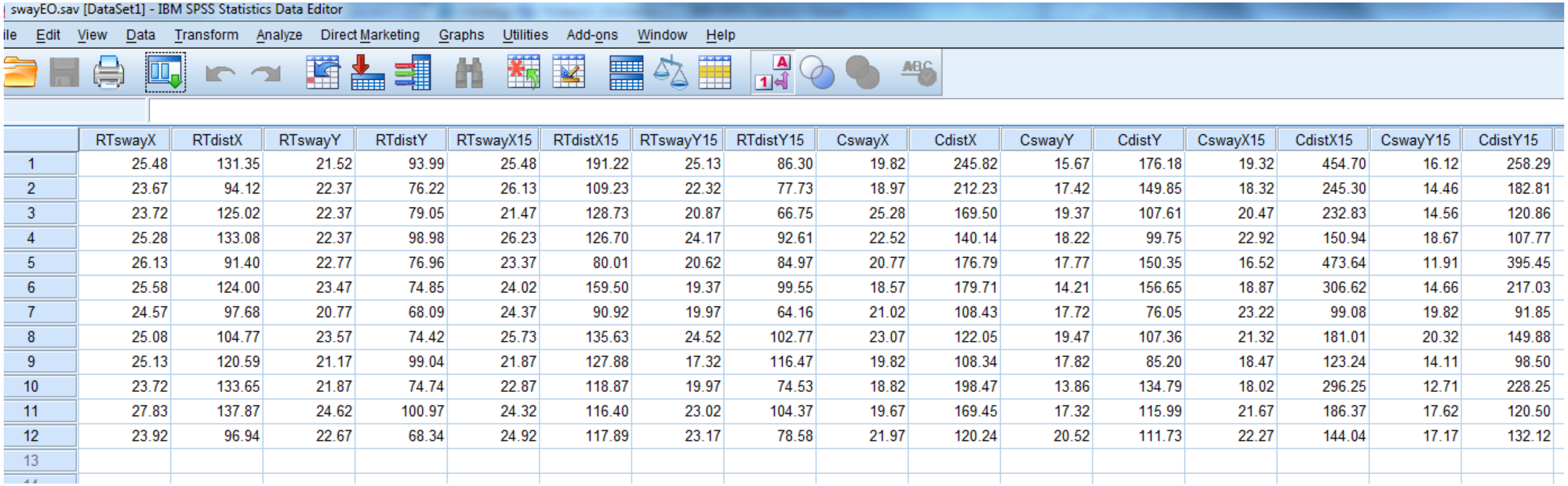
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	874.802	1	874.802	31.683	.000	.798	31.683	.998
Error	220.890	8	27.611					

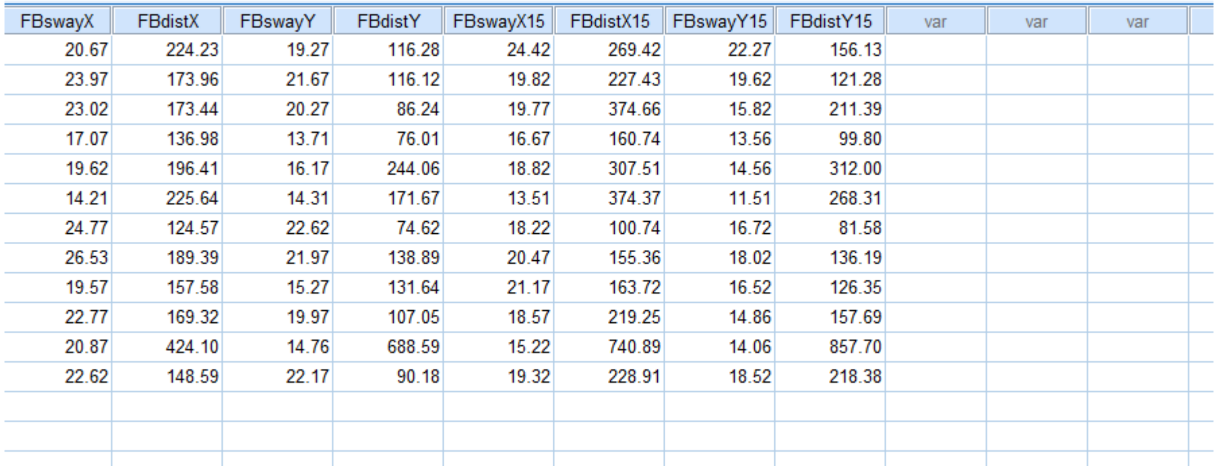
a. Computed using alpha = .05

Appendix 11

POSTURAL
SWAY ANALYSIS
STUDY 4



	RTswayX	RTdistX	RTswayY	RTdistY	RTswayX15	RTdistX15	RTswayY15	RTdistY15	CswayX	CdistX	CswayY	CdistY	CswayX15	CdistX15	CswayY15	CdistY15
1	25.48	131.35	21.52	93.99	25.48	191.22	25.13	86.30	19.82	245.82	15.67	176.18	19.32	454.70	16.12	258.29
2	23.67	94.12	22.37	76.22	26.13	109.23	22.32	77.73	18.97	212.23	17.42	149.85	18.32	245.30	14.46	182.81
3	23.72	125.02	22.37	79.05	21.47	128.73	20.87	66.75	25.28	169.50	19.37	107.61	20.47	232.83	14.56	120.86
4	25.28	133.08	22.37	98.98	26.23	126.70	24.17	92.61	22.52	140.14	18.22	99.75	22.92	150.94	18.67	107.77
5	26.13	91.40	22.77	76.96	23.37	80.01	20.62	84.97	20.77	176.79	17.77	150.35	16.52	473.64	11.91	395.45
6	25.58	124.00	23.47	74.85	24.02	159.50	19.37	99.55	18.57	179.71	14.21	156.65	18.87	306.62	14.66	217.03
7	24.57	97.68	20.77	68.09	24.37	90.92	19.97	64.16	21.02	108.43	17.72	76.05	23.22	99.08	19.82	91.85
8	25.08	104.77	23.57	74.42	25.73	135.63	24.52	102.77	23.07	122.05	19.47	107.36	21.32	181.01	20.32	149.88
9	25.13	120.59	21.17	99.04	21.87	127.88	17.32	116.47	19.82	108.34	17.82	85.20	18.47	123.24	14.11	98.50
10	23.72	133.65	21.87	74.74	22.87	118.87	19.97	74.53	18.82	198.47	13.86	134.79	18.02	296.25	12.71	228.25
11	27.83	137.87	24.62	100.97	24.32	116.40	23.02	104.37	19.67	169.45	17.32	115.99	21.67	186.37	17.62	120.50
12	23.92	96.94	22.67	68.34	24.92	117.89	23.17	78.58	21.97	120.24	20.52	111.73	22.27	144.04	17.17	132.12
13																



FBswayX	FBdistX	FBswayY	FBdistY	FBswayX15	FBdistX15	FBswayY15	FBdistY15	var	var	var
20.67	224.23	19.27	116.28	24.42	269.42	22.27	156.13			
23.97	173.96	21.67	116.12	19.82	227.43	19.62	121.28			
23.02	173.44	20.27	86.24	19.77	374.66	15.82	211.39			
17.07	136.98	13.71	76.01	16.67	160.74	13.56	99.80			
19.62	196.41	16.17	244.06	18.82	307.51	14.56	312.00			
14.21	225.64	14.31	171.67	13.51	374.37	11.51	268.31			
24.77	124.57	22.62	74.62	18.22	100.74	16.72	81.58			
26.53	189.39	21.97	138.89	20.47	155.36	18.02	136.19			
19.57	157.58	15.27	131.64	21.17	163.72	16.52	126.35			
22.77	169.32	19.97	107.05	18.57	219.25	14.86	157.69			
20.87	424.10	14.76	688.59	15.22	740.89	14.06	857.70			
22.62	148.59	22.17	90.18	19.32	228.91	18.52	218.38			

