Evaluation of the Physical Ability Assessment For QFRS

Peter Reaburn PhD

April, 2005

Executive Summary

The purpose of this report is to answer the following questions pertaining to the proposed implementation of the Physical Abilities Assessment (PAA) into the QFRS recruiting process. The following questions were posed:

1. Should the "Beep Test" be included in recruit screening or is it duplicating what is measured in the PAA test, as suggested in a previous KPMG report.
2. Do the CPAT and "Beep Test" test the same thing – aerobic capacity?
3. Maximum and minimum test conditions regarding temperature
4. Are the CPAT tests job-specific?
5. Relate current QFRS recruit tests to other states and NZ recruit tests.
6. Compare and contrast the QFRS McLachlan report of 2000 with the CPAT manual's outcomes on PAA/CPAT task criticalities, importance and perceptions of physical effort as determined by operational fire-fighters.

In summary, the following responses are made:

1. *Should the "Beep Test" be included in recruit screening or is it duplicating what is measured in the PAA test, as suggested in a previous KPMG report.*

Yes, both the results of the study conducted by Central Queensland University and reported in Appendix A of this report, and previous unpublished and published studies, strongly suggest that the "Beep Test" measures maximal aerobic capacity that is crucial to fire fighter performance, fire fighter health, and the ability to tolerate heat. Previous unpublished research plus the results of the Central Queensland University study, clearly show the PAA does not stress the aerobic system to maximal capacity as the "Beep Test" does. Thus, the suggestion by KPMG that the proposed PAA test may be classed as a measure of aerobic capacity should be rejected and both the PAA and "Beep Test" both be included in recruit screening.

2. *Do the CPAT and "Beep Test" test the same thing – aerobic capacity?*

No, results from the Central Queensland University study in this report's Appendix and unpublished data contained in this report, both strongly suggest the PAA and "Beep Test" measure different capacities, all of which are crucial for fire fighting tasks. The Central Queensland University study showed the, in 10 potential QFRS recruits, "Beep Test"

produced an aerobic capacity of 51.7±4.5 ml/kg/min while the PAA test produced an aerobic peak of 44.7±5.0 ml/kg/min, a statistically lower value.

3. *Maximum and minimum test conditions regarding temperature.*

The CPAT manual clearly states the PAA test should not be held in excessively hot, cold or wet conditions. Specifically, candidates must NOT be tested in an environment where:

a. Temperature is below 7^{o}C.
b. The Apparent Heat Index (see tables 3 and 4 of report) is greater than 35^{o}C
c. There is a measurable amount of rain (light drizzle only if working surfaces are safe to walk on and props, tools and test equipment can be kept dry.
d. Sustained wind is greater than 32 kph.

If the PAA is planned to be portable and taken to regional Queensland, the QFRS needs to time the testing of recruits for regional areas for the winter months and monitor the conditions stated above.

4. *Are the CPAT tests job-specific?*

After years of involvement in the physical fitness testing and eight years of involvement with the QFRS on testing and fitness standards, there is no doubt in my mind the PAA/CPAT is the most valid and reliable test of job-related fitness developed to date. The CPAT has been shown to be both valid and reliable, two of the key criteria for any fitness or physical abilities test. Moreover, the QFRS McLachlan Report (2000) strongly supports the CPAT panel of experts in what tasks are critical for fire fighting performance, all of which are elements of the PAA/CPAT.

5. *Relate current QFRS recruit tests to other states and NZ recruit tests.*

The QFRS needs to take the lead and unite all Australian fire and rescue authorities in standardising their recruit testing. As discussed in detail in this report, the range of unvalidated, unreliable, non-job-related, and ad hoc tests existing around Australia and New Zealand, defies belief. Adoption of the PAA/CPAT, given it's validity and reliability, should become the standard. Given the critical importance of aerobic fitness for fire suppression activities and fire fighter health, the most cost and time-effective test of indirectly measuring aerobic capacity – the "Beep Test" – should also be retained.

6. *Compare and contrast the QFRS McLachlan report of 2000 with the CPAT manual's outcomes on PAA/CPAT task criticalities, importance and perceptions of physical effort as determined by operational fire fighters.*

The QFRS McLachlan report of 2000 also highlighted the importance of PAA test elements and strongly supports the results of the studies done by a panel of experts in the development of the CPAT in North America. The McLachlan report surveyed a total of 791 QFRS members, including 204 station officers and 583 operational fire fighters from all over Queensland and ranging from one to more than 16 years of service, all age groups and including six females. The report concluded that:

- *Excessive* to *moderate* effort was required for each of the PAA elements including a stair climb, hose drag, equipment carry, ladder raise and extension, forcible entry, search, rescue, and ceiling breach and pull.
- Task importance of *extremely* to *very important* was rated for each the PAA elements listed above.

These findings are in total agreement with the CPAT panel of experts findings.

Conclusions and Recommendations:

1. **The PAA/CPAT is the most valid and reliable instrument for assessing the job-related demands of fire fighting.**
2. **Incorporate the PAA into recruit screening.**
3. **Ensure that the PAA ambient conditions are monitored and assessment timed to meet the environmental demands of regional Queensland.**
4. **Maintain the "Beep Test" as a time and cost effective measure of aerobic endurance so crucial to fire fighting.**
5. **Queensland needs to take the lead and adopt the PAA/CPAT and unite the Australian fire fighting authorities to do the same.**

Physical Ability Assessment Project

Final Report to QFRS

Associate Professor Peter Reaburn PhD

Introduction

Physical Assessment Project Officer, Gavin Shuker, on behalf of the Queensland Fire and Rescue Service (QFRS), requested a report on the Physical Ability Test (PAA) being examined by the QFRS to be used as a recruiting tool. The PAA is the Queensland equivalent of the Candidate Physical Ability Test (CPAT) widely used in North America as a means of screening recruits. The following report addresses the key questions put to me by Officer Shuker. These include:

1. Should the "Beep Test" be included in recruit screening or is it duplicating what is measured in the PAA test, as suggested in a previous KPMG report.
2. Do the CPAT and "Beep Test" test the same thing – aerobic capacity?
3. Maximum and minimum test conditions regarding temperature
4. Are the CPAT tests job-specific?
5. Relate current QFRS recruit tests to other states and NZ recruit tests.
6. Compare and contrast the QFRS McLachlan report of 2000 with the CPAT manual's outcomes on PAA/CPAT task criticalities, importance and perceptions of physical effort as determined by operational fire fighters.

The report below addresses each of these questions in turn.

1. Inclusion of the "Beep Test" in Recruit Screening?

There is no doubt in my opinion the "beep test" should remain part of the recruit screening process. Fire fighting is considered one of the most physically demanding and hazardous of all civilian occupations (Gledhill & Jamnik, 1992). During both training drills and actual fire suppression activities, firefighters perform numerous tasks that require high levels of muscular strength, and both muscular and cardiovascular endurance. The operational fire fighter must be able to carry and climb ladders while wearing heavy protective clothing and breathing apparatus, lift, drag and control charged fire hoses, swing an axe or sledgehammer to gain to gain or clear entry, lift, drag or carry victims to safety, and perform these tasks continuously or intermittently until an emergency is resolved.

Scientific research has consistently shown that aerobic capacity (VO_2max) or endurance fitness is critical for safe and effective firefighting (Adams et al., 1986; Davis,

Dotson & Santa Maria, 1982; Gilman & Davis, 1993; Gledhill & Jamnik, 1992; Peate, Lundergan & Johnson, 2002; Pyke et al., 1987; Sothmann et al. 1990, Sothmann et al. 1992; Swank, Adams, Barnard, Berning & Stamford, 2000b). Specifically, the following research highlights the importance of high levels of aerobic fitness for firefighters:

- Davis and others (1982) observed that firefighters with a higher VO_2max had faster performance times on a simulated fire suppression protocol than their lower VO_2max counterparts;
- Adams and others (1986) observed that firefighters who had increased their VO_2max through physical training performed faster in fire suppression tasks than a control group who had not increased their VO_2max;
- Pyke and others (1987), Schonfeld and others (1990) and Sothmann and others (1990a and 1990b) all found that the single most important factor in fast performance of a fire suppression simulation was aerobic power with a statistically significant negative correlation (r = -0-54-0.74) showing that the higher the aerobic capacity, the faster the fire suppression activity.

Thus, in terms of a duty of care to both firefighters and public safety and reducing damage to infrastructure, getting the fire suppression activity done quickly is imperative. The above research strongly suggests that speed of fire suppression activities are related to endurance fitness and aerobic capacity or VO_2max. The "Beep Test" is a well-validated test of VO_2max in adult males and females (Leger and Gadoury, 1989; Paliczka et al., 1987) and athletes who do intermittent activities (St Clair-Gibson et al, 1998) such as firefighters undertake.

As evidenced in Appendix A of this report (see Table 1 on page 15), the "Beep Test", an indirect but cost and time effective means of measuring the crucial VO_2max, produced a significantly higher (51.7±4.5 ml/kg/min) VO_{2peak} than their VO_{2peak} observed during the PAA (44.7±5.0 ml/kg/min). This result strongly suggests that the PAA test measures other capacities important to fire fighting (strength, muscle endurance) than just aerobic endurance. Thus, the suggestion by the KPMG report that the PAA (CPAT) measures aerobic capacity as well as the "Beep Test" is not valid and the "Beep Test" should remain a crucial component of the recruitment process.

High levels of aerobic fitness are also important for reasons of thermoregulation. Fire suppression activities take place in thermally stressful environments where high levels of radiant heat combined with wearing heavy protective clothing and breathing apparatus prevent heat loss via evaporative cooling (Richardson & Capra, 2001; Smith, Petruzzello,

Kramer & Misner, 1997; Smith & Petruzzello, 1998). A high level of endurance fitness as exhibited by a high VO_2max is conclusively associated with improved exercise-heat tolerance (see Cheung, McLellan & Tanaglia, 2000 for review), again highlighting the importance of a high VO_2max in operational firefighters. Again, numerous scientific and peer-reviewed studies have consistently shown that high levels of VO_2max are important in coping with fire suppression activities in hot and humid conditions. Examples are:

- O'Connell and others (1986) found that firefighters doing stair climbing simulations in personal protective equipment (PPE) found that less fit (lower VO_2max) firefighters operated at 97% of their capacity (VO_2max) while fitter firefighters operated at 63% of their VO2max. The less fit firefighters would thus have a large energy contribution from anaerobic sources and produce lactic acid that would lead to fatigue more quickly, poorer decision making and a smaller reserve capacity to cope with increased work should a critical incident arise. In a real emergency, this may be the difference between life and death
- Louhevaara and others (1994) observed that the relative cardiac strain (heart rate) experienced by firefighters during fire suppression simulations was significantly lower in those with a higher VO_2max ($r = - 0.50$, $p < 0.001$)
- Havenith and others (1995a and 1995b) found that a high VO_2max of adult and younger subjects (not firefighters) exercising in hot and humid conditions was related to lower heart rates, lower core temperatures, lower blood pressures (and thus less heart strain) and higher sweat rates and forearm blood flows essential for heat loss.
- Donovan and McConnell (1999) found that firefighters with high VO_2max values had lower ventilation rates while wearing breathing apparatus (BA), this suggesting longer endurance time while wearing BA in fire suppression activities in more aerobically fit recruits.
- Cheung and McLellan (1998) found that subjects with high VO_2max values were able to perform longer than those with lower VO_2max values during military exercises while wearing personal protective equipment.

Thus, a high level of aerobic fitness as demonstrated by a high VO_2max is essential for reasons of increased heat tolerance, ability to thermoregulate and work endurance time in the heat. Again, the "Beep Test" is a well-validated test of VO_{2max} in adult males and females (Leger and Gadoury, 1989; Paliczka et al., 1987) and athletes who do intermittent activities (St Clair-Gibson et al, 1998) such as firefighters undertake.

Finally, high levels of aerobic fitness or VO_2max are associated with decreased mortality and cardiovascular disease and to improved cardiovascular disease risk factors such as lower cholesterol levels, lowered blood pressure, and improved glucose tolerance and insulin sensitivity (Blair, Kohl, Barlow, Paffenbarger, Gibbons & Macera, 1995; US Department of Health and Human Services, 1996). However, previous research has shown that the leading occupation-related cause of premature termination of service for operational firefighters is cardiovascular disease and that the same cohort has increased cardiovascular disease rates than the general population (National Fire Protection Association, 1997; Swank, Adams, Barnard, Berning, Ottersbach, & Bowerman, 2000a). Furthermore, recent data has shown that 41.7% (professional firefighters) and 47.6% (volunteer firefighter) of United States on-duty firefighter fatalities were due to myocardial infarctions and the majority of these firefighters had a prior history of cardiovascular disease (Fahy & Leblac, 2002).

Thus, a high level of endurance fitness that comes with regular physical training is crucial for reduced risk of heart disease and reduced morbidity (illness) and mortality (death). Again, the "Beep Test" is a well-validated test of endurance fitness or VO_2max in adult males and females (Leger and Gadoury, 1989; Paliczka et al., 1987) and athletes who do intermittent activities (St Clair-Gibson et al, 1998) such as firefighters undertake.

In summary, the overwhelming conclusion from the scientific and peer-reviewed literature is that aerobic or endurance fitness is the most important physiological factor in fire fighting. For reasons of improved and safer fire suppression performance, improved heat tolerance, and reduced injury and death rates, the QFRS should be recruiting and retaining the most highly aerobically fit candidates possible. The "Beep Test" validly measures this capacity and thus should be used as a screening tool for recruits. Furthermore, the study undertaken and reported in Appendix A strongly suggests the PAA does not stress the aerobic capacity to the level that the "Beep Test" does. Thus the suggestion by KPMG that the PAA/CPAT and "Beep Test" measure the same capacity can be rejected.

Do the CPAT and "Beep Test" test the same thing – aerobic capacity?

Research on children, adults and athletes has consistently shown that the "Beep Test" is a valid and reliable measure of aerobic capacity (Leger and Gadoury, 1989; Liu et al., 1992; Paliczka et al., 1987).

The question then must be asked, does the PAA/CPAT measure this capacity directly or indirectly. To this author's knowledge, after an extensive literature search and reading of all the CPAT literature made available to me, no published scientific evidence is available to validly show a relationship between the two tests. However, limited unpublished data from the Austin, Texas (USA) fire fighting service suggests that while the CPAT is aerobically demanding, it does not measure aerobic capacity or VO_2max as the "Beep Test" has consistently been shown to do in healthy adults (Leger and Gadoury, 1989; Paliczka et al., 1987).

Table 1: Results of CPAT trials measuring heart rates and VO_2 (oxygen consumption) on four firefighters.

Trial #	Duration (min:sec)	Peak VO_2 (ml/kg/min)	Avg. VO2 (ml/kg/min)	Avg. R	Peak HR (bpm)	Avg. HR (bpm)
1	00:09:58	46.59	33.48	1.04	188.00	172
2	00:08:31	47.32	34.80	1.03	190.46	174
3	00:09:01	47.66	34.85	1.00	185.23	173
4	00:08:38	48.60	35.35	1.01	191.89	175

To be valid, a test of aerobic capacity or VO_2max must exhibit an R (Respiratory Quotient) value of 1.10 or greater and a maximal heart rate at or close to a person's maximum heart rate. The respiratory quotient is measured using gas analysis equipment and is the ratio of carbon dioxide expired to oxygen consumed during exercise. Table 1 suggests that the average R value for the CPAT in the four subjects is between 1.00 and 1.04, thus not approaching the 1.10 value required to validly suggest VO_2max has been achieved. Furthermore, the average heart rates and VO_2 values appear much lower than the peak heart rates and peak VO_2 values, suggesting the overall work rate is sub maximal, despite some activities during the PAA/CPAT being at or close to maximal as demonstrated by the peak heart rate values. If the testers from Austin had have done an actual VO_2max test that also gives maximal heart rates and used far more than four subjects, we would have been able to determine that the PAA/CPAT does maximally or near-maximally stress the aerobic system.

The Appendix attached to this report strongly supports the suggestion above. In brief, the table below highlights and supports the results from table 1 that suggests the CPAT/PAA

does not maximally stress the aerobic system as the "Beep Test" does with the "Beep Test" VO_{2peak} being statistically higher than that observed during the PAA.

Table 2: Mean and standard deviations of each of the variables measured during the PAA, Beep Test and Treadmill test.

* Two of the 10 subjects failed to complete the test within the 10 min 20 sec time period allowed but time to completion was recorded and analysed.

significantly different to both treadmill (p=0.02) and PAA (p=0.001)

Variable	Result
Maximal oxygen uptake (ml/kg/min)	
PAA	44.7±5.0
Beep Test	51.7±4.5 #
Treadmill	47.5±4.5
Heart rate (bpm)	
PAA	187.9±10.8
Treadmill	189.6±11.2
Beep test (shuttles)	84.9±17.8
*PAA time to completion (seconds)**	601.1±126.8

In summary, there is insufficient current evidence to suggest the "Beep Test" and PAA/CPAT measure the same thing – aerobic capacity or VO_2max.

Maximum and minimum test conditions regarding temperature conditions for CPAT.

There is conclusive evidence that temperatures affect endurance exercise performance (see Cheung, McLellan & Tanaglia, 2000 for review). However, as pointed out on pages 17-18 of the CPAT manual, the following logistical and environmental factors will *optimise the candidate's safety and provide for consistency amongst candidates*:

1. CPAT should not be held in excessively hot, cold or wet conditions.
2. Candidates must NOT be tested in an environment where:
    a. Temperature is below 7^oC.
    b. The Apparent Heat Index (see below) is greater than 35^oC (95^oC).
    c. There is a measurable amount of rain (light drizzle only if working surfaces are safe to walk on and props, tools and test equipment can be kept dry.
    d. Sustained wind is greater than 32 kph

The apparent heat index is the "feels like" temperature. As relative humidity increases, the air seems warmer than it actually is because the body is less able to cool itself via evaporation of perspiration. The apparent heat index combines the effects of heat and humidity (see chart below). When heat and humidity combine to reduce the amount of evaporation of sweat from the body, outdoor exercise becomes dangerous.

Table 3: Apparent Heat Index Chart (Degrees Fahrenheit). No testing should take place when the Apparent Heat Index is greater than 95^{O}F.

Heat Index Chart

Temperature (F) \ % Relative Humidity	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
110	108	112	117	123	130											
105	102	105	108	113	117	122	130									
100	97	98	102	104	107	110	115	120	126	132						
95	91	93	95	96	98	100	104	106	109	113	119	124	130			
90	86	87	88	90	91	92	95	97	98	100	103	106	110	114	117	121
85	81	82	83	84	85	86	87	88	89	90	92	94	96	97	100	102
80	76	77	78	78	79	79	80	81	82	83	84	85	86	87	88	89

Legend	
80-89 degrees	Fatigue is possible with prolonged exposure and/or physical activity.
90-104 degrees	Sunstroke, heat cramps and heat exhaustion are possible with prolonged exposure and/or physical activity.
105-129 degrees	Sunstroke, heat cramps and heat exhaustion are likely. Heat stroke is possible with prolonged exposure and/or physical activity.
130+ degrees	Heatstroke/sunstroke is highly likely with continued exposure.

Table 4: Apparent Heat Index Chart (Degrees Celsius). No testing should take place when the Apparent Heat Index is greater than 35^{O}C.

Heat Index Chart

% Relative Humidity

Temperature (C)	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
43.3	42.2	44.4	47.2	50.6	54.4											
40.6	38.9	40.6	42.2	45.0	47.2	50.0	54.4									
37.8	36.1	36.7	38.9	40.0	41.7	43.3	46.1	48.9	52.2	55.6						
35.0	32.8	33.9	35.0	35.6	36.7	37.8	40.0	41.1	42.8	45.0	48.3	51.1	54.4			
32.2	30.0	30.6	31.1	32.2	32.8	33.3	35.0	36.1	36.7	37.8	39.4	41.1	43.3	45.6	47.2	49.4
29.4	27.2	27.8	28.3	28.9	29.4	30.0	30.6	31.1	31.7	32.2	33.3	34.4	35.6	36.1	37.8	38.9
26.7	24.4	25	25.6	25.6	26.1	26.1	26.7	27.2	27.8	28.3	28.9	29.4	30	30.6	31.1	31.7

Legend	
26.7-31.7 degrees	Fatigue is possible with prolonged exposure and/or physical activity.
32.2-40.0 degrees	Sunstroke, heat cramps and heat exhaustion are possible with prolonged exposure and/or physical activity.
40.6-53.9 degrees	Sunstroke, heat cramps and heat exhaustion are likely. Heat stroke is possible with prolonged exposure and/or physical activity.
54.4+ degrees	Heatstroke/sunstroke is highly likely with continued exposure.

To use the chart, locate the air temperature along the left column and the relative humidity along the top. The cell where the two intersect is the heat index. For example, an air temperature of 90 degrees Fahrenheit and a relative humidity of 60 percent intersect at a heat index of 100 degrees. In other words, the temperature would feel like 100 degrees with this humidity/temperature combination. Heat index values were devised for shady light wind conditions. Exposure to full sunlight can increase values by up to 15 degrees Fahrenheit.

(Taken from: http://www.tvweather.com/awpage/heat_index_chart.htm)

Given that it is proposed that the PAA may be used in a portable fashion throughout Queensland, it is obviously important to adhere to the CPAT environment guidelines outlined above and both minimise the risk of heat injury and ensure the reliability of the CPAT test by ensuring that testing was conducted in the mid-winter months for the Cairns, Townsville, Mackay, Rockhampton, Gladstone and Bundaberg testing. Given the guidelines above, there is the need to examine and measure the mean temperatures and humidity for the major centres throughout Queensland where PAA will take place.

Are the CPAT tests job-specific?

There is absolutely no doubt in my opinion, that the CPAT remains the most valid test of North American fire fighting physical abilities that I have seen. The question posed – is the highly validated CPAT test and skills contained within the PAA/CPAT, job-specific to Queensland conditions? However, a major survey of operational firefighters in Queensland (McLachlan, 2000) would support the use of the PAA/CPAT as a job-specific test of fire fighting physical abilities with over 85% of those surveyed supporting the CPAT as testing job-specific physical abilities.

For a physical test to be universally accepted within exercise science, it must demonstrate the following features:

- Validity – it actually measures what it was designed to measure. There are two major types of validity:
    1. Content validity – the elements of the test are similar to the elements of the job
    2. Criterion validity – the test can predict or are related to actual performance
- Reliability – a measure of the consistency of the test results, usually determined by the test-retest method, where the first measure is compared to the second measure on the same subjects under the same conditions.
- Objectivity – the data are collected without bias by the measurers.
- Specificity – related to validity but referring to the test actually measuring the skills of capacities of the task required.

The CPAT manual goes to great lengths to highlight these four key characteristics of the CPAT. Specifically, the following evidence conclusively demonstrates that the CPAT is a valid, reliable, objective and specific test for fire fighting in North America:

1. The International Association of Firefighters (IAFF) and International Association of Fire Chiefs (IAFC) approved the CPAT to be *the fairest, most valid and functional candidate physical ability tests ever created for the fire service* (p. iii of CPAT manual).
2. A panel of experts (including operational fire fighters, line officers, training officers, union presidents, exercise physiologists, biomechanists, physicians, attorneys, labour and employment lawyers, industrial psychologists) lead and approved the four-year validation and reliability process outlined below:
    a. The panel of experts examined the previously existing physical ability tests and firefighters job task analysis for 10 jurisdictions.

b. The panel of experts narrowed the tasks down to 31 major tasks based on physicality and criticality
c. The panel of experts undertook a survey of 980 operational firefighters from a range of age groups, ranks, genders, ethic backgrounds, and experience levels to determine the most critical and physical of these 31 tasks.
d. The panel of experts developed a series of tests to measure the most critical and physical tasks identified in the survey. These were:
    i. *Stair Climb*: >95% of respondents said this was a critical and physical task
    ii. *Hose Drag*: >96% of respondents said this was a critical and physical task
    iii. *Equipment Carry*: >95% of respondents said this was a critical and physical task
    iv. *Ladder Raise and Extension*: >95% of respondents said this was a critical and physical task
    v. *Forcible Entry*: >96% of respondents said this was a critical and physical task
    vi. *Search*: >96% of respondents said this was a critical and physical task
    vii. *Rescue*: >95% of respondents said this was a critical and physical task
    viii. *Ceiling Breech and Pull*: >95% of respondents said this was a critical and physical task
e. The panel of experts *unanimously* agreed the tests developed were equal to or superior in validity and specificity to those currently used by 10 jurisdictions (p. 63 CPAT Manual).
f. A survey of equipment used in the critical tasks was undertaken by the panel of experts to determine what equipment would be used in the CPAT tests.
g. The panel surveyed 161 firefighters and emergency services personnel as to what rate of climbing stairs was the most realistic in their day-to-day activities and unanimously arrived at 60 steps / minute.
h. Placed each of eight tasks above in the order above to replicate what would happen at a typical fire suppression activity.
i. Determined the weight of the rescue dummy by examining the hospital admission data and determining the average body weight.

j. Had 89 operational firefighters and 33 training academy subject matter experts highly skilled and well-acquainted with the job demands of fire fighting in one location complete the CPAT.
    i. 93% of them stated the CPAT required physical exertion similar to the physical exertion required by essential fire fighting job duties
    ii. 94% said the test events could be performed by individuals with little or no orientation or training
    iii. 90% said the test events required a range of activities that are similar in nature to the activities required by actual job tasks.
k. Established the cut-off score of 10min 20sec by having 33 training officers time and rate and 13 probationary firefighters on minimally acceptable job performance of each event and the CPAT as a whole. The range of times for CPAT completion was 7min 30sec to 12min 10sec. However, the majority of evaluators said 10min 11sec was clearly acceptable but 10min 30sec was marginally acceptable. Thus, validly, the cut-off score was determined as 10min 20sec.

3. Once the validity and specificity of the CPAT was determined, it was then essential that the panel of experts to ensure the reliability and objectivity of the CPAT. On June 15-18, 1999, 12 candidates (aged 17-21 years) and 14 evaluators who had never seen the CPAT before but who were operational firefighters were oriented with the CPAT through written and video material and then walked through the series of CPAT events. Appendix 6-14 of the CPAT manual conclusively demonstrates that the CPAT can be administered with a high degree of reliability.
4. The objectivity of the CPAT was determined by having the evaluators of the reliability study involved in a study to:
    a. Determine the reliability of written CPAT instructions
    b. The effectiveness of the CPAT candidate evaluation form
    c. The reliability of the test administration guide's candidate instructions
    d. Quality of the test administration guide's pre-CPAT orientation procedures

    Again, the technical panel determined high CPAT inter-rater reliability to provide statistical and evaluator assurances that the CPAT is a reliable method to allow a fire department to obtain a pool of trainable candidates that are physically able to perform the essential job tasks at fire scenes.

The McLachlan report of 2000 also highlighted the importance of PAA test elements. A total of 791 QFRS members, including 204 station officers and 583 operational fire fighters from all over Queensland and ranging from one to more than 16 years of service, all age groups and including six females, concluded that:

- *Excessive* to *moderate* effort was required for each of the PAA elements including a stair climb, hose drag, equipment carry, ladder raise and extension, forcible entry, search, rescue, and ceiling breach and pull.
- Task importance of *extremely* to *very important* was rated for each the PAA elements listed above.

In summary and in my opinion, there is conclusive evidence from both the CPAT validation studies, the McLachlan report, and the study attached in Appendix A, that the PAA/CPAT is a valid, reliable and objective test that has scientific credibility and that has achieved its objective of being the fairest, most valid and functional candidate physical ability test ever created for the fire service.

Relate current QFRS recruit tests to other states and NZ recruit tests.

I have examined in detail each Australian state's and New Zealand's recruit entry testing. Below are some general comments:

i. None appear to have any evidence of reliability or validity except they are appear to be a random set of tests that may specifically measure a critical task (eg hose drag, ladder raise, drum carry etc) or non-specific tests that are invalid and legally indefensible in terms of job-specificity (eg New Zealand's grip strength, push-ups, dead lift and shoulder press).
ii. Many (eg WA also have tests of acrophobia (fear of heights), balance (eg ACT, Tas) claustrophobia (eg ACT, NT, WA, Tas) or vertigo (dizziness) included in physical tests (eg Q'ld)
iii. The instructions for most appear very "loose" with statements such as "tests may be changed on the day due to availability of personnel or equipment" (Tas) or "assessments may vary" (NT)
iv. During some test events many wear BA, gloves, helmets etc (eg WA, SA) that recruits are not familiar with.

v. Beep tests are widely used by all states but the minimum standard varies from level 9.6 / 45 ml/kg/min VO_2 (NSW, SA, ACT, