Association between external training loads and injury incidence during 44 weeks of military training

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Abstract

Military training is physically arduous and associated with high injury incidence. Unlike in high-performance sport, the interaction between training load and injury has not been extensively researched in military personnel. Sixty-three (43 men, 20 women; age 24 ± 2 years; stature 1.76 ± 0.09 m; body mass 79.1 ± 10.8 kg) British Army Officer Cadets undergoing 44 weeks of training at the Royal Military Academy Sandhurst volunteered to participate. Weekly training load (cumulative 7-day moderate-vigorous physical activity [MVPA], vigorous PA [VPA] and the ratio between MVPA and sedentary-light PA [SLPA; MVPA:SLPA]) was monitored using a wrist-worn accelerometer (GENEActiv, UK). Self-report injury data were collected and combined with musculoskeletal injuries recorded at the Academy medical centre. Training loads were divided into quartiles with the lowest load group used as the reference to enable comparisons using Odds Ratios (OR) and 95% confidence intervals (95% CI). Overall injury incidence was 60% with the most common injury sites being the ankle (22%) and knee (18%). High (load; OR; 95% CI [>2327 mins; 3.44; 1.80–6.56]) weekly cumulative MVPA exposure significantly increased odds of injury. Similarly, likelihood of injury significantly increased when exposed to low-moderate (0.42–0.47; 2.45 [1.19–5.04]), high-moderate (0.48–0.51;2.48 [1.21–5.10]) and high MVPA:SLPA loads (>0.51; 3.60 [1.80–7.21]). High MVPA, and high-moderate MVPA:SLPA increased odds of injury by ~2.0–3.5 fold, suggesting that the ratio of workload to recovery is important for mitigating injury occurrence.

KEY WORDS: Training load; Military Training; Injury Incidence

INTRODUCTION

Initial military training is a demanding structured programme that aims to develop, in civilians, the skills and physical fitness required for military service. Military injury epidemiology research reports overall military training-related musculoskeletal injury incidences ~40–60%, with the knee and the ankle the most common sites(1–8). A range of military training-related injury risk factors have been identified, including lower (relative) levels of physical fitness (1-6), high / low body mass, high / low body mass index (BMI) (2,5,6), high / low age (2,4,9) and sex (female) (3). Although non-modifiable factors such as age and sex may be of interest, it is arguably more important to study modifiable factors, such as fitness, body mass, BMI, nutrition and training loads, as these can be modified through appropriate recruitment and selection procedure, physical training and exercise prescription.

Training load is defined as the cumulative stress placed on an individual from single or multiple training sessions over a period of time (10) and has purported interaction with likelihood of injury occurrence in athletic populations and high performance sport (11,12). Given the similar arduous nature of military training and high incidence of injury, there is emerging interest in quantifying military training load (13.14), but little is understood regarding its potential role in injury risk and/or whether demands of training can be better managed to mitigate injury risk. The association between training load volume and injury risk is reported (i.e. number of steps taken) (15), but there is little known on the effect of volumes of training load at various intensities (e.g. vigorous physical activity time) and its potential role on injury incidence or whether the demands of training can be better prescribed to attenuate risk of injury.

Training loads are categorised as external (i.e. absolute amount of work performed) or internal (i.e. an individual's physiological response to the external load). Typically, in high-performance sport, external training loads are monitored using Global Positioning Systems (GPS) or accelerometers (12,16) and internal loads quantified using heart rate (HR) monitors or the session-rating of perceived exertion method (sRPE) (17,18). Longitudinal training load monitoring during military training is inherently difficult; access to participants is extremely limited and it is of the utmost importance that any monitoring method used is not distracting for the individual, leading to poor compliance because of competing priorities or changes in typical behaviours. Therefore, typical monitoring methods used in high-performance sport, such as GPS and HR monitoring, are not practical in the military environment due to inadequate battery life and potential comfort issues. Consequently, research investigating the longitudinal physical demands of military training has relied on techniques such as daily running logs (19), pedometers (15) and accelerometers (20,21) to provide a measure of training volume.

Military research has shown that high training volumes are associated with an increased injury risk (15,20-23). Wyss et al. (20) and Roos et al. (21) used body-worn accelerometers and identified that high physical activity (PA) is associated with an increased injury risk. The authors reported that adaptations to the programme—progressive marching distance (low to high manner)—decreased injury incidence. Although training loads are mostly determined by volume, insights from high-performance sport research suggest that training intensity is also a relevant measure of load, and training at high intensities can have a significant impact on injury risk(12).

This study aimed to examine the association between external training load at different intensities and injury incidence over 44 weeks of British Army Officer Cadet military training.

MATERIALS AND METHODS

Participants

Sixty three British Army Officer Cadets (OCs; 43 men; 24 ± 2 years, 1.80 ± 0.08 m, 83.7 ± 9.3 kg; 20 women; 24 ± 2 years, 1.68 ± 0.06 m, 69.1 ± 6.0 kg) undergoing training at the Royal Military Academy Sandhurst (RMAS) volunteered to participate in the study. Participants were given a verbal and written brief and then provided written informed consent. The study protocol was approved by the UK Ministry of Defence Research Ethics Committee (780/MoDREC/2017).

Procedures

The 44-week Commissioning Course (CC) at RMAS (three 14-week terms and 2 weeks of adventure training) consists of physically demanding military field exercises, regimental drill and formal physical training. This was an observational study where training load was monitored throughout the 44 weeks using an unobtrusive, wrist-worn accelerometer. Training load was not monitored during two weeks of adventure training (between Terms 2 and 3). Adventure training is completed by OCs in various locations (some overseas), therefore, whilst likely physically demanding, it was not possible to monitor this period due to logistical constraints

Training Load

Weekly training load (sum of 7-day period) throughout 44 weeks was quantified using a wrist-worn PA monitor (GENEActiv Original, GENEActiv™, Activinsights, Cambridge, UK). The GENEActiv Original is a tri-axial, ± 8 g seismic acceleration sensor, which is small (43mm x 40mm x 13mm), lightweight (16 grams) and splash proof. The GENEActiv has high instrument reliability and criterion validity, and research investigating PA cut points using the GENEActiv have demonstrated excellent classification accuracy of different intensities (sedentary, light, moderate and vigorous) (24,25,26,27). Participants were instructed to wear their monitor at all times (excluding showering). After consultation with participants, they were instructed to wear the watch on their preferred wrist in order to improve compliance. Individuals' daily data were excluded from the analysis if the device had been worn for <65% of the 24-hour day and their training week (7 days) data were considered invalid and excluded from the analysis if there were <4 days that met wear-time criteria (28). To prevent artificially low training load recommendations due to missing weekly data, a correction was applied to weekly data included in the event that the training load was calculated using ≥4 but <7 days. The correction divided the weekly cumulative load by the number of valid days then multiplied by 7. For example, if a participant only had 5 valid days of data within the training week, the cumulative load for that week would be divided by 5 and then multiplied by 7 to provide a more likely estimation of training load.

Measured PA was coded into categories with intensity cut-points defined using the sum of signal vector magnitudes (SVMgs [Equation 1]). GENEActiv measurement frequency was selected at 50 Hz and converted to summarise data over 60 s epochs, allowing an appropriate frequency to capture human movement whilst providing ~14 days of battery life. Due to this, researchers visited participants on-site every ~2 weeks to exchange their current device for a 'fresh' one. When recording at 50 Hz, time spent in each PA intensity was determined using the following automated thresholds within the GENEActiv Physical Activity Macro: sedentary (< 241 g·min [excluding time in bed]), light (241–338 g·min), moderate (339–1131 g·min), or vigorous (≥ 1132 g·min) activity. These cut-points are taken from the literature and scaled according to the measurement frequency (25).

$$\sum \left| \sqrt{x^2 + y^2 + z^2} - g \right|$$

Equation 1. Sum of signal vector magnitudes.

This equation is used to calculate the sum ($\sum$) of the signal vector magnitude (SVMgs)$\sqrt{x^2 + y^2 + z^2}$ with gravity subtracted (-g).

Summed moderate-vigorous PA (MVPA), vigorous PA (VPA) and the ratio between MVPA load and summed sedentary-light PA load (SLPA; MVPA:SLPA]) were used to quantify weekly training loads. The MVPA:SLPA ratio was selected as an exploratory measure to enable a calculation of an indicator of more strenuous activities to light/recovery activities; sedentary and light were grouped together due to the small window for light activity classification (241–338 g·min)

Weekly training loads were averaged over each Term to enable comparisons between Terms. Subsequently, for each of the PA metrics, each training week throughout the CC was categorised into quartiles (low, low-moderate, high-moderate, high) to investigate the influence on injury incidence. Therefore, categorisation of quartiles is only relative to this dataset and may not apply to other military training programmes.