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

condition	time	Dependent Variable
1	1	RTswayX
	2	RTswayX15
2	1	CswayX
	2	CswayX15
3	1	FBswayX
	2	FBswayX15

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	.798	2.253	2	.324	.832	.963	.500
time	1.000	.000	0	.	1.000	1.000	1.000
condition * time	.707	3.472	2	.176	.773	.876	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: condition + time + condition * time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Sphericity Assumed	303.713	2	151.856	20.410	.000	.650	40.820	1.000
	Greenhouse-Geisser	303.713	1.664	182.487	20.410	.000	.650	33.968	.999
	Huynh-Feldt	303.713	1.925	157.770	20.410	.000	.650	39.290	1.000
	Lower-bound	303.713	1.000	303.713	20.410	.001	.650	20.410	.984
Error(condition)	Sphericity Assumed	163.687	22	7.440					
	Greenhouse-Geisser	163.687	18.307	8.941					
	Huynh-Feldt	163.687	21.175	7.730					
	Lower-bound	163.687	11.000	14.881					
time	Sphericity Assumed	31.931	1	31.931	12.618	.005	.534	12.618	.898
	Greenhouse-Geisser	31.931	1.000	31.931	12.618	.005	.534	12.618	.898
	Huynh-Feldt	31.931	1.000	31.931	12.618	.005	.534	12.618	.898
	Lower-bound	31.931	1.000	31.931	12.618	.005	.534	12.618	.898
Error(time)	Sphericity Assumed	27.837	11	2.531					
	Greenhouse-Geisser	27.837	11.000	2.531					
	Huynh-Feldt	27.837	11.000	2.531					
	Lower-bound	27.837	11.000	2.531					
condition * time	Sphericity Assumed	11.815	2	5.907	1.774	.193	.139	3.549	.331
	Greenhouse-Geisser	11.815	1.546	7.640	1.774	.202	.139	2.744	.287
	Huynh-Feldt	11.815	1.751	6.746	1.774	.198	.139	3.108	.307
	Lower-bound	11.815	1.000	11.815	1.774	.210	.139	1.774	.230
Error(condition*time)	Sphericity Assumed	73.239	22	3.329					
	Greenhouse-Geisser	73.239	17.010	4.306					
	Huynh-Feldt	73.239	19.265	3.802					
	Lower-bound	73.239	11.000	6.658					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	condition	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Linear		248.472	1	248.472	25.957	.000	.702	25.957	.996
	Quadratic		55.241	1	55.241	10.407	.008	.486	10.407	.835
Error(condition)	Linear		105.298	11	9.573					
	Quadratic		58.389	11	5.308					
time		Linear	31.931	1	31.931	12.618	.005	.534	12.618	.898
Error(time)		Linear	27.837	11	2.531					
condition * time	Linear	Linear	8.687	1	8.687	2.201	.166	.167	2.201	.273
	Quadratic	Linear	3.127	1	3.127	1.154	.306	.095	1.154	.166
Error(condition*time)	Linear	Linear	43.427	11	3.948					
	Quadratic	Linear	29.813	11	2.710					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	33985.037	1	33985.037	4070.774	.000	.997	4070.774	1.000
Error	91.834	11	8.349					

a. Computed using alpha = .05

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

condition	time	Dependent Variable
1	1	RTswayY
	2	RTswayY15
2	1	CswayY
	2	CswayY15
3	1	FBswayY
	2	FBswayY15

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	.737	3.058	2	.217	.791	.902	.500
time	1.000	.000	0	.	1.000	1.000	1.000
condition * time	.855	1.566	2	.457	.873	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: condition + time + condition * time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Sphericity Assumed	406.957	2	203.479	28.228	.000	.720	56.456	1.000
	Greenhouse-Geisser	406.957	1.583	257.094	28.228	.000	.720	44.683	1.000
	Huynh-Feldt	406.957	1.805	225.499	28.228	.000	.720	50.943	1.000
	Lower-bound	406.957	1.000	406.957	28.228	.000	.720	28.228	.998
Error(condition)	Sphericity Assumed	158.583	22	7.208					
	Greenhouse-Geisser	158.583	17.412	9.108					
	Huynh-Feldt	158.583	19.852	7.988					
	Lower-bound	158.583	11.000	14.417					
time	Sphericity Assumed	38.212	1	38.212	9.045	.012	.451	9.045	.782
	Greenhouse-Geisser	38.212	1.000	38.212	9.045	.012	.451	9.045	.782
	Huynh-Feldt	38.212	1.000	38.212	9.045	.012	.451	9.045	.782
	Lower-bound	38.212	1.000	38.212	9.045	.012	.451	9.045	.782
Error(time)	Sphericity Assumed	46.472	11	4.225					
	Greenhouse-Geisser	46.472	11.000	4.225					
	Huynh-Feldt	46.472	11.000	4.225					
	Lower-bound	46.472	11.000	4.225					
condition * time	Sphericity Assumed	6.037	2	3.019	1.154	.334	.095	2.308	.227
	Greenhouse-Geisser	6.037	1.747	3.456	1.154	.330	.095	2.016	.212
	Huynh-Feldt	6.037	2.000	3.019	1.154	.334	.095	2.308	.227
	Lower-bound	6.037	1.000	6.037	1.154	.306	.095	1.154	.166
Error(condition*time)	Sphericity Assumed	57.538	22	2.615					
	Greenhouse-Geisser	57.538	19.214	2.995					
	Huynh-Feldt	57.538	22.000	2.615					
	Lower-bound	57.538	11.000	5.231					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	condition	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power^{a}
condition	Linear		260.456	1	260.456	27.898	.000	.717	27.898	.998
	Quadratic		146.501	1	146.501	28.835	.000	.724	28.835	.998
Error(condition)	Linear		102.695	11	9.336					
	Quadratic		55.888	11	5.081					
time		Linear	38.212	1	38.212	9.045	.012	.451	9.045	.782
Error(time)		Linear	46.472	11	4.225					
condition * time	Linear	Linear	6.033	1	6.033	2.674	.130	.196	2.674	.321
	Quadratic	Linear	.004	1	.004	.001	.970	.000	.001	.050
Error(condition*time)	Linear	Linear	24.819	11	2.256					
	Quadratic	Linear	32.719	11	2.974					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power^{a}
Intercept	25303.116	1	25303.116	1703.303	.000	.994	1703.303	1.000
Error	163.409	11	14.855					

a. Computed using alpha = .05

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

condition	time	Dependent Variable
1	1	RTdistX
	2	RTdistX15
2	1	CdistX
	2	CswayX15
3	1	FBdistX
	2	FBdistX15

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	.104	22.651	2	.000	.527	.536	.500
time	1.000	.000	0	.	1.000	1.000	1.000
condition * time	.518	6.570	2	.037	.675	.736	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
 Within Subjects Design: condition + time + condition * time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Sphericity Assumed	281361.298	2	140680.649	14.976	.000	.577	29.951	.997
	Greenhouse-Geisser	281361.298	1.055	266756.435	14.976	.002	.577	15.796	.949
	Huynh-Feldt	281361.298	1.072	262570.058	14.976	.002	.577	16.048	.951
	Lower-bound	281361.298	1.000	281361.298	14.976	.003	.577	14.976	.940
Error(condition)	Sphericity Assumed	206665.839	22	9393.902					
	Greenhouse-Geisser	206665.839	11.602	17812.569					
	Huynh-Feldt	206665.839	11.787	17533.025					
	Lower-bound	206665.839	11.000	18787.804					
time	Sphericity Assumed	5313.218	1	5313.218	3.948	.072	.264	3.948	.442
	Greenhouse-Geisser	5313.218	1.000	5313.218	3.948	.072	.264	3.948	.442
	Huynh-Feldt	5313.218	1.000	5313.218	3.948	.072	.264	3.948	.442
	Lower-bound	5313.218	1.000	5313.218	3.948	.072	.264	3.948	.442
Error(time)	Sphericity Assumed	14803.539	11	1345.776					
	Greenhouse-Geisser	14803.539	11.000	1345.776					
	Huynh-Feldt	14803.539	11.000	1345.776					
	Lower-bound	14803.539	11.000	1345.776					
condition * time	Sphericity Assumed	156938.430	2	78469.215	31.191	.000	.739	62.383	1.000
	Greenhouse-Geisser	156938.430	1.350	116260.407	31.191	.000	.739	42.105	1.000
	Huynh-Feldt	156938.430	1.471	106663.240	31.191	.000	.739	45.893	1.000
	Lower-bound	156938.430	1.000	156938.430	31.191	.000	.739	31.191	.999
Error(condition*time)	Sphericity Assumed	55346.321	22	2515.742					
	Greenhouse-Geisser	55346.321	14.849	3727.337					
	Huynh-Feldt	55346.321	16.185	3419.649					
	Lower-bound	55346.321	11.000	5031.484					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	condition	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Linear		160287.038	1	160287.038	11.410	.006	.509	11.410	.867
	Quadratic		121074.260	1	121074.260	25.541	.000	.699	25.541	.996
Error(condition)	Linear		154520.983	11	14047.362					
	Quadratic		52144.855	11	4740.441					
time		Linear	5313.218	1	5313.218	3.948	.072	.264	3.948	.442
Error(time)		Linear	14803.539	11	1345.776					
condition * time	Linear	Linear	15633.033	1	15633.033	5.151	.044	.319	5.151	.544
	Quadratic	Linear	141305.397	1	141305.397	70.767	.000	.865	70.767	1.000
Error(condition*time)	Linear	Linear	33381.781	11	3034.707					
	Quadratic	Linear	21964.540	11	1996.776					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	1605995.316	1	1605995.316	125.913	.000	.920	125.913	1.000
Error	140302.830	11	12754.803					

a. Computed using alpha = .05

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

condition	time	Dependent Variable
1	1	RTdistY
	2	RTdistY15
2	1	CdistY
	2	CdistY15
3	1	FBdistY
	2	FBdistY15

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	.258	13.556	2	.001	.574	.598	.500
time	1.000	.000	0	.	1.000	1.000	1.000
condition * time	.755	2.805	2	.246	.803	.920	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: condition + time + condition * time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Sphericity Assumed	158720.117	2	79360.059	3.176	.061	.224	6.352	.548
	Greenhouse-Geisser	158720.117	1.148	138262.014	3.176	.095	.224	3.646	.399
	Huynh-Feldt	158720.117	1.195	132792.956	3.176	.093	.224	3.796	.409
	Lower-bound	158720.117	1.000	158720.117	3.176	.102	.224	3.176	.370
Error(condition)	Sphericity Assumed	549727.940	22	24987.634					
	Greenhouse-Geisser	549727.940	12.628	43533.745					
	Huynh-Feldt	549727.940	13.148	41811.735					
	Lower-bound	549727.940	11.000	49975.267					
time	Sphericity Assumed	27236.146	1	27236.146	20.717	.001	.653	20.717	.985
	Greenhouse-Geisser	27236.146	1.000	27236.146	20.717	.001	.653	20.717	.985
	Huynh-Feldt	27236.146	1.000	27236.146	20.717	.001	.653	20.717	.985
	Lower-bound	27236.146	1.000	27236.146	20.717	.001	.653	20.717	.985
Error(time)	Sphericity Assumed	14461.160	11	1314.651					
	Greenhouse-Geisser	14461.160	11.000	1314.651					
	Huynh-Feldt	14461.160	11.000	1314.651					
	Lower-bound	14461.160	11.000	1314.651					
condition * time	Sphericity Assumed	10296.754	2	5148.377	3.723	.040	.253	7.445	.620
	Greenhouse-Geisser	10296.754	1.607	6407.648	3.723	.053	.253	5.982	.550
	Huynh-Feldt	10296.754	1.840	5596.012	3.723	.045	.253	6.850	.593
	Lower-bound	10296.754	1.000	10296.754	3.723	.080	.253	3.723	.421
Error(condition*time)	Sphericity Assumed	30425.167	22	1382.962					
	Greenhouse-Geisser	30425.167	17.676	1721.229					
	Huynh-Feldt	30425.167	20.240	1503.206					
	Lower-bound	30425.167	11.000	2765.924					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	condition	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Linear		157977.360	1	157977.360	4.689	.053	.299	4.689	.506
	Quadratic		742.758	1	742.758	.046	.835	.004	.046	.054
Error(condition)	Linear		370569.922	11	33688.175					
	Quadratic		179158.018	11	16287.093					
time		Linear	27236.146	1	27236.146	20.717	.001	.653	20.717	.985
Error(time)		Linear	14461.160	11	1314.651					
condition * time	Linear	Linear	8594.964	1	8594.964	9.000	.012	.450	9.000	.780
	Quadratic	Linear	1701.789	1	1701.789	.940	.353	.079	.940	.144
Error(condition*time)	Linear	Linear	10505.098	11	955.009					
	Quadratic	Linear	19920.070	11	1810.915					

a. Computed using alpha = .05

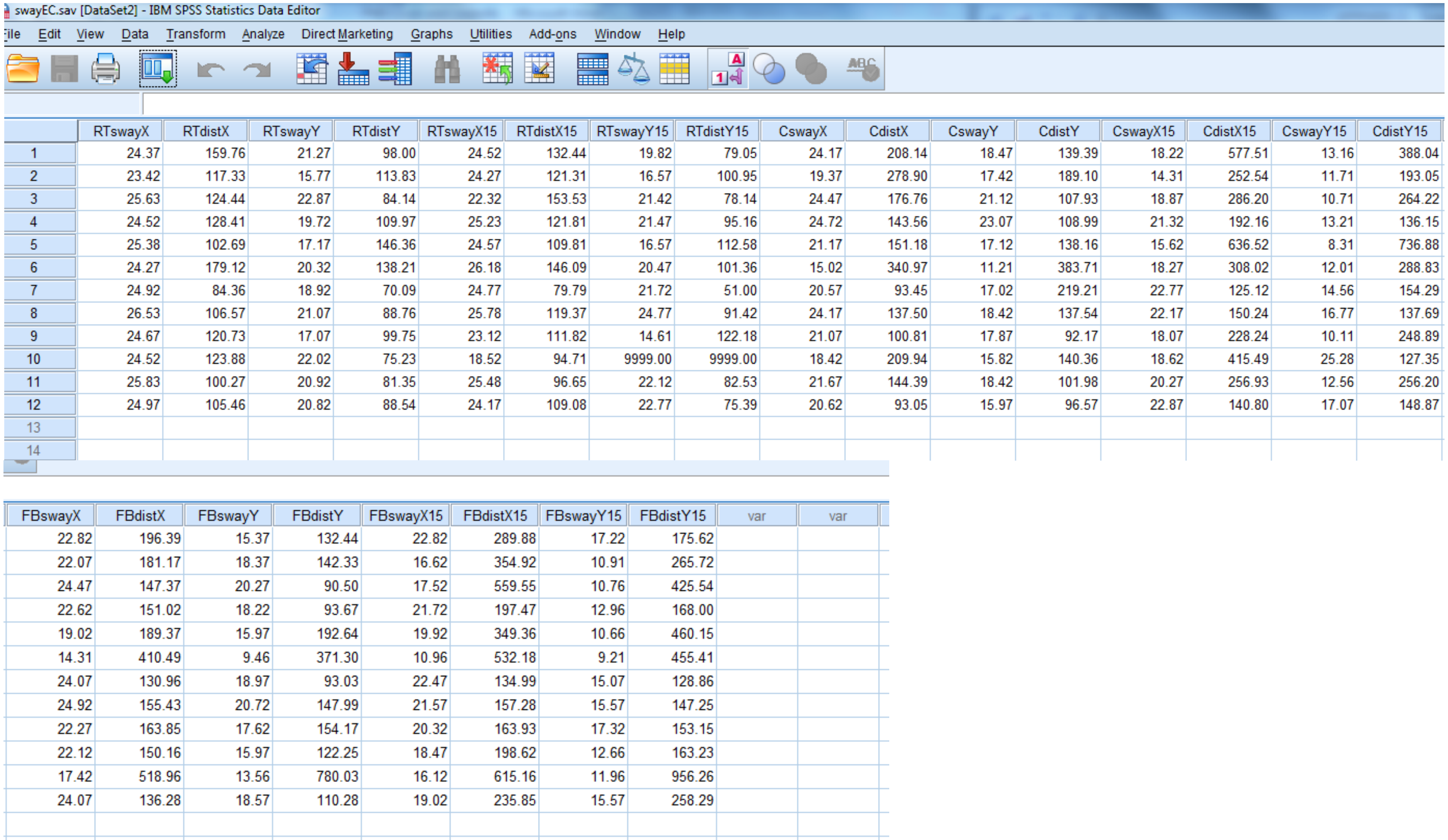
Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	1501456.187	1	1501456.187	53.656	.000	.830	53.656	1.000
Error	307815.891	11	27983.263					

a. Computed using alpha = .05



	RTswayX	RTdistX	RTswayY	RTdistY	RTswayX15	RTdistX15	RTswayY15	RTdistY15	CswayX	CdistX	CswayY	CdistY	CswayX15	CdistX15	CswayY15	CdistY15
1	24.37	159.76	21.27	98.00	24.52	132.44	19.82	79.05	24.17	208.14	18.47	139.39	18.22	577.51	13.16	388.04
2	23.42	117.33	15.77	113.83	24.27	121.31	16.57	100.95	19.37	278.90	17.42	189.10	14.31	252.54	11.71	193.05
3	25.63	124.44	22.87	84.14	22.32	153.53	21.42	78.14	24.47	176.76	21.12	107.93	18.87	286.20	10.71	264.22
4	24.52	128.41	19.72	109.97	25.23	121.81	21.47	95.16	24.72	143.56	23.07	108.99	21.32	192.16	13.21	136.15
5	25.38	102.69	17.17	146.36	24.57	109.81	16.57	112.58	21.17	151.18	17.12	138.16	15.62	636.52	8.31	736.88
6	24.27	179.12	20.32	138.21	26.18	146.09	20.47	101.36	15.02	340.97	11.21	383.71	18.27	308.02	12.01	288.83
7	24.92	84.36	18.92	70.09	24.77	79.79	21.72	51.00	20.57	93.45	17.02	219.21	22.77	125.12	14.56	154.29
8	26.53	106.57	21.07	88.76	25.78	119.37	24.77	91.42	24.17	137.50	18.42	137.54	22.17	150.24	16.77	137.69
9	24.67	120.73	17.07	99.75	23.12	111.82	14.61	122.18	21.07	100.81	17.87	92.17	18.07	228.24	10.11	248.89
10	24.52	123.88	22.02	75.23	18.52	94.71	9999.00	9999.00	18.42	209.94	15.82	140.36	18.62	415.49	25.28	127.35
11	25.83	100.27	20.92	81.35	25.48	96.65	22.12	82.53	21.67	144.39	18.42	101.98	20.27	256.93	12.56	256.20
12	24.97	105.46	20.82	88.54	24.17	109.08	22.77	75.39	20.62	93.05	15.97	96.57	22.87	140.80	17.07	148.87
13																
14																

FBswayX	FBdistX	FBswayY	FBdistY	FBswayX15	FBdistX15	FBswayY15	FBdistY15	var	var
22.82	196.39	15.37	132.44	22.82	289.88	17.22	175.62		
22.07	181.17	18.37	142.33	16.62	354.92	10.91	265.72		
24.47	147.37	20.27	90.50	17.52	559.55	10.76	425.54		
22.62	151.02	18.22	93.67	21.72	197.47	12.96	168.00		
19.02	189.37	15.97	192.64	19.92	349.36	10.66	460.15		
14.31	410.49	9.46	371.30	10.96	532.18	9.21	455.41		
24.07	130.96	18.97	93.03	22.47	134.99	15.07	128.86		
24.92	155.43	20.72	147.99	21.57	157.28	15.57	147.25		
22.27	163.85	17.62	154.17	20.32	163.93	17.32	153.15		
22.12	150.16	15.97	122.25	18.47	198.62	12.66	163.23		
17.42	518.96	13.56	780.03	16.12	615.16	11.96	956.26		
24.07	136.28	18.57	110.28	19.02	235.85	15.57	258.29		

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

condition	time	Dependent Variable
1	1	RTswayX
	2	RTswayX15
2	1	CswayX
	2	CswayX15
3	1	FBswayX
	2	FBswayX15

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	.573	5.570	2	.062	.701	.772	.500
time	1.000	.000	0	.	1.000	1.000	1.000
condition * time	.735	3.083	2	.214	.790	.901	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: condition + time + condition * time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Sphericity Assumed	281.701	2	140.851	20.356	.000	.649	40.713	1.000
	Greenhouse-Geisser	281.701	1.401	201.001	20.356	.000	.649	28.529	.997
	Huynh-Feldt	281.701	1.544	182.476	20.356	.000	.649	31.426	.999
	Lower-bound	281.701	1.000	281.701	20.356	.001	.649	20.356	.983
Error(condition)	Sphericity Assumed	152.223	22	6.919					
	Greenhouse-Geisser	152.223	15.416	9.874					
	Huynh-Feldt	152.223	16.982	8.964					
	Lower-bound	152.223	11.000	13.838					
time	Sphericity Assumed	62.100	1	62.100	16.815	.002	.605	16.815	.961
	Greenhouse-Geisser	62.100	1.000	62.100	16.815	.002	.605	16.815	.961
	Huynh-Feldt	62.100	1.000	62.100	16.815	.002	.605	16.815	.961
	Lower-bound	62.100	1.000	62.100	16.815	.002	.605	16.815	.961
Error(time)	Sphericity Assumed	40.625	11	3.693					
	Greenhouse-Geisser	40.625	11.000	3.693					
	Huynh-Feldt	40.625	11.000	3.693					
	Lower-bound	40.625	11.000	3.693					
condition * time	Sphericity Assumed	10.814	2	5.407	1.598	.225	.127	3.197	.301
	Greenhouse-Geisser	10.814	1.581	6.842	1.598	.230	.127	2.527	.265
	Huynh-Feldt	10.814	1.801	6.003	1.598	.228	.127	2.879	.285
	Lower-bound	10.814	1.000	10.814	1.598	.232	.127	1.598	.212
Error(condition*time)	Sphericity Assumed	74.420	22	3.383					
	Greenhouse-Geisser	74.420	17.387	4.280					
	Huynh-Feldt	74.420	19.815	3.756					
	Lower-bound	74.420	11.000	6.765					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	condition	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Linear		209.377	1	209.377	18.312	.001	.625	18.312	.973
	Quadratic		72.324	1	72.324	30.077	.000	.732	30.077	.999
Error(condition)	Linear		125.772	11	11.434					
	Quadratic		26.451	11	2.405					
time		Linear	62.100	1	62.100	16.815	.002	.605	16.815	.961
Error(time)		Linear	40.625	11	3.693					
condition * time	Linear	Linear	10.615	1	10.615	6.039	.032	.354	6.039	.610
	Quadratic	Linear	.199	1	.199	.040	.846	.004	.040	.054
Error(condition*time)	Linear	Linear	19.334	11	1.758					
	Quadratic	Linear	55.085	11	5.008					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	33911.136	1	33911.136	1911.331	.000	.994	1911.331	1.000
Error	195.164	11	17.742					

a. Computed using alpha = .05

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

condition	time	Dependent Variable
1	1	RTswayY
	2	RTswayY15
2	1	CswayY
	2	CswayY15
3	1	FBswayY
	2	FBswayY15

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	.386	8.569	2	.014	.620	.664	.500
time	1.000	.000	0	.	1.000	1.000	1.000
condition * time	.947	.493	2	.781	.949	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: condition + time + condition * time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Sphericity Assumed	321.282	2	160.641	24.982	.000	.714	49.964	1.000
	Greenhouse-Geisser	321.282	1.239	259.290	24.982	.000	.714	30.955	.999
	Huynh-Feldt	321.282	1.327	242.024	24.982	.000	.714	33.163	.999
	Lower-bound	321.282	1.000	321.282	24.982	.001	.714	24.982	.994
Error(condition)	Sphericity Assumed	128.605	20	6.430					
	Greenhouse-Geisser	128.605	12.391	10.379					
	Huynh-Feldt	128.605	13.275	9.688					
	Lower-bound	128.605	10.000	12.860					
time	Sphericity Assumed	121.068	1	121.068	15.303	.003	.605	15.303	.940
	Greenhouse-Geisser	121.068	1.000	121.068	15.303	.003	.605	15.303	.940
	Huynh-Feldt	121.068	1.000	121.068	15.303	.003	.605	15.303	.940
	Lower-bound	121.068	1.000	121.068	15.303	.003	.605	15.303	.940
Error(time)	Sphericity Assumed	79.113	10	7.911					
	Greenhouse-Geisser	79.113	10.000	7.911					
	Huynh-Feldt	79.113	10.000	7.911					
	Lower-bound	79.113	10.000	7.911					
condition * time	Sphericity Assumed	95.192	2	47.596	12.038	.000	.546	24.076	.987
	Greenhouse-Geisser	95.192	1.899	50.135	12.038	.000	.546	22.857	.984
	Huynh-Feldt	95.192	2.000	47.596	12.038	.000	.546	24.076	.987
	Lower-bound	95.192	1.000	95.192	12.038	.006	.546	12.038	.877
Error(condition*time)	Sphericity Assumed	79.075	20	3.954					
	Greenhouse-Geisser	79.075	18.987	4.165					
	Huynh-Feldt	79.075	20.000	3.954					
	Lower-bound	79.075	10.000	7.908					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	condition	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Linear		245.601	1	245.601	21.483	.001	.682	21.483	.986
	Quadratic		75.682	1	75.682	52.989	.000	.841	52.989	1.000
Error(condition)	Linear		114.322	10	11.432					
	Quadratic		14.282	10	1.428					
time		Linear	121.068	1	121.068	15.303	.003	.605	15.303	.940
Error(time)		Linear	79.113	10	7.911					
condition * time	Linear	Linear	48.712	1	48.712	10.760	.008	.518	10.760	.840
	Quadratic	Linear	46.480	1	46.480	13.750	.004	.579	13.750	.915
Error(condition*time)	Linear	Linear	45.271	10	4.527					
	Quadratic	Linear	33.804	10	3.380					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	18628.136	1	18628.136	916.737	.000	.989	916.737	1.000
Error	203.200	10	20.320					

a. Computed using alpha = .05

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

condition	time	Dependent Variable
1	1	RTdistX
	2	RTdistX15
2	1	CdistX
	2	CdistX15
3	1	FBdistX
	2	FBdistX15

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	.791	2.350	2	.309	.827	.955	.500
time	1.000	.000	0	.	1.000	1.000	1.000
condition * time	.673	3.953	2	.139	.754	.848	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: condition + time + condition * time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Sphericity Assumed	282440.816	2	141220.408	9.213	.001	.456	18.427	.957
	Greenhouse-Geisser	282440.816	1.654	170795.298	9.213	.003	.456	15.236	.923
	Huynh-Feldt	282440.816	1.909	147935.329	9.213	.002	.456	17.590	.950
	Lower-bound	282440.816	1.000	282440.816	9.213	.011	.456	9.213	.789
Error(condition)	Sphericity Assumed	337208.083	22	15327.640					
	Greenhouse-Geisser	337208.083	18.190	18537.610					
	Huynh-Feldt	337208.083	21.001	16056.457					
	Lower-bound	337208.083	11.000	30655.280					
time	Sphericity Assumed	100669.360	1	100669.360	13.851	.003	.557	13.851	.922
	Greenhouse-Geisser	100669.360	1.000	100669.360	13.851	.003	.557	13.851	.922
	Huynh-Feldt	100669.360	1.000	100669.360	13.851	.003	.557	13.851	.922
	Lower-bound	100669.360	1.000	100669.360	13.851	.003	.557	13.851	.922
Error(time)	Sphericity Assumed	79947.140	11	7267.922					
	Greenhouse-Geisser	79947.140	11.000	7267.922					
	Huynh-Feldt	79947.140	11.000	7267.922					
	Lower-bound	79947.140	11.000	7267.922					
condition * time	Sphericity Assumed	58019.683	2	29009.842	4.867	.018	.307	9.733	.744
	Greenhouse-Geisser	58019.683	1.508	38482.125	4.867	.029	.307	7.337	.649
	Huynh-Feldt	58019.683	1.695	34223.485	4.867	.024	.307	8.250	.688
	Lower-bound	58019.683	1.000	58019.683	4.867	.050	.307	4.867	.521
Error(condition*time)	Sphericity Assumed	131143.015	22	5961.046					
	Greenhouse-Geisser	131143.015	16.585	7907.445					
	Huynh-Feldt	131143.015	18.648	7032.364					
	Lower-bound	131143.015	11.000	11922.092					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	condition	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Linear		251028.217	1	251028.217	14.718	.003	.572	14.718	.936
	Quadratic		31412.600	1	31412.600	2.310	.157	.174	2.310	.284
Error(condition)	Linear		187615.386	11	17055.944					
	Quadratic		149592.697	11	13599.336					
time		Linear	100669.360	1	100669.360	13.851	.003	.557	13.851	.922
Error(time)		Linear	79947.140	11	7267.922					
condition * time	Linear	Linear	35990.791	1	35990.791	13.001	.004	.542	13.001	.906
	Quadratic	Linear	22028.892	1	22028.892	2.407	.149	.180	2.407	.294
Error(condition*time)	Linear	Linear	30452.043	11	2768.368					
	Quadratic	Linear	100690.973	11	9153.725					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	3049831.296	1	3049831.296	108.367	.000	.908	108.367	1.000
Error	309577.886	11	28143.444					

a. Computed using alpha = .05

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

condition	time	Dependent Variable
1	1	RTdistY
	2	RTdistY15
2	1	CdistY
	2	CdistY15
3	1	FBdistY
	2	FBdistY15

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	.385	8.591	2	.014	.619	.663	.500
time	1.000	.000	0	.	1.000	1.000	1.000
condition * time	.693	3.301	2	.192	.765	.876	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: condition + time + condition * time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Sphericity Assumed	340415.978	2	170207.989	4.908	.018	.329	9.815	.741
	Greenhouse-Geisser	340415.978	1.238	274885.209	4.908	.040	.329	6.078	.581
	Huynh-Feldt	340415.978	1.327	256626.006	4.908	.037	.329	6.510	.603
	Lower-bound	340415.978	1.000	340415.978	4.908	.051	.329	4.908	.516
Error(condition)	Sphericity Assumed	693648.653	20	34682.433					
	Greenhouse-Geisser	693648.653	12.384	56011.988					
	Huynh-Feldt	693648.653	13.265	52291.401					
	Lower-bound	693648.653	10.000	69364.865					
time	Sphericity Assumed	86911.212	1	86911.212	7.630	.020	.433	7.630	.702
	Greenhouse-Geisser	86911.212	1.000	86911.212	7.630	.020	.433	7.630	.702
	Huynh-Feldt	86911.212	1.000	86911.212	7.630	.020	.433	7.630	.702
	Lower-bound	86911.212	1.000	86911.212	7.630	.020	.433	7.630	.702
Error(time)	Sphericity Assumed	113912.755	10	11391.276					
	Greenhouse-Geisser	113912.755	10.000	11391.276					
	Huynh-Feldt	113912.755	10.000	11391.276					
	Lower-bound	113912.755	10.000	11391.276					
condition * time	Sphericity Assumed	58715.530	2	29357.765	4.469	.025	.309	8.937	.698
	Greenhouse-Geisser	58715.530	1.530	38370.547	4.469	.038	.309	6.838	.608
	Huynh-Feldt	58715.530	1.751	33528.308	4.469	.031	.309	7.826	.653
	Lower-bound	58715.530	1.000	58715.530	4.469	.061	.309	4.469	.480
Error(condition*time)	Sphericity Assumed	131393.399	20	6569.670					
	Greenhouse-Geisser	131393.399	15.302	8586.547					
	Huynh-Feldt	131393.399	17.512	7502.953					
	Lower-bound	131393.399	10.000	13139.340					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	condition	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Linear		327129.717	1	327129.717	6.818	.026	.405	6.818	.654
	Quadratic		13286.260	1	13286.260	.621	.449	.058	.621	.110
Error(condition)	Linear		479813.740	10	47981.374					
	Quadratic		213834.913	10	21383.491					
time		Linear	86911.212	1	86911.212	7.630	.020	.433	7.630	.702
Error(time)		Linear	113912.755	10	11391.276					
condition * time	Linear	Linear	45513.089	1	45513.089	13.978	.004	.583	13.978	.919
	Quadratic	Linear	13202.440	1	13202.440	1.336	.275	.118	1.336	.182
Error(condition*time)	Linear	Linear	32559.471	10	3255.947					
	Quadratic	Linear	98833.928	10	9883.393					

a. Computed using alpha = .05

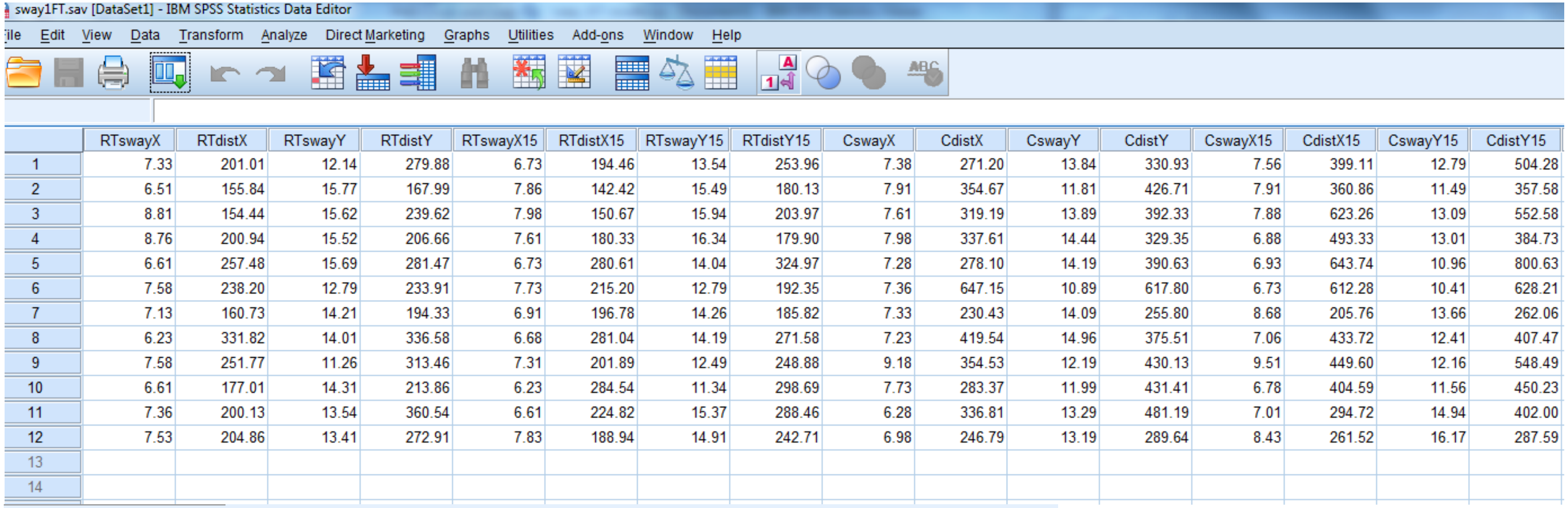
Tests of Between-Subjects Effects

Measure: MEASURE_1

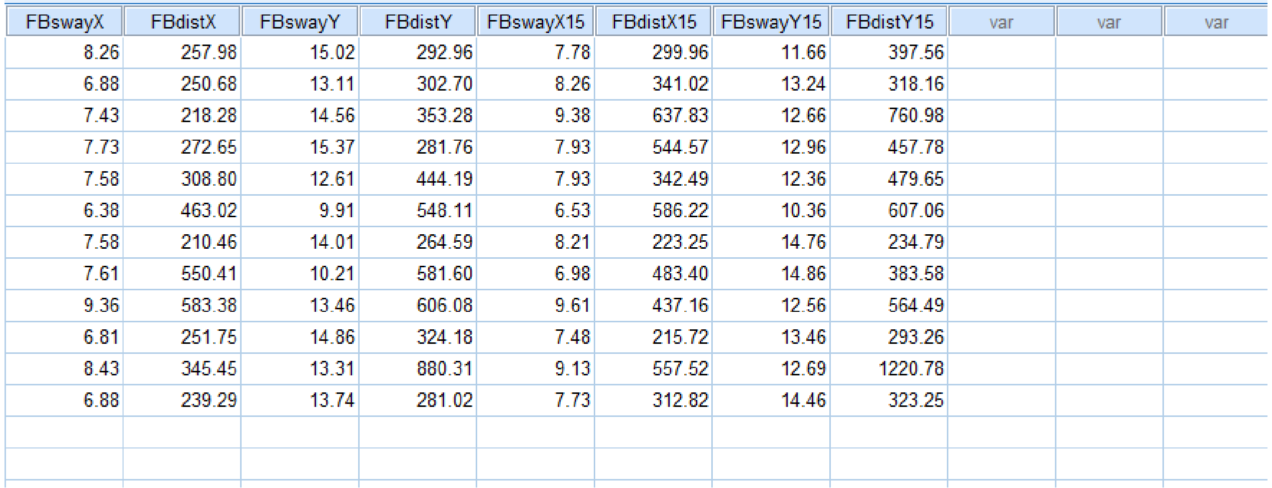
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	2435792.659	1	2435792.659	52.451	.000	.840	52.451	1.000
Error	464391.602	10	46439.160					

a. Computed using alpha = .05



	RTswayX	RTdistX	RTswayY	RTdistY	RTswayX15	RTdistX15	RTswayY15	RTdistY15	CswayX	CdistX	CswayY	CdistY	CswayX15	CdistX15	CswayY15	CdistY15
1	7.33	201.01	12.14	279.88	6.73	194.46	13.54	253.96	7.38	271.20	13.84	330.93	7.56	399.11	12.79	504.28
2	6.51	155.84	15.77	167.99	7.86	142.42	15.49	180.13	7.91	354.67	11.81	426.71	7.91	360.86	11.49	357.58
3	8.81	154.44	15.62	239.62	7.98	150.67	15.94	203.97	7.61	319.19	13.89	392.33	7.88	623.26	13.09	552.58
4	8.76	200.94	15.52	206.66	7.61	180.33	16.34	179.90	7.98	337.61	14.44	329.35	6.88	493.33	13.01	384.73
5	6.61	257.48	15.69	281.47	6.73	280.61	14.04	324.97	7.28	278.10	14.19	390.63	6.93	643.74	10.96	800.63
6	7.58	238.20	12.79	233.91	7.73	215.20	12.79	192.35	7.36	647.15	10.89	617.80	6.73	612.28	10.41	628.21
7	7.13	160.73	14.21	194.33	6.91	196.78	14.26	185.82	7.33	230.43	14.09	255.80	8.68	205.76	13.66	262.06
8	6.23	331.82	14.01	336.58	6.68	281.04	14.19	271.58	7.23	419.54	14.96	375.51	7.06	433.72	12.41	407.47
9	7.58	251.77	11.26	313.46	7.31	201.89	12.49	248.88	9.18	354.53	12.19	430.13	9.51	449.60	12.16	548.49
10	6.61	177.01	14.31	213.86	6.23	284.54	11.34	298.69	7.73	283.37	11.99	431.41	6.78	404.59	11.56	450.23
11	7.36	200.13	13.54	360.54	6.61	224.82	15.37	288.46	6.28	336.81	13.29	481.19	7.01	294.72	14.94	402.00
12	7.53	204.86	13.41	272.91	7.83	188.94	14.91	242.71	6.98	246.79	13.19	289.64	8.43	261.52	16.17	287.59
13																
14																



FBswayX	FBdistX	FBswayY	FBdistY	FBswayX15	FBdistX15	FBswayY15	FBdistY15	var	var	var
8.26	257.98	15.02	292.96	7.78	299.96	11.66	397.56			
6.88	250.68	13.11	302.70	8.26	341.02	13.24	318.16			
7.43	218.28	14.56	353.28	9.38	637.83	12.66	760.98			
7.73	272.65	15.37	281.76	7.93	544.57	12.96	457.78			
7.58	308.80	12.61	444.19	7.93	342.49	12.36	479.65			
6.38	463.02	9.91	548.11	6.53	586.22	10.36	607.06			
7.58	210.46	14.01	264.59	8.21	223.25	14.76	234.79			
7.61	550.41	10.21	581.60	6.98	483.40	14.86	383.58			
9.36	583.38	13.46	606.08	9.61	437.16	12.56	564.49			
6.81	251.75	14.86	324.18	7.48	215.72	13.46	293.26			
8.43	345.45	13.31	880.31	9.13	557.52	12.69	1220.78			
6.88	239.29	13.74	281.02	7.73	312.82	14.46	323.25			

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

condition	time	Dependent Variable
1	1	RTswayX
	2	RTswayX15
2	1	CswayX
	2	CswayX15
3	1	FBswayX
	2	FBswayX15

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	.912	.925	2	.630	.919	1.000	.500
time	1.000	.000	0	.	1.000	1.000	1.000
condition * time	.995	.046	2	.977	.995	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: condition + time + condition * time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Sphericity Assumed	3.898	2	1.949	2.881	.077	.208	5.762	.506
	Greenhouse-Geisser	3.898	1.838	2.121	2.881	.083	.208	5.294	.481
	Huynh-Feldt	3.898	2.000	1.949	2.881	.077	.208	5.762	.506
	Lower-bound	3.898	1.000	3.898	2.881	.118	.208	2.881	.341
Error(condition)	Sphericity Assumed	14.884	22	.677					
	Greenhouse-Geisser	14.884	20.213	.736					
	Huynh-Feldt	14.884	22.000	.677					
	Lower-bound	14.884	11.000	1.353					
time	Sphericity Assumed	.391	1	.391	1.115	.314	.092	1.115	.162
	Greenhouse-Geisser	.391	1.000	.391	1.115	.314	.092	1.115	.162
	Huynh-Feldt	.391	1.000	.391	1.115	.314	.092	1.115	.162
	Lower-bound	.391	1.000	.391	1.115	.314	.092	1.115	.162
Error(time)	Sphericity Assumed	3.856	11	.351					
	Greenhouse-Geisser	3.856	11.000	.351					
	Huynh-Feldt	3.856	11.000	.351					
	Lower-bound	3.856	11.000	.351					
condition * time	Sphericity Assumed	1.314	2	.657	2.835	.080	.205	5.669	.499
	Greenhouse-Geisser	1.314	1.991	.660	2.835	.081	.205	5.643	.497
	Huynh-Feldt	1.314	2.000	.657	2.835	.080	.205	5.669	.499
	Lower-bound	1.314	1.000	1.314	2.835	.120	.205	2.835	.337
Error(condition*time)	Sphericity Assumed	5.100	22	.232					
	Greenhouse-Geisser	5.100	21.898	.233					
	Huynh-Feldt	5.100	22.000	.232					
	Lower-bound	5.100	11.000	.464					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	condition	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Linear		3.889	1	3.889	4.488	.058	.290	4.488	.489
	Quadratic		.008	1	.008	.017	.898	.002	.017	.052
Error(condition)	Linear		9.533	11	.867					
	Quadratic		5.351	11	.486					
time		Linear	.391	1	.391	1.115	.314	.092	1.115	.162
Error(time)		Linear	3.856	11	.351					
condition * time	Linear	Linear	1.286	1	1.286	5.584	.038	.337	5.584	.577
	Quadratic	Linear	.028	1	.028	.119	.736	.011	.119	.062
Error(condition*time)	Linear	Linear	2.534	11	.230					
	Quadratic	Linear	2.566	11	.233					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	4107.107	1	4107.107	2469.840	.000	.996	2469.840	1.000
Error	18.292	11	1.663					

a. Computed using alpha = .05

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

condition	time	Dependent Variable
1	1	RTswayY
	2	RTswayY15
2	1	CswayY
	2	CswayY15
3	1	FBswayY
	2	FBswayY15

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	.853	1.590	2	.452	.872	1.000	.500
time	1.000	.000	0	.	1.000	1.000	1.000
condition * time	.684	3.799	2	.150	.760	.856	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: condition + time + condition * time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power^a
condition	Sphericity Assumed	18.039	2	9.019	5.168	.014	.320	10.336	.770
	Greenhouse-Geisser	18.039	1.744	10.345	5.168	.019	.320	9.011	.725
	Huynh-Feldt	18.039	2.000	9.019	5.168	.014	.320	10.336	.770
	Lower-bound	18.039	1.000	18.039	5.168	.044	.320	5.168	.545
Error(condition)	Sphericity Assumed	38.395	22	1.745					
	Greenhouse-Geisser	38.395	19.180	2.002					
	Huynh-Feldt	38.395	22.000	1.745					
	Lower-bound	38.395	11.000	3.490					
time	Sphericity Assumed	.847	1	.847	.513	.489	.045	.513	.101
	Greenhouse-Geisser	.847	1.000	.847	.513	.489	.045	.513	.101
	Huynh-Feldt	.847	1.000	.847	.513	.489	.045	.513	.101
	Lower-bound	.847	1.000	.847	.513	.489	.045	.513	.101
Error(time)	Sphericity Assumed	18.148	11	1.650					
	Greenhouse-Geisser	18.148	11.000	1.650					
	Huynh-Feldt	18.148	11.000	1.650					
	Lower-bound	18.148	11.000	1.650					
condition * time	Sphericity Assumed	1.663	2	.831	.609	.553	.052	1.218	.138
	Greenhouse-Geisser	1.663	1.520	1.094	.609	.512	.052	.925	.126
	Huynh-Feldt	1.663	1.713	.971	.609	.530	.052	1.043	.131
	Lower-bound	1.663	1.000	1.663	.609	.452	.052	.609	.110
Error(condition*time)	Sphericity Assumed	30.042	22	1.366					
	Greenhouse-Geisser	30.042	16.717	1.797					
	Huynh-Feldt	30.042	18.839	1.595					
	Lower-bound	30.042	11.000	2.731					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	condition	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Linear		10.757	1	10.757	5.000	.047	.313	5.000	.532
	Quadratic		7.282	1	7.282	5.438	.040	.331	5.438	.566
Error(condition)	Linear		23.664	11	2.151					
	Quadratic		14.731	11	1.339					
time		Linear	.847	1	.847	.513	.489	.045	.513	.101
Error(time)		Linear	18.148	11	1.650					
condition * time	Linear	Linear	.896	1	.896	.556	.472	.048	.556	.105
	Quadratic	Linear	.767	1	.767	.685	.425	.059	.685	.118
Error(condition*time)	Linear	Linear	17.729	11	1.612					
	Quadratic	Linear	12.312	11	1.119					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	12977.051	1	12977.051	2341.982	.000	.995	2341.982	1.000
Error	60.952	11	5.541					

a. Computed using alpha = .05

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

condition	time	Dependent Variable
1	1	RTdistX
	2	RTdistX15
2	1	CdistX
	2	CdistX15
3	1	FBdistX
	2	FBdistX15

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	.954	.471	2	.790	.956	1.000	.500
time	1.000	.000	0	.	1.000	1.000	1.000
condition * time	.911	.932	2	.628	.918	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: condition + time + condition * time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Sphericity Assumed	451597.934	2	225798.967	22.446	.000	.671	44.893	1.000
	Greenhouse-Geisser	451597.934	1.912	236189.497	22.446	.000	.671	42.918	1.000
	Huynh-Feldt	451597.934	2.000	225798.967	22.446	.000	.671	44.893	1.000
	Lower-bound	451597.934	1.000	451597.934	22.446	.001	.671	22.446	.990
Error(condition)	Sphericity Assumed	221309.758	22	10059.534					
	Greenhouse-Geisser	221309.758	21.032	10522.441					
	Huynh-Feldt	221309.758	22.000	10059.534					
	Lower-bound	221309.758	11.000	20119.069					
time	Sphericity Assumed	63629.960	1	63629.960	6.771	.025	.381	6.771	.660
	Greenhouse-Geisser	63629.960	1.000	63629.960	6.771	.025	.381	6.771	.660
	Huynh-Feldt	63629.960	1.000	63629.960	6.771	.025	.381	6.771	.660
	Lower-bound	63629.960	1.000	63629.960	6.771	.025	.381	6.771	.660
Error(time)	Sphericity Assumed	103366.889	11	9396.990					
	Greenhouse-Geisser	103366.889	11.000	9396.990					
	Huynh-Feldt	103366.889	11.000	9396.990					
	Lower-bound	103366.889	11.000	9396.990					
condition * time	Sphericity Assumed	31264.299	2	15632.149	2.525	.103	.187	5.049	.452
	Greenhouse-Geisser	31264.299	1.837	17023.045	2.525	.109	.187	4.636	.430
	Huynh-Feldt	31264.299	2.000	15632.149	2.525	.103	.187	5.049	.452
	Lower-bound	31264.299	1.000	31264.299	2.525	.140	.187	2.525	.306
Error(condition*time)	Sphericity Assumed	136226.816	22	6192.128					
	Greenhouse-Geisser	136226.816	20.202	6743.082					
	Huynh-Feldt	136226.816	22.000	6192.128					
	Lower-bound	136226.816	11.000	12384.256					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	condition	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Linear		310116.007	1	310116.007	27.763	.000	.716	27.763	.998
	Quadratic		141481.927	1	141481.927	15.810	.002	.590	15.810	.951
Error(condition)	Linear		122870.924	11	11170.084					
	Quadratic		98438.834	11	8948.985					
time		Linear	63629.960	1	63629.960	6.771	.025	.381	6.771	.660
Error(time)		Linear	103366.889	11	9396.990					
condition * time	Linear	Linear	21775.331	1	21775.331	3.349	.094	.233	3.349	.386
	Quadratic	Linear	9488.968	1	9488.968	1.613	.230	.128	1.613	.213
Error(condition*time)	Linear	Linear	71521.145	11	6501.922					
	Quadratic	Linear	64705.671	11	5882.334					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	7521961.295	1	7521961.295	222.793	.000	.953	222.793	1.000
Error	371383.996	11	33762.181					

a. Computed using alpha = .05

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

condition	time	Dependent Variable
1	1	RTdistY
	2	RTdistY15
2	1	CdistY
	2	CdistY15
3	1	FBdistY
	2	FBdistY15

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	.609	4.957	2	.084	.719	.798	.500
time	1.000	.000	0	.	1.000	1.000	1.000
condition * time	.734	3.094	2	.213	.790	.900	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: condition + time + condition * time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Sphericity Assumed	654805.121	2	327402.561	11.173	.000	.504	22.346	.982
	Greenhouse-Geisser	654805.121	1.438	455368.636	11.173	.002	.504	16.067	.942
	Huynh-Feldt	654805.121	1.595	410424.102	11.173	.001	.504	17.826	.958
	Lower-bound	654805.121	1.000	654805.121	11.173	.007	.504	11.173	.860
Error(condition)	Sphericity Assumed	644656.752	22	29302.580					
	Greenhouse-Geisser	644656.752	15.818	40755.563					
	Huynh-Feldt	644656.752	17.550	36733.020					
	Lower-bound	644656.752	11.000	58605.159					
time	Sphericity Assumed	30636.149	1	30636.149	3.729	.080	.253	3.729	.422
	Greenhouse-Geisser	30636.149	1.000	30636.149	3.729	.080	.253	3.729	.422
	Huynh-Feldt	30636.149	1.000	30636.149	3.729	.080	.253	3.729	.422
	Lower-bound	30636.149	1.000	30636.149	3.729	.080	.253	3.729	.422
Error(time)	Sphericity Assumed	90374.023	11	8215.820					
	Greenhouse-Geisser	90374.023	11.000	8215.820					
	Huynh-Feldt	90374.023	11.000	8215.820					
	Lower-bound	90374.023	11.000	8215.820					
condition * time	Sphericity Assumed	32883.536	2	16441.768	2.082	.149	.159	4.164	.381
	Greenhouse-Geisser	32883.536	1.580	20816.570	2.082	.161	.159	3.289	.333
	Huynh-Feldt	32883.536	1.800	18269.067	2.082	.154	.159	3.747	.359
	Lower-bound	32883.536	1.000	32883.536	2.082	.177	.159	2.082	.261
Error(condition*time)	Sphericity Assumed	173747.131	22	7897.597					
	Greenhouse-Geisser	173747.131	17.376	9998.978					
	Huynh-Feldt	173747.131	19.800	8775.317					
	Lower-bound	173747.131	11.000	15795.194					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	condition	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
condition	Linear		569744.111	1	569744.111	15.052	.003	.578	15.052	.941
	Quadratic		85061.011	1	85061.011	4.099	.068	.271	4.099	.455
Error(condition)	Linear		416371.284	11	37851.935					
	Quadratic		228285.468	11	20753.224					
time		Linear	30636.149	1	30636.149	3.729	.080	.253	3.729	.422
Error(time)		Linear	90374.023	11	8215.820					
condition * time	Linear	Linear	25685.703	1	25685.703	3.057	.108	.217	3.057	.358
	Quadratic	Linear	7197.833	1	7197.833	.974	.345	.081	.974	.147
Error(condition*time)	Linear	Linear	92419.150	11	8401.741					
	Quadratic	Linear	81327.980	11	7393.453					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	10512674.133	1	10512674.133	162.263	.000	.937	162.263	1.000
Error	712664.755	11	64787.705					

a. Computed using alpha = .05