Physical Employment Standards for UK Fire and Rescue Service Personnel

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Abstract

Background Evidence-based physical employment standards are vital for recruiting, training and maintaining the operational effectiveness of personnel in physically demanding occupations.

Aims (1) Develop criterion tests for in-service physical assessment, which simulate the role-related physical demands of UK Fire and Rescue Service (UK FRS) personnel. (2) Develop practical physical selection tests for FRS applicants. (3) Evaluate the validity of the selection tests to predict criterion test performance.

Methods Stage 1: We conducted a physical demands analysis involving seven workshops and an expert panel to document the key physical tasks required of UK FRS personnel and to develop 'criterion' and 'selection' tests. Stage 2: We measured the performance of 137 trainee and 50 trained UK FRS personnel on selection, criterion and 'field' measures of aerobic power, strength and body size. Statistical models were developed to predict criterion test performance. Stage 3: Subject matter experts derived minimum performance standards.

Results We developed single person simulations of the key physical tasks required of UK FRS personnel as criterion and selection tests (Rural Fire, Domestic Fire, Ladder Lift, Ladder Extension, Ladder Climb, Pump Assembly, Enclosed Space Search). Selection tests were marginally stronger predictors of criterion test performance (r=0.88–0.94, 95 % Limits of Agreement [LoA] 7.6–14.0 %) than field test scores (r=0.84–0.94, 95 % LoA 8.0–19.8 %) and offered greater face and content validity and more practical implementation.

Conclusions This study outlines the development of role-related, gender-free physical employment tests for the UK FRS, which conform to equal opportunities law.

Key words: emergency services, personnel, physical fitness, physical training, occupational fitness, screening, fitness for work, load carriage

Introduction

Physical employment standards are vital for recruiting, training and maintaining the operational effectiveness of personnel in physically demanding occupations (e.g. fire and rescue, police, military). They can be used at the point of selection and/or in service and their content, structure and pass standards should meet the requirements of equal opportunity law [1]. In the United Kingdom (UK) equal opportunities in employment are defined in the Equality Act 2010 [2], which covers nine protected characteristics including age, gender and sex. The legislation prohibits direct or indirect discrimination because of a protected characteristic. Direct discrimination occurs if someone is treated less favourably because of a protected characteristic (e.g. a different standard for men and women) and is not defendable by law. Indirect discrimination occurs if a provision, criterion or practice (such as a fitness test) puts someone from a protected group at a disadvantage, and cannot be justified as being a proportionate means of achieving a legitimate aim (e.g. if the test and/or pass standards do not reflect the job requirements). Similar legal requirements are in place across Europe, the United States (US) and Australia [1].

Constable and Palmer [3] provide a detailed commentary on the recommended processes to establish legally defensible physical employment standards and two excellent recently published reviews support their guidance [1, 4]. In brief, this process requires:

1. Conducting a job analysis to identify the physical demands of key criterion tasks (e.g. mass of objects, distance of movement, physiological strain)
2. Developing simulations of these tasks which are representative of the actual job but sufficiently controlled to be safe, and reliable (i.e. criterion tests)
3. Establishing the efficacy of using selection tests and/or generic fitness tests to assess personnel and establish whether training conducted between point of selection and taking up a qualified role influences criterion task performance

4. Proposing evidence-based performance standards.

The work of Fire and Rescue Service (FRS) personnel involves tasks such as manual handling, climbing, casualty extraction and fire fighting, typically wearing personal protective equipment (PPE, including breathing apparatus (BA)) and carrying equipment such as hose and cutters, resulting in considerable physiological strain [5, 6]. The physical demands of the roles of FRS personnel vary between nations, e.g. operating over vast areas of wild-land fires in Australia and the US [7] which would not be required to the same extent in smaller more temperate countries in Northern Europe [8]. There may also be regional differences e.g. tackling wild-land fires in rural areas versus high-rise building fires in urban areas. The UK FRS requires interoperability between local and regional hubs driving the need for generic nationwide employment standards.

In the UK, three studies have previously documented the physical requirements of FRS personnel roles [9-11] and were used to support the initial development of the first physical employment standards for UK FRS personnel. However, these studies and the resultant standards had four limitations: (1) different tests and standards were being used by different sub-groups within the UK FRS (i.e. it was not a truly national model); (2) the evidence base which underpinned the tests and standards was incomplete; (3) it was unclear whether the criterion tests still represented the current physical demands of UK FRS personnel's roles; (4) the tests did not examine the effects of changes in fitness and performance during induction training, rendering them of limited value as a tool to select applicants.

Therefore, the aims of this study were to: (1) Develop criterion tests to simulate the role-related physical capability of UK FRS personnel; (2) Develop practical physical selection tests for FRS applicants; (3) Evaluate the validity of the selection tests to predict criterion test performance.

Methods

We conducted this study between June 2002 and June 2005, following the recommended approach for developing physical employment tests [1, 3, 4]. Institutional ethics approval was granted. All procedures were conducted in accordance with the Declaration of Helsinki 2000 and all participants provided informed consent following a written and verbal brief of all procedures.

We collected data in three stages: Stage 1 consisted of a series of physical demands analysis workshops to underpin the development of criterion tests. We facilitated seven workshops where data from the peer-reviewed literature and technical reports were used to support discussions between subject matter experts (researchers, policymakers and trainers) and FRS personnel of different ages, genders, ranks, ethnicities and operational experience. The details of these workshops have been reported in detail elsewhere [12] and are summarised in Box 1. We used the outcomes to develop 'criterion' tests to simulate the key physical tasks required of FRS personnel, quantify personnel's performance and develop simplified 'selection' tests which could be undertaken by operationally untrained participants such as applicants to the UK FRS (described in Table 1).

In Stage 2 we measured performance on criterion tests, selection tests and generic fitness tests. Ideally, participants would have undertaken the selection tests at the time of application and the criterion tests at the end of initial training. However, attrition rates between application and successful completion of training were high and untenable for the purpose of our study, so we recruited trainees instead of applicants and tested them in weeks one and ten of initial training. A shortfall in the target numbers of female fire-fighters and those from ethnic minorities in the initial volunteer group necessitated the recruitment of a second cohort, which consisted of trained fire-fighters, who we tested over one week, with at least

24 hours rest between each testing session. We accounted for the 'operational training status' of participants (i.e. 'trained' vs. 'applicant') in the statistical analysis.

Participants completed three test sessions in the following order: (1) The 'selection tests' (Table 1; scores used to predict performance on the criterion tests). (2) The 'generic fitness tests' of aerobic fitness, muscular strength and body size (used to predict criterion test performances and assess their potential as an alternative to use at the point of application, compared to the 'selection tests'). We measured maximal aerobic power (VO_2max) using a Multistage Fitness Test (MSFT) [13]. We measured explosive leg power using a standing broad jump [14]. We estimated whole body strength from an upright pull test requiring participants to exert a maximal isometric force by pulling upwards for ~3 s on a bar connected to a strain gauge positioned 38 cm from the floor [14]. We measured body mass, fat mass and fat-free mass with participants wearing shorts and underwear. (3) The 'criterion tests' (as a measure of in service role-related physical performance; Table 1).

For Stage 3 we facilitated a series of subject matter expert meetings to propose pass standards. The panel of subject matter experts comprising currently serving and retired fire-fighters, and representatives from the employers, management and unions, attended a series of workshops to observe the tests being conducted and participate in discussions to: (1) Identify and document the essential physically demanding tasks in an operational environment required of all trained fire-fighters at the end of initial training. (2) Devise single person simulations of these essential tasks (criterion tests). (3) Define minimal standards of acceptable performance, and where appropriate higher standards of optimal performance, on the simulations.

Data are expressed as mean ± one standard deviation (SD). We performed comparative analyses between the different cohorts (e.g. male vs. female, white vs. ethnic minority) using Analysis of Variance (ANOVA) and independent sample t-tests using the Statistical Package for the Social Sciences (SPSS) version 11 for Windows. We made post-hoc pair wise comparisons using Tukey's honestly significant differences test [15]. Statistical significance was set a-priori at $p<0.05$. We used bivariate (paired) correlation analysis and Limits of Agreement (LoA) to compare the agreement between tests [16]; and we developed statistical models to predict criterion test performance from the selection and the generic fitness test scores using linear regression.

Results

Initially, 137 trainees from a range of UK FRSs volunteered to participate in the study (127 males and 10 females; 124 white and 13 ethnic minority groups; 122 whole-time and 15 retained). The second cohort comprised 50 trained fire-fighters (31 males and 19 females; 39 white and 11 ethnic minority groups; 44 whole-time and six retained).

The job analysis, shown in Box 1, documents the participants, structure, activities and outcomes from the seven workshops, which led to the development and majority approval by the expert panel of the protocols and standards of the proposed criterion and selection tests described in Table 1. Table 2 documents participants' performance scores on these tests.

Before potential implementation of the tests, we evaluated redundancy in the test battery (i.e. different tests measuring the same physical fitness component) by correlating the performance scores from the selection and criterion tests with one another (Table 3).

Tables 5 and 6 show that the models predict criterion test performance from the selection tests and the generic fitness tests. Through discussion at the workshops (Box 1) the expert panel decided that the ladder climb would be performed as a competency assessment only, at both selection and criterion test points (i.e. no performance time would be set); thus a final model to predict this criterion test is not presented in Table 6. The predictive accuracy of the tests was quantified from LoA, where a high LoA is indicative of poorer predictive accuracy (e.g. Table 6 Enclosed Space test) and low LoA is indicative of stronger predictive accuracy (e.g. Table 6 Rural Fire test).

[Insert Tables 1 – 6 Here]

Discussion

This study describes the development and validation of evidenced-based, role-related, gender-free physical employment standards for the UK FRS which conforms with equality legislation [2]. A job analysis was conducted and used to develop task simulations of key role-related tasks to be used as selection and criterion tests. Through statistical analysis and expert panel consultation we established that the task simulation selection tests were more appropriate predictors of criterion test performance than a battery of generic fitness tests.

The strengths of this study were the national focus to encompass the broad range of tasks the UK FRS are required to undertake and inclusion of participants representative of personnel serving in the UK FRS (i.e. male and female from all ethnic groups), the detailed approach of the job analysis following established guidelines, and the frequent consultation and engagement with stakeholders. A weakness was the use of 50 trained firefighters to account for a shortfall in the target numbers of female fire-fighters and those from ethnic minorities, which was accounted for in the statistical analysis.

The main tasks we identified in the job analysis were similar to those previously documented for the UK FRSs. Scott [11] identified rural fires as the most demanding incidents UK FRS personnel attend, while David *et al.* [10] and Brewer [9] identified domestic fires as being aerobically physically demanding for this population. David and colleagues [10] documented BA operations and hose running as the most aerobically demanding tasks during domestic fire fighting, and casualty evacuations and the material handling as the most taxing regarding muscular strength and muscular endurance. All of these physical sub-tasks are contained within the Rural Fire and Domestic Fire simulations in this study (Table 1).

The physical demands of attending road traffic accidents (RTA) for UK FRS personnel were discussed by Scott [11] and Brewer [9], but only the aerobic demands were measured so neither study identified the RTA as "physically demanding". However, taking into consideration the mass of RTA cutting/spreading equipment and the heights, positions and durations in and for which they need to be used, we concluded that RTA incidents require considerable muscular strength and muscular endurance. A reliable single person simulation of this task could not be easily developed, so this simulation was not pursued (Box 1). The complexity of developing reliable single person simulations for RTA tasks is supported by Lindberg and colleagues [17]. Workshop participants in our study concluded the muscular strength and muscular endurance required in the rural simulation is likely to test the physical competencies required to provide assistance in a RTA rescue and that the technical skills could be taught if participants had adequate physical capability. Additionally, individuals with greater muscular strength and greater fat free mass (FFM).

were more successful at ladder lifting (Table 4), which is in keeping with previous studies [18-20] and underpins the relevance of including such capabilities in a test battery.

Our study reconfirmed the work of David *et al.* [10] which identified the need for UK FRS personnel to work at height and in confined spaces wearing BA - skills that are assessed by the ladder climb and enclosed space tests (Table 1). Raising ladders has been documented as one of the most physically demanding tasks experienced by FRS personnel and has been previously incorporated into physical test batteries [21-23]. The physiological strain during search and rescue with [24] and without [5] fire has been investigated with UK fire-fighters. The studies documented the high aerobic, muscular and thermal demands involved in completing these tasks when wearing BA, moving through confined space and handling hose

[5, 24]. The data provide support for the outcomes of the job analysis in this study (Box 1) and subsequent inclusion of these activities in the rural fire, domestic fire and enclosed space tasks (Table 1).

The strongest generic fitness test predictors of the domestic and rural criterion tests were a higher 'absolute' VO_2max ($L \cdot min^{-1}$) as single variable, or a greater 'relative' VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$) *combined with* higher FFM or body mass as multiple variables (Table 6). The domestic and rural simulations involve carrying heavy equipment, and individuals with higher absolute aerobic power are more capable of exercise performance when carrying external loads [25, 26]. This has high practical importance for the implementation of such tests. If tests which measure 'relative' aerobic power (e.g. MSFT) are used for selection, individuals with different body sizes would need different MSFT scores to pass the criterion test standard. Lighter participants require higher MSFT scores to meet the rural pass standard compared to their heavier counterparts [27]. Conversely, by setting a 'relative' aerobic fitness entry standard by defining a single pass standard on such tests (e.g. 45 $ml \cdot kg^{-1} \cdot min^{-1}$ as has been previously implemented by various FRSs [28]) and not accounting for body size may exclude larger individuals who are very capable of completing fire fighting tasks by favouring smaller, leaner individuals [26]. Although the validity of absolute and not relative VO_2max is well accepted for predicting performance in occupations involving load carriage [25, 26, 29], the expert panel rejected setting different pass standards for applicants of different body masses. However, the job simulations account for the differences in performance of individuals of differing body size, muscular strength and aerobic capacity by requiring participants to perform them carrying an external load, thereby accommodating these potential confounding factors.

The project stakeholders' decision to base the final models to predict criterion test performance on the selection tests rather than generic fitness tests, was due to a combination of the selection tests accounting for differences in body size, slightly stronger predictive capability of the selection tests and their greater face and content validity.

The final proposed criterion and selection tests and accompanying standards derived from this study are presented in Table 1. These were selected because, based on the evidence and data gathered in this study, the majority of researchers, expert panel members and stakeholders deemed these to best assess the physical capabilities required of UK FRS personnel to safely and effectively conduct their occupational roles.

Key Points

- This study used an established scientific process to develop role-related, gender-free physical employment tests for the UK FRS, which conform to the requirements of equal opportunities law.
- Seven 'criterion tests' were developed to safely simulate the critical physical activities which UK FRS personnel are required to undertake, which could be used to assess the role-related physical capabilities of incumbents in service.
- Seven job-simulation 'selection tests' were developed and down-selected as the most appropriate test battery to select applicants physically suited to roles in the UK FRS as they were the best predictors of criterion test performance, most easily accommodated the requirement to select personnel with higher fat-free mass, and had the greatest face and content validity.

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References

1. Payne W, Harvey J. A framework for the design and development of physical employment tests and standards *Ergonomics* 2010;**53**:858-871.

2. Great Britain. Parliament. Equality Act 2010: Elizabeth II. Chapter 15. London: Stationery Office, 2010.

3. Constable SH, Palmer B. The Process of Physical Fitness Standards Development*State-Of-the-Art-Report (SOAR)*. Wright-Patterson Air force Base, OH: Human Systems Information Analysis Center, 2000; 288.

4. Tipton MJ, Milligan GS, Reilly TJ. Physiological employment standards I. Occupational fitness standards: objectively subjective? *Eur J Appl Physiol* 2013;**113**:2435-2446.

5. Richmond VL, Rayson MP, Wilkinson DM, Carter JC, Blacker SD. Physical demands of firefighter search and rescue in ambient environmental conditions *Ergonomics* 2008;**51**:1023 - 1031.

6. Barr D, Gregson W, Reilly T. The thermal ergonomics of firefighting reviewed *Appl Ergon* 2009;**41**:161-172.

7. Petersen A, Payne W, Phillips M, Netto K, Nichols D, Aisbett B. Validity and relevance of the pack hike wildland firefighter work capacity test: a review *Ergonomics* 2010;**53**:1276-1285.

8. Lindberg AS, Malm C, Oksa J, Gavhed D. Self-rated physical loads of work tasks among firefighters *Int J Occup Saf Ergon* 2014;**20**:309-321.

9. Brewer J. A fitness standard for the operational workforce of the London Fire and Civil Defence Authority: London Fire Service; internal report, 1999.

10. David G, Hoffman J, Randle I, Thrush D, Stubbs D. Practical aptitude tests for Fire Service recruits: Robens Institute, 1997.

11. Scott G. The physical fitness of firemen: a summary report: University of London, Chelsea College, 1988.

12. Rayson MP, Wilkinson DM, Carter JM, Nevill AM. National firefighter selection process. Development and validation of national firefighter selection tests: Physical tests. London, UK: Department for Communities and Local Government, 2009.

13. Ramsbottom R, Brewer J, Williams C. A progressive shuttle run test to estimate maximal oxygen uptake *Br J Sports Med* 1988;**22**:141-144.

14. Coulson M, Archer D. Practical Fitness Testing: Analysis in Exercise and Sport (Fitness Professionals). London, UK: A&C Black Publishers Ltd, 2009.

15. Tukey JW. Exploratory Data Analysis. Reading, Massachusetts, USA: Addison-Wesley, 1977.

16. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement *Biochimica Clinica* 1986;**11**:399-404.

17. Lindberg AS. Firefighters' physical work capacity*Department of Surgical and Perioperative Sciences, Sports Medicine Unit,*. Umeå, Sweden: Umeå University, 2014.

18. Lindberg AS, Oksa J, Malm C. Laboratory or field tests for evaluating firefighters' work capacity? *PloS one* 2014;**9**:e91215.

19. Sothmann MS, Gebhardt DL, Baker TA, Kastello GM, Sheppard VA. Performance requirements of physically strenuous occupations: validating minimum standards for muscular strength and endurance *Ergonomics* 2004;**47**:864-875.

20. Henderson ND, Berry MW, Matic T. Field measures of strength and fitness predict firefighting performance on physically demanding tasks *Personnel Psychol* 2007;**60**:431–473.

21. Lusa S, Louhevaara V, Kinnunen K. Are the job demands on physical work capacity equal for young and aging firefighters? *J Occup Med* 1994;**36**:70-74.

22. Lemon PW, Hermiston RT. The human energy cost of fire fighting *J Occup Med* 1977;**19**:558-562.

23. Williams-Bell FM, Villar R, Sharratt MT, Hughson RL. Physiological demands of the firefighter Candidate Physical Ability Test *Med Sci Sports Exerc* 2009;**41**:653-662.

24. Rayson MP, Carter JC, Wilkinson DM, Richmond VL, Blacker SD. Recovery duration required prior to re-deployment during firefighting, search and rescue *Med Sci Sports Exerc* 2007;**39**:S154.

25. Bilzon JL, Allsopp AJ, Tipton MJ. Assessment of physical fitness for occupations encompassing load-carriage tasks *Occup Med (Lond)* 2001;**51**:357-361.

26. Vanderburgh PM. Occupational relevance and body mass bias in military physical fitness tests *Med Sci Sports Exerc* 2008;**40**:1538-1545.

27. Rayson M, Wilkinson D, Richmond V, Blacker S, Carter J. National Firefighter Selection Process; A comparison of firefighter physical fitness tests. London, UK: Department for Communities and Local Government, 2009.

28. Wynn P, Hawdon P. Cardiorespiratory fitness selection standard and occupational outcomes in trainee firefighters *Occup Med (Lond)* 2012;**62**:123-128.

29. Wilkinson DM, Rayson MP, Carter JM, Blacker SD. Development of an aerobic fitness entry standard for British Territorial Army recruits *Med Sci Sports Exerc* 2008;**40**:S238.

Table 1 – Description of the test protocols and suggested pass standards for the criterion and selection tests. Selection test grading pass criteria are based on the probability that the applicant will meet the criterion test pass criteria; A (90 %), B (80 %) and C (70 %).

Test	Criterion Test Description	Pass	Selection Test Description	Pass
Rural Fire	Candidate (performing along a 50 m shuttle) to drag a hose (15 kg) from the reel on appliance for 50 m, jog back 50 m, pick and carry 2 x 70 mm coiled hoses (2 x 15 kg) placing the first at 175 m and the second at 200 m, run out the two placed hoses (50 m), jog back 150 m to appliance, Pick up and carry 2.4 m 100 mm suction hose (12 kg) and basket (4.4 kg) 200 m, jog back 200 m to appliance, pick up and carry LPP simulator (33 kg) 200 m.	780 s	Candidate (performing along a 25 m shuttle) to drag a hose (15 kg) from the reel on appliance for 25 m, jog back 25 m, pick and carry 2 x 70 mm coiled hoses (2 x 15 kg), placing them at 100 m, run out the one placed hose (25 m), jog back 75 m to appliance, pick up and carry 2.4 m 100 mm suction hose (12 kg) and basket (4.4 kg) 100 m, jog back 100 m to appliance, pick up and carry LPP simulator (33 kg) 100 m.	A=337 s B=347 s C=356 s
Domestic Fire	Candidate wearing BA under air to drag a hose (15 kg) from reel from the appliance for 30 m (10 m turn left 90°, 10 m turn left 90°, 10 m, locate and recover a 30 kg child casualty (30 m retracing route), walk 10 m (back along initial route), pause for 30 seconds (while BA obscuration mask fitted), unsighted crawl 20 m (following initial route), locate and recover (30 m) a second adult male casualty (55 kg) (returning along initial 30 m route).	240 s	Candidate to drag a 55 kg casualty (using a two hand grip on the neck handle walking backwards while guided by the assessor) around a 30 m course (10 m turn left 90°, 10 m turn left 90°, 10 m) in the fastest possible time.	A=37.4 s B=41.3 s C=44.3 s
Ladder Lift	Candidate to raise the free end of the pivoted ladder arm (13.5 m mass = 26 kg) supported 75 cm off the ground to a height of 182 cm and back down to the 75 cm support. The mass of the ladder at the lifting point will start at 20 kg and increase by 4 kg (5 kg added to the simulator) after every successful attempt (following at least 60 seconds of rest). The maximum load to be added to the simulator is 45 kg on the cradle.	30 kg	Candidate to raise the free end of the pivoted ladder arm (13.5 m, mass = 26 kg) supported 75 cm off the ground to a height of 182 cm and back down to the 75 cm support. The mass of the ladder at the lifting point will start at 20 kg and increase by 4 kg (5 kg added to the simulator) after every successful attempt (following at least 60 seconds of rest). The maximum load to be added to the simulator is 30 kg on the cradle.	A=30 kg B=30 kg C=30 kg
Ladder Extension	Candidate to fully extend a 13.5 metre pitched ladder from the 1st to the 9th pawl (1 storey height), secure it, and lower it under control to the grounded position.	14 s	Candidate to raise a 62 kg by pulling through 4.5 m of line (equivalent to 90% of weight required to extend a 13.5 m ladder from 1st to 2nd floor) and lower. Using PowerSport /Tallescope.	A=16.5/17.4) s B=17.9/18.9) s C=18.9/20.0) s
Ladder Climb	Candidate to ascend an extended 13.5 m ladder to the third floor where they alight onto the landing, before getting back on the ladder and descending to the ground.	40 s	Candidate to ascend a fully extended 13.5 m ladder to a point two thirds of the full working height, take a leg lock, remove hands from the ladder and look down to the assessor to identify the symbol placed flat on the ground at the foot of the ladder.	Pass/fail
Pump Assembly	Candidate to assemble the PortoPower unit following the colour-coded diagrams provided.	244 s	Candidate to assemble and dissemble the PortoPower unit following the colour-coded diagrams provided.	A=283 s B=308 s C=328 s
Enclosed Space	Candidate to negotiate a 80 cm^3 crawlway unsighted containing 8 obstacles wearing a full BA set (started up) and a face mask that is obscured.	420 s	Candidate to negotiate a 80 cm^3 crawl way containing 8 obstacles wearing a BA face mask (no cylinder) with clear vision, and return along the same route with vision obscured.	A=383 s B=433 s C=472 s

Table 2 - Performance test scores for the selection tests and criterion tests (mean ± SD)

	Selection Tests		Criterion Tests	
	n	**Score**	**n**	**Score**
Rural Simulation (s)	186	296 ± 35	142	596 ± 95
Domestic Simulation (s)	182	20.4 ± 3.8	150	179 ± 23
PortoPower Assembly (s)	182	158 ± 40	154	130 ± 30
Enclosed Space (s)	185	167 ± 42	153	167 ± 44
Ladder Lift (kg)	23 [1]	35.5 ± 4.7	23 [2]	35.8 ± 6.5
Tallescope Ladder Extension (s)	56	9.4 ± 3.1	N/A	N/A
PowerSport Ladder Extension (s)	69	7.9 ± 2.8	N/A	N/A
135 m Ladder Extension (s)	N/A	N/A	116	12.0 ± 7.5

n is number of participants; N/A not applicable

[1] includes only participants who did not reach the maximum limit of 44 kg

[2] includes only participants who did not reach the maximum limit of 56 kg

Table 3 – Pearson correlation coefficient (number used to derive the correlation coefficient) for the selection tests (values to the top and right of the shaded cells) and criterion tests (below and to the left of the shaded cells).

	Rural Simulation	Domestic Simulation	PortoPower Assembly	Enclosed Space Run	Ladder Lift [1]	Tallescope Ladder Extension	PowerSport Ladder Extension
Rural Simulation		0.568** (182)	0.242** (182)	0.336** (184)	-0.506* (23)	0.565** (56)	0.515** (69)
Domestic Simulation	0.615** (141)		0.153* (182)	0.278** (182)	-0.555** (23)	0.522** (56)	0.524** (69)
PortoPower Assembly	0.140 (142)	0.251** (150)		0.201** (182)	-0.456* (23)	0.418** (56)	0.502** (69)
Enclosed Space Run	0.156 (141)	0.229** (150)	0.243** (153)		-0.159 (23)	0.170 (56)	0.132 (14)
Ladder Lift [1]	-0.364 (22)	-0.546** (22)	-0.374 (23)	-0.251 (22)		-0.829** (69)	-0.681** (16)
Tallescope Ladder Extension	NA	NA	NA	NA	NA		0.921** (56)
PowerSport Ladder Extension	NA	NA	NA	NA	NA	NA	
135 m Ladder Extension	0.128 (105)	0.131 (109)	0.501** (112)	0.185 (111)	-0.139 (14)	NA	

Symbols show * p<0.05; ** p<0.01; [1] includes only those participants who did not reach the maximum limit for the test (44 kg for the selection test and 56 kg for criterion test) and NA indicates 'Not Applicable' because the Tallescope and PowerSport ladders were not conducted in the criterion test battery.

Table 4 - Linear and multiple regression equations using both selection and the generic fitness tests for each criterion test and their associated Limits of Agreement. For the PortoPower and Enclosed Space criterion tests there were no statistically significant relationships between the fitness tests or multiple selection tests and therefore for simplicity the single relationships between criterion and selection tests are not shown.

Criterion Test	Approach	No of Variables	Variable Description	r	Bias (%)	95 % LoA (%)
Rural Simulation	Selection	Single	Rural Selection	0.907	0	7.6
		Multiple	Rural Selection; PowerSport Ladder Extension	0.930	0	6.7
	Field Tests	Single	VO_2max ($L \cdot min^{-1}$)	0.895	0	8.0
		Multiple	VO_2max ($mL \cdot kg^{-1} \cdot min^{-1}$); FFM	0.943	0	5.6
Domestic Simulation	Selection	Single	Domestic Selection	0.878	0	7.6
		Multiple	No additional variables improved model	-	-	-
	Field Tests	Single	VO_2max ($L \cdot min^{-1}$)	0.841	0	9.1
		Multiple	VO_2max ($mL \cdot kg^{-1} \cdot min^{-1}$); BM; SBJ	0.910	0	7.0
Ladder Lift	Selection	Single	Selection Ladder Lift	0.908	0.1	13.7
		Multiple	No additional variables improved model	-	-	-
	Field Tests	Single	40 cm upright pull	0.838	0.2	19.8
		Multiple	40 cm upright pull; SBJ, BM	0.903	0.1	13.8
Ladder Extension	Selection	Single	PowerSport ladder extension	0.941	0.1	14.0
		Multiple	No additional variables improved model	-	-	-
	Field Tests	Single	FFM	0.956	0	12.0
		Multiple	No additional variables improved model	-	-	-

R is Pearson correlation coefficient, LoA is limits of agreement, VO_2max is maximum rate of oxygen uptake, FFM is fat free mass, BM is body mass, SBJ is standing broad jump

Table 5 – The final proposed statistical models to predict criterion test performance from selection test performance

Test	Equation*	R^2	SD	n	95 % LoA (%)	Bias (%)	Validation sample (n)
Rural criterion test (s)	= -149 + (2.638*Rural selection) – (45*Training status)	0.68	54	77	19.4	-0.1	64
Domestic Fire criterion test (s)	= 77.4 + (5.423*Domestic selection) + (53.9*Training Status) – (3.217*Domestic selection*Training Status)	0.38	19	83	19.5	1.5	65
Ladder Lift criterion test (kg)	= -8.6 + (Ladder Lift selection*1.204) + (4.2*Training status)	0.74	3.5	23	19.6	0.3	23 #
Ladder Extension criterion test (s)	= 1.6 + (PowerSport selection*0.634) – (0.8*Training status)	0.73	1.1	59	38.8	1.4	59 #
PortoPower criterion test (s)	= 48.0 + (0.531*PortoPower selection)	0.50	23	86	34.0	5.3 $	66
Enclosed Space criterion test (s)	= 53.85 + (0.675*Enclosed Space selection)	0.42	35	85	57.4	2.0	66

*Where training status is coded 0 for trained and 1 for trainees

LoA is Limits of Agreement, n is number of participants

#Cross validation was not possible, so model was validated on the same participants

$ Significant bias ($p<0.01$)

Box 1 – Description of the purpose and outcomes of the workshops conducted to determine the physical demands of the roles of UK Fire and Rescue Service Personnel

Workshop 1 - April 2002 - Greater Manchester
Attendees - 18 training officers and experienced firefighters
Objectives

a) Identify and document essential tasks
b) Start devising single person simulations
c) Explore defining minimal and optimal standards of performance on simulated tasks.

Outcomes

Four scenarios were identified, 2 single person simulations were outlined, best effort and panel-derived draft standards were agreed:

i. Conduct Search and Rescue in industrial building which was on fire. Key tasks included removing equipment from appliance and carrying it 50 m; under-running and extending ladders; climbing ladders; entering the building, searching while dragging a charged hose; firefighting; locating a casualty; rescuing casualty from the building. A first attempt at designing a single person simulation included a 300 m brisk walk, a 60 m carry of a load representing 25% of the 13.5 m ladder, an under-run of the ladder, ladder extension, ladder climb, entry into the building, and a 30 m casualty (60 kg) drag. The best effort times on this simulation ranged from 330 s to 435 s, while times paced by a panel of 4 to represent a minimum acceptable speed were between 480 and 540 s.
ii. A Domestic Fire scenario was developed that incorporated donning PPE; pulling out a hose reel 40 m; crawling up a flight of stairs; and extracting casualties. An approximate time limit of 270 s was suggested.
iii. A Road Traffic Accident (RTA) was identified and partially developed as a simulation, including deploying pumps, generators, hoses, and handling that equipment to stabilise and cut the vehicle. This RTA task was difficult to simulate; no standards of performance were articulated.
iv. A Rural Fire (grassland) was also identified as a key task, though not developed into a single person simulation.

Workshop 2 - June 2002 **-** Fire Service College (FSC) Moreton-in-Marsh
Attendees - 7 stakeholders and 13 firefighters
Objectives

a) Identify and document essential physically demanding tasks in an operational environment required of all trained firefighters at the end of initial training
b) Devise single person simulations of these essential tasks
c) Define standards of performance on simulations

Outcomes

i. The workshop's focus was on agreeing and detailing the 'reasonable worst case' within these scenarios:
ii. RTA - rescuing a casualty from a car that had run off the road and down an embankment, using the power tools to cut off the car roof and a stretcher to carry the casualty to the road. The sole unique subtask in this scenario was the assembly of the hydraulic equipment, which later was to evolve into the Manual Dexterity test.
iii. Domestic Fire Search and Rescue - search for and rescue multiple hidden casualties on the first floor via front door entry, while firefighting in BA. A series of subtasks involving dragging hose, lifting and carrying casualties were reconstructed along three sides of a 10 m square as a single person simulation. A minimum acceptable standard on the simulation of 240 s was proposed.
iv. Domestic Fire Salvage - salvage in BA to include covering roof with tarpaulin. The scenario involved deploying the 13.5 m ladder, climbing the ladder with various items of equipment, taking a leg lock and using the item of equipment. The weights and start/end heights of the ladder lifts were proposed, and the need for both a ladder extension simulator and the ability to

work at height with confidence were recognised.

v. Rural Fire - incorporating hose laying, water relay (both pumps), BA and beating. These subtasks were reconstructed along a linear 50 m course and a minimum standard on the simulation of 780 s was proposed. It was agreed that, within safety constraints, the faster the simulation could be performed the lower the potential risk of loss of life or property would be.

vi. Enclosed Space Search - an aspect to firefighter operational performance not adequately encompassed within the scenarios devised in Workshop 1 was that of moving in an enclosed space, while using BA and deprived of visual stimuli. Relevant aspects of performance include whole body co-ordination and agility, and an absence of claustrophobia. A modified version of an existing 'BA Crawlway' was deemed an appropriate test. Further development work was conducted in Workshop 4.

Workshop 3 - Sep 2002 - FSC Moreton-in-Marsh

Attendees - 23 firefighters and expert panel

Objectives

a) Assess practicalities and firefighters' views of possible selection and 'fitness' test batteries
b) Test the equipment and collect normative data
c) Investigate the potential to predict criterion test performance from the possible selection tests

Outcomes

i. Two batteries of potential selection tests were designed and assembled based on an international literature review and practical considerations. The tests were grouped into content valid (involving similar tasks to those employed in the single person simulations) and criterion valid (involving the generic fitness tests) tests.

ii. The content validity tests comprised: half distance Rural Fire simulation, Casualty Drag, Ladder Lift, Ladder Extension, Ladder Climb, PortoPower Assembly (manual dexterity), BA Crawlway.

iii. The 'fitness' tests comprised: height, mass, body composition, handgrip, MSFT, 40 cm upright pull, standing broad jumps, 182 cm upright push.

iv. Normative data and constructive feedback were collected from all participating firefighters on all tests. Male and female firefighter opinions on minimal acceptable performance standards for trained firefighters were more stringent than those proposed by the expert panel.

v. The case for the adoption of the content valid approach was presented at a Steering Group meeting on 14 October 2002. The content approach had been shown in this small study to be predictive of the job performance criteria. The approach was preferred by both candidates and serving personnel alike, providing what was perceived to be a useful experience for the applicant.

Workshop 4 - July 2003 - Southwark Fire Station

Attendees - Small expert group

Objective

Resolve the technical issues outstanding on some of the proposed selection tests and job performance criteria, mainly concerning the Enclosed Space and Ladder Extension tests

Outcomes

i. The requirement for firefighters to operate with zero visibility, in confined spaces, using BA and other equipment was confirmed. A modular crawlway comprising mesh 'cages' with dimensions of approximately 80 cm^3, a walking and crawling distance of ~25 m in total, and negotiating 8 obstacles, were agreed. The event would be scored on a pass/fail basis; the standard would be set by the expert panel at Workshop 5.

ii. It was decided that the applicant firefighter test should retain as many elements as possible less the highly skilled, taught elements, e.g. the use of BA and dragging an object. The group proposed that applicants be asked firstly to travel the length of the crawlway while wearing an unobscured facemask, and then to reverse their travel back through the crawlway with an obscured facemask.

iii. The task to establish the load on the PowerSport ladder extension simulator to reflect the physical demands of extending a 13.5 m ladder was undertaken by building on previous work, while further dynamic and static force measures of 7 individuals on both a 13.5 m ladder and a new PowerSport simulator were also made. This work supported the adoption of a simulator loading of 62-67 kg.

Workshop 5 - October 2003 – FSC Moreton-in-Marsh
Attendees - Expert panel & 9 trained firefighters; 19 female firefighters
Objectives

a) Scrutinise the amended job simulation protocols and to propose minimum acceptable standards on each
b) Assess the likely impact of these standards on trained female firefighters

Outcomes

i. Minor amendments to the protocols had been approved since their original conception; hence the need to revisit the standards. The expert panel succeeded in agreeing proposed standards for all job performance criteria. The Ladder Lift simulator load was increased by 4 kg to 30 kg, to match the mean best estimate of equivalent load by the sample of 9 firefighters, suggesting that for this lift applying a 20% team lift correction factor was appropriate.
ii. The 19 female firefighters undertook the proposed job performance criteria and achieved scores in all instances. These scores were then assessed relative to the proposed standards. The expert panel's proposed standards were: Ladder Lift - 30 kg, PortoPower assembly & disassembly - 240 s, Ladder Climb - 30 s, Domestic Search & Rescue - 240 s, Rural Fire (water relay) Simulation - 750 s, Ladder Extension - 25 s, Enclosed Space - 420 s
iii. The pass rates among women firefighters ranged from 100% on the Domestic Simulation and Enclosed Space Test to 37% on the Ladder Climb. 21% of the women passed the proposed standards on all tests, though the highest failure rate on the Ladder Climb could be explained by procedural shortcomings, and the second highest failure rate on the Rural Fire Simulation might in part be explained by cumulative fatigue.
iv. These low pass rates posed a dilemma; they suggest that either the standards proposed by the expert panel were unrealistically high or the standards of performance among the female firefighters were unacceptably low. It was agreed that setting applicant standards would be reviewed again following the validation study.

Workshop 6 - November 2004 – FSC Moreton-in-Marsh
Objectives

a) Down-select gloves for ladder extension and PortoPower assembly
b) Decide worst case scenario for extension of 13.5 m ladder (1 vs. 2 person; distance of extension)
c) Agree a minimal acceptable standard (duration) to complete the ladder extension
d) Evaluate the Tallescope work platform as an alternative to the PowerSport ladder extension simulator
e) After trialling a number of different pairs of gloves the panel agreed that the SHOWA No. 310 gloves offered the best combination of grip and feel for both the ladder extension and the PortoPower assembly

Outcomes

i. After discussion, the panel agreed the reasonable worst case scenario as a requirement for trained firefighters for extension of a 13.5 m ladder was: (1) One person to extend the 13.5 m ladder one storey (estimated as extending the ladder from 1st to 9th pawl); (2) The start and end point of the job simulation test should be with the pawls engaged; (3) 12 s was a suitable minimum acceptable standard.
ii. Static and dynamic forces were measured on the Tallescope aluminium work platform with an additional load of 30 kg. The test and load were found to provide an alternative equivalent ladder extension simulation test to the PowerSport ladder extension simulator.

Workshop 7 - April 2005 - FSC Moreton-in-Marsh
Attendees - Expert panel of 12 comprising representatives from all stakeholders; 6 trained

firefighters.

Objective

Revisit criterion performance standards proposed by previous expert panels in light of the impact of the standards on both trainee and trained firefighters (failure rates of 19% for trainees at the end of initial training [18% in males; 30% in females], and 34% for trained firefighters [23% in males; 53% in females

Outcomes

i. The projected failure rates from the field/validation study reinforced the suggestion that either the standards expected of trained firefighters on the 7 criterion tests were unrealistically high, or that performance standards in trained firefighters were unacceptably low.
ii. The panel observed the firefighters undertaking the criterion tests, participated in the criterion tests, and discussed what would constitute minimum acceptable standards of performance in light of the views of former expert panels and the normative data collected to date.
iii. The event culminated in the expert panel being asked to provide both their individual recommended minimum acceptable standard of performance on each criterion test and to vote on the most commonly proposed standards.
iv. The workshop was successful in meeting its objective. The previously-proposed standards on four of the criterion tests were reconfirmed (PortoPower Assembly; Domestic; Ladder Extension; Enclosed Space), while those on the remaining three were reduced (Ladder Climb; Rural; Ladder Extension). The final test procedures and standards are described in Table 2.