Injury Incidence

Injury data were collected using a modified version of an Injury Reporting Questionnaire (IRQ), which has been used to document injuries in UK Armed Forces Personnel (8). Participants were asked to document every musculoskeletal injury, even if medical treatment was not required. These IRQ data were later combined with musculoskeletal injuries recorded at the RMAS medical centre during training extracted from the Defence Medical Information

Capability Programme (DMICP). Any duplicate injuries reported in self-report questionnaires and extracted from DMICP were only recorded as one single injury.

Injury incidence, which is the average risk of sustaining one or more injuries per OC, was calculated using Equation 3.

$$Incidence = \left(\frac{Number\ of\ OCs\ injured}{Number\ of\ OCs\ at\ risk}\right) \times 100$$

Equation 2. Calculation of injury incidence (29).The calculation was performed for each training week, for each training load quartile and for the duration of CC. The number of OCs at risk varied with the number of participants in the study, specifically with participant drop-out and an additional recruitment in Term 2 (Figure 1).

<< Insert Figure 1 about here >>

Incidence proportion: risk of repeat injury (IPRRI), which is an estimate of the probability of sustaining a second injury throughout the duration of the CC was also calculated for overall injury using Equation 4.

$$IPRRI = \left(\frac{Number\ of\ OCs\ with\ \geq 2\ injuries}{Number\ of\ OCs\ injured}\right) \times 100$$

Equation 3. Calculation of incidence proportion: risk of repeat injury (IPRRI)(29).The proportion of all injuries that represented the onset of injury (acute or overuse), the diagnosis (bone, joint, muscle or other), the anatomical site, and the activity associated with injury (adventure training, military operations or exercise, military work [not operations or exercise], physical training, recreation, sports, unsure or other), were also calculated as a percentage using Equation 4.

$$Injury\ proportion = \left(\frac{Number\ of\ injuries\ within\ category}{Total\ number\ of\ injuries}\right) \times 100$$

Equation 4. Calculation of injury proportion

Statistical Analysis

The sample size in this study was determined through opportunistic sampling and limited to practical resources. Data were analysed using SPSS Version 23.0 (IBM Corporation, New York, USA). One-way repeated measures analysis of variance (ANOVA) was used to assess mean differences in training load (MVPA, VPA and MVPA:SLPA) and injury incidence across the three terms. Where data were not normally distributed, a Friedman adjustment was used with Kendall's W reported. Where differences in training loads and injury incidence between terms were shown, *post hoc* tests with Bonferroni adjustment were used to control type I error rate. To assess the association between training load and injury incidence, mean weekly training loads across all three terms (full CC) were split into quartiles for analysis; quartile 1 (Q1 [low]), quartile 2 (Q2 [low-moderate]), quartile 3 (Q3 [high-moderate]) and quartile 4 (Q4 [high]). The low load range was used as the reference group to enable the comparison of injury risk with low-moderate, high-moderate and high loads using Odds Ratios (OR) and 95% confidence intervals (95% CI). Data are reported as mean ± SD and significance was set at $p<0.05$.

RESULTS

Injury Summary

The 63 OCs in the present study consented to self-report their injuries, but only 38 OCs consented for their injury data to be extracted from their medical records in DMICP. The medical records and IRQ each identified 27 injured OCs, however, only 16 were contained in both datasets so the same injuries were not consistently reported with each method.

Merged injury datasets identified 38 OCs with one or more injuries, resulting in an overall musculoskeletal injury incidence of 60%, with 65% incurring time lost from full duty. A greater proportion of injuries occurred acutely (55%) than those categorised as overuse (45%). Injury incidence was 80% in female OCs and 51% in male OCs. Once an OC sustained an injury during training the probability of sustaining another was 66%.

The total number of injuries reported was 116, with proportions of injury categories presented in Table 1. The most prevalent injury type sustained was to muscle (41%), followed by joint (33%). The majority of injuries occurred to the lower body (67%) where the most common injury site was the ankle (22%), followed by knee (18%), and the most highly reported activity associated with injury was ‘military exercise’ (59%).

<< Insert Table 1 about here>>

Between Term Training Load

Wear-Time Analysis

Mean daily wear time for Terms 1, 2 and 3 were 77 ± 30%, 74 ± 30% and 71 ± 33%, respectively.

Vigorous Physical Activity Minutes

Weekly VPA minutes for Terms 1, 2 and 3 were 339 ± 103, 226 ± 94 and 191 ± 87 minutes/week, respectively. There was a significant main effect of term in VPA ($x^2[2] = 6.727$, $p = 0.035$, Kendall’s $W = 0.31$), where Term 1 VPA was higher than Term 3 (mean difference: 148 minutes/week; $p = 0.003$). However, after correction for multiple comparisons *post* hoc pairwise comparisons VPA training loads did not significantly differ between Terms 1 and 2 (p = 0.018) or Terms 2 and 3 (p = 1.000).

Moderate-Vigorous Physical Activity Minutes

Weekly MVPA minutes for Terms 1, 2 and 3 were 2370 ± 264, 1982 ± 362 and 1882 ± 216 minutes/week, respectively. There was a significant main effect of term in MVPA ($x^2[2] = 7.818$, $p = 0.020$, Kendall's W = 0.36), Where Term 1 MVPA was higher than Term 3 (mean difference: 488 minutes/week; p = 0.002). However, after correction for multiple comparisons *post* hoc pairwise comparisons MVPA training loads did not significantly differ between Terms 1 and 2 (p = 0.033) or Terms 2 and 3 (p = 0.801).

MVPA:SLPA

Weekly MVPA:SLPA for Terms 1, 2 and 3 was 0.54 ± 0.09, 0.52 ± 0.10 and 0.44 ± 0.05, respectively. Although initial analysis indicated weekly MVPA:SLPA may differ between terms ($x^2[2] = 7.091$, $p = 0.029$, Kendall's W = .32), after correction for multiple comparisons *post* hoc pairwise comparisons showed differences were not statistically significant

Injury Incidence

Mean (± SD) weekly injury incidence for Term 1, 2 and 3 were 4.1 ± 1.8, 2.9 ± 2.5 and 2.5 ± 2.4 %, respectively. There was no significant difference in injury incidence between the three terms ($x^2[2] = 4.136$, $p = 0.126$, Kendall's W = .41)

Training Load and Injury Incidence

Mean weekly training loads and injury incidence during the CC are presented in Figure 2.

<< Insert Figure 2 about here >>

The quartiles of training load and likelihood of injury compared to the low load reference group are reported in Table 2. Compared to the low load referent, OCs were less likely to sustain an injury when exposed to high-moderate VPA training loads (243–316 minutes; OR = 0.52, 95% CI = 0.28–0.97; $p = 0.038$) in comparison to the low load reference group (< 199 minutes). However, OCs were significantly more likely to suffer an injury when in the high (> 2327 minutes; OR = 3.44, 95% CI = 1.80–6.56; $p = 0.002$) training load quartiles of MVPA in comparison to the low load (< 1767 minutes) reference group. Also, the likelihood of an OC sustaining an injury was significantly greater when in the low-moderate (0.42–0.47; OR = 2.45, 95% CI = 1.19–5.04; $p = 0.015$), high-moderate (0.47–0.51; OR = 2.48, 95% CI = 1.21–5.10; $p = 0.013$) and high (> 0.51; OR = 3.60, 95% CI = 1.80–7.21; $p < 0.001$) training load quartiles of MVPA:SLPA in comparison to the low load (< 0.42) reference group.

<< Insert Table 2 about here >>

DISCUSSION

This study examined the association between training load and injury incidence during military training. The key findings demonstrate higher VPA and MVPA:SLPA in Term 1 than Terms 2 and 3, respectively, suggesting a greater physical demand at the beginning of the training course. The overall injury incidence was 60% and the most common injury sites were the ankle and knee. Most notably, injury incidence did not differ between terms, and the likelihood of suffering an injury was significantly greater when OCs were exposed to high and high-moderate MVPA and MVPA:SLPA.

There was a significant difference in VPA, MVPA and MVPA:SLPA across terms, demonstrating that volume and intensity of training fluctuated throughout the course. Term 1 had a greater VPA training load than Term 3. Unlike traditional team sports where training load would be expected to increase gradually, following the overload principle (30), the objective of the CC is to physically and tactically prepare OCs to be operationally effective thus training loads are highly dependent on the specific military exercises programmed. Therefore, the increased demand at the beginning of training is not surprising. The highest VPA training load across the CC was seen in week 2 (562minutes) and the lowest in week 39 (43 minutes), indicating that within-term training load was not progressive. Similarly, whilst not statistically significant, MVPA:SLPA load was higher for Terms 1 and Term 2 compared to Term 3.In Terms 1 and 2 the MVPA:SLPA load was >0.5, indicating OCs were exposed to a greater amount of MVPA in relation to light activity and rest. These results correspond with a previous study of the physical demands of the CC at RMAS, which showed the highest physical activity counts (PACs) and percent heart rate reserve (%HRR) in week 6 of Term 1 (31). Similarly, the physical demands of the Combined Infantryman's Course for Parachute Regiment recruits was examined using PACs and authors reported little structured progression over the 24 weeks of training (32). Moreover, the high PACs during the Pre-Parachute Selection Test Week events (highly demanding 7-day period of physical tests) completed in weeks 19–20 were similar to the reported PACs in weeks 1–2, reinforcing the lack of progression of training stress. Little evidence of progression—measured by PACs—was found throughout 14 weeks of British Army Basic Training for both male and female recruits at a different training establishment (33). Indeed, the highest cardiovascular strain was reported in week 1 for both sexes. Likewise, recent research of US Army initial entry training demonstrated higher overall PA in the first three weeks compared to the overall training average (34).Whilst is noted that those data from previous studies are older and training may have changed, the results from the present study and previous literature are consistent, highlighting that the introduction of progression in the physical demands of training may optimise training, reducing the risk of injury and promoting physiological adaptation (30).

The present study demonstrated an overall injury incidence of 60%, with the most common site of injury being the ankle and knee. This finding is in agreement with previous literature investigating injuries sustained during military training (1-8) and is typically associated with the volume and frequency of marching and running, particularly while carrying external load, in trainees naïve in this practice Additionally, it has been noted in previous research that exposure to great amounts of PA, including bouts of load carriage, during military training can lead to a decline in neuromuscular function(35). A decline in neuromuscular fatigue may exacerbate poor biomechanics and decrease efficiency of movement, further contributing to an increase in injury risk (36). Findings from the present study suggest once an OC sustained an injury during training the probability of sustaining another was 66 %, highlighting the importance of identifying strategies to mitigate the likelihood of sustaining an initial injury. Although average weekly injury incidence was greatest in Term 1, this was not significantly higher than Terms 2 or 3. Injury rates are typically reported to be greater at the start of military training (6,21,37) and it is possible that the restriction in sample size in the current study meant it was underpowered to detect this difference. These findings, coupled with the tendency for military training to be more physically demanding in the early stages, as illustrated by the present and previous research (31,33,34), suggests that physical training load is imbalanced in the initial weeks of training.

To the authors' knowledge, no other study has examined the possible influence of training loads, at various intensities, on the likelihood of injury during military training. Furthermore, this research aimed to identify training load 'thresholds' whereby injury risk may be increased or decreased; previous research regarding training load and injury risk in this respect has focused on high-performance sport (18,38) and previous military research on this topic has focused on assessing the interaction between training volume and injury incidence (15,19,20). The present study demonstrated that OCs were significantly more likely to suffer an injury when in the high training load quartile of MVPA in comparison to the low-load reference group. Similar results were found in the moderate and high training load quartiles of MVPA:SLPA in comparison to the low load reference group. These results support the importance for OCs to have sufficient rest and light activity included in their programmes to recover from the more intense periods of training. Specifically, based on these data, weekly (sum of 7 days) MVPA training loads should be ~2000 minutes—accompanied by ~5000 minutes of SLPA—to reduce the odds of injury during the CC. This strategy would ensure the ratio between MVPA loads and SLPA is ~0.40, thus keeping OCs within these thresholds, which may be an optimum ratio of work to recovery, such that the body is not overworked. Additionally, this provides ~3080 minutes per week for time to sleep. Within the MVPA training load prescription, ensuring OCs are exposed to ~300 mins per week of vigorous activity and limiting moderate activity to ~1700 mins per week may provide the most suitable breakdown of activity.

This study has several limitations. Although it has been demonstrated that the GENEActiv wrist-worn accelerometer is a valid measurement tool of EE in military populations (39) and research investigating cut-points has demonstrated excellent classification accuracy of different intensities of PA (sedentary, light, moderate and vigorous)(25,26,27), individual calibration of activity intensity classification would be preferable and likely improve understanding of inter-individual training load differences. Intensity of activity largely depends on an individual's fitness level, that is, a fitter individual would be working at a lower relative intensity than their less-fit counterpart, despite the same absolute intensity. Calibrating for initial fitness levels this would take a substantial amount of time before training monitoring begins for both researchers and participants, which may be too burdensome to schedule within military training, particularly on a large-scale cohort that would notionally be monitored in this environment. Additionally, this study has applied a correction to account for missing weekly training load data. This correction works under the assumption that the missing data during the training week would be of the same volume and intensity as the recorded data. Whilst this is a major assumption, this presents one method of handling missing data captured from wearables when attempting to provide suitable, evidence-based recommendations. Not applying a correction to account for missing data in this context would cause artificially low training loads and therefore inaccurate recommendations. On average, participants provided 94 ± 60 (54 ± 17 %) days of data that met the wear-time criteria, highlighting the difficulties of compliance during longitudinal monitoring research. This study was not designed to predict injury but demonstrate the efficacy of objective approaches to monitor training and show a more evidence-based strategy is warranted in order to better prescribe training and potentially mitigate the risk of injury. Additionally, it is noted that other factors (e.g. injury history, participant characteristics, nutrition, smoking status may also contribute to injury risk. Furthermore, the small sample size, limited due to practical reasons, may not be sufficient for determining injury risk but beneficial for initial exploration of the association between training load and injury incidence in a military population. However, the sample size used in this study is similar to that of previous military research using repeated measures (32,33). Also, it is important to note that reporting of injuries may be underestimated in this population as it is possible that OCs would not report an injury, or seek medical attention, for minor injuries that they deem non-treatment worthy and/or fear of repercussions regarding their advancement in training.

Further evidence is required to determine the effectiveness of methods of monitoring internal training loads during military training. Although heart rate-derived internal loads have been quantified during acute periods of military training(13,14), longitudinal monitoring of the internal training loads of military personnel is inherently difficult; therefore, further investigation is warranted. Additionally, research assessing the effects of different components of fitness have on successful military performance is necessary to optimise military training programmes.

PERSPECTIVE

External training loads, monitored using a wrist-worn accelerometer, were associated with injury incidence during 44 weeks of basic military training for officers. Training loads were generally greater at the beginning of training and injury incidence was similar to previous UK military research. Officer Cadets were at an increased risk of injury when exposed to the highest loads of MVPA and MVPA:SLPA, supporting the need for adequate recovery during arduous training. These data suggest that limiting MVPA training loads to 2000 minutes and MVPA:SLPA to 0.40 might mitigate injury risk. Further interventions examining the effectiveness of these thresholds should be undertaken. This study highlights the need to monitor the training loads of military personnel during training and provides practitioners with an evidence-base to inform training prescription. Further research that assesses the validity of internal load monitoring and identifies the relevant components of fitness for successful military performance is recommended.

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Table 1. Number and proportion of each injury category and severity of time-loss injuries.

			All injuries		Time-loss injuries
	Injuries				Severity
Category	(n)	Proportion	Injuries (n)	Proportion	Median days of limited duty (IQR)
Activity					
Exercise	68	59%	41	55%	15 (20)
Physical Training	13	11%	9	12%	3 (4)
Military work	12	10%	7	9%	8 (7)
Sports	11	9%	8	11%	9 (25)
Recreation	5	4%	4	5%	20 (9)
Unsure (gradual onset)	4	3%	4	5%	6 (3)
Adventure Training	2	2%	1	1%	3 (-)
Other	1	1%	1	1%	6 (-)
Anatomical site					
Ankle	26	22%	16	21%	6 (12)
Knee	21	18%	14	19%	6 (6)
Leg	18	16%	14	19%	9 (25)
Shoulder	12	10%	10	13%	9 (13)
Lower back	8	7%	5	7%	10 (6)
Thigh/Hamstring	8	7%	7	9%	3 (4)
Chest/Ribs	6	5%	3	4%	14 (8)
Wrist/Hand/Fingers	6	5%	1	1%	51 (-)
Foot/Toe	4	3%	1	1%	29 (-)
Neck	3	3%	3	4%	2 (2)
Arm	2	2%	1	1%	34 (-)
Elbow	1	1%	0	0%	1 (-)
Hip/Pelvis/Groin	1	1%	0	0%	1 (-)
Diagnosis					
Muscle	47	41%	28	37%	4 (7)
Joint	38	33%	27	36%	13 (29)
Other	19	16%	13	17%	7 (10)

Bone	12	10%	7	9%	17 (20)

Table 2. Quartiles of training load and the likelihood of injury in comparison with the low load reference group.

Training Load	Load Thresholds	Odds Ratio	95% Confidence Intervals	
			Lower	Upper
VPA	< 199 minutes (reference)	1.00		
	199 to 242 minutes	0.69	0.39	1.23
	243 to 316 minutes	0.52*	0.28	0.97
	> 316 minutes	1.08	0.63	1.83
MVPA	< 1767 minutes (reference)	1.00		
	1767 to 2031 minutes	1.70	0.84	3.45
	2032 to 2327 minutes	1.95	0.98	3.89
	> 2327 minutes	3.44*	1.80	6.56
MVPA:SLPA	< 0.42 (reference)	1.00		
	0.42 to 0.47	2.25*	1.19	5.04
	0.48 to 0.51	2.48*	1.21	5.10
	> 0.51	3.60*	1.80	7.21

Note: Training load thresholds are defined as low, low-moderate, high-moderate, and high.

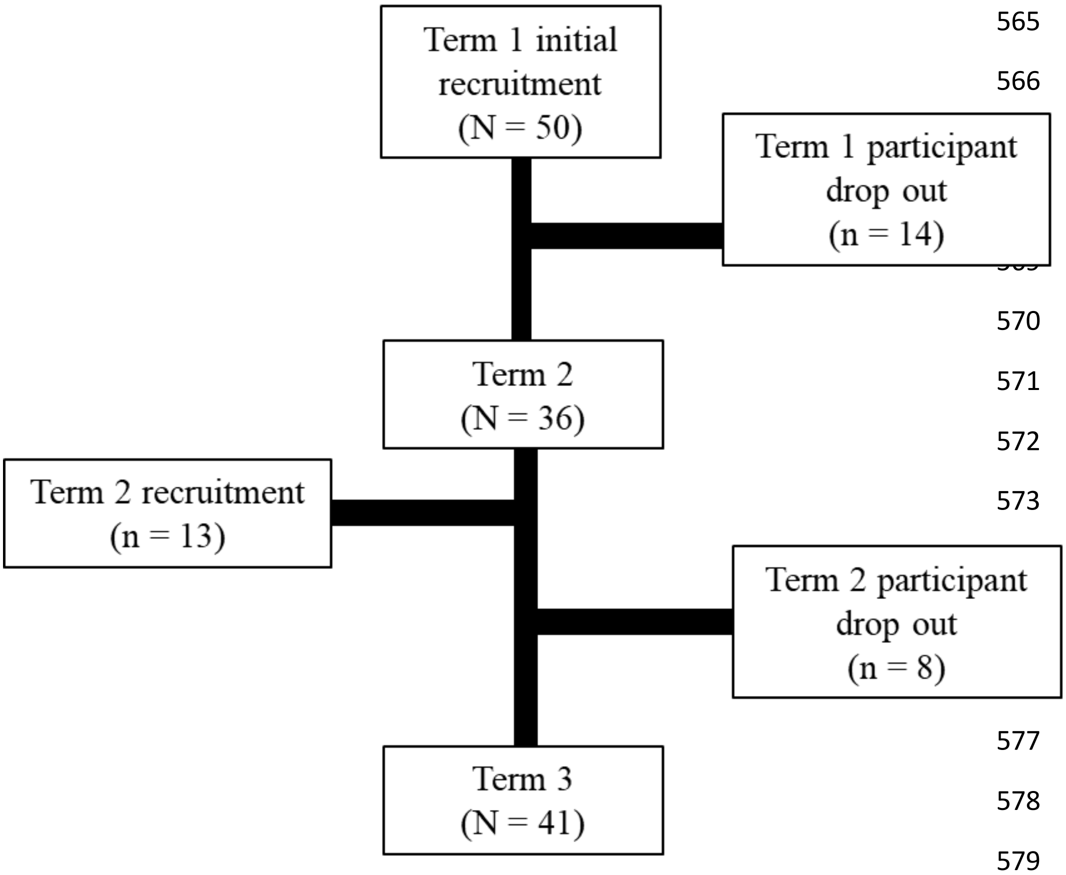
*Significantly different injury risk in comparison with reference group ($p<0.05$)

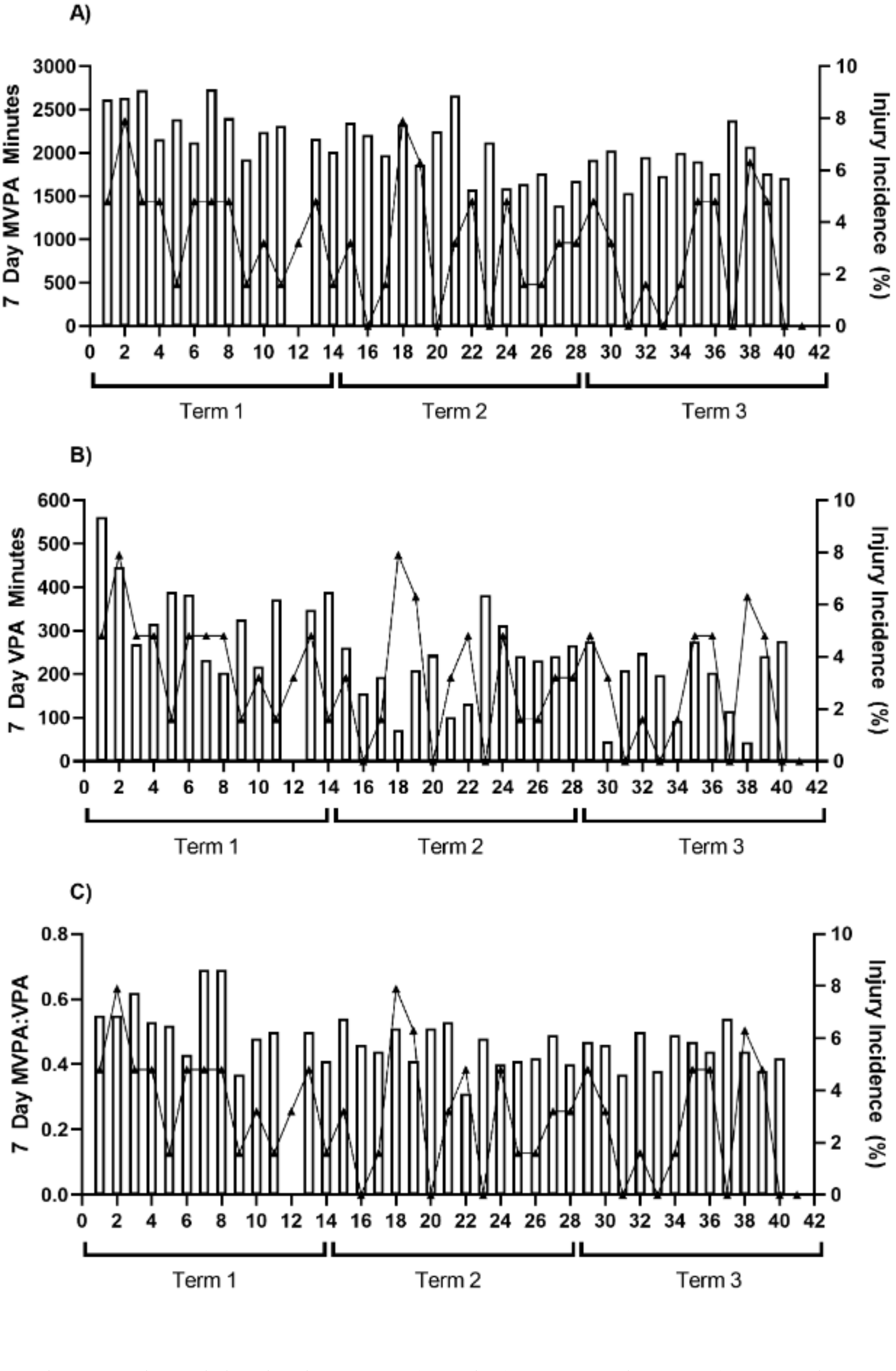
** Significantly different injury risk in comparison with reference group ($p<0.001$)

FIGURE LEGENDS

Figure 1. Participant recruitment and drop out throughout the CC.

Figure 2. OC initial military training mean weekly training loads and injury incidence. A) VPA minutes. B) MVPA minutes. C) MVPA:SLPA.





Note: Where bars are the training load measure (Panel A) MVPA minutes; B) VPA minutes; C) MVPA:SLPA) and black lines and markers are injury incidence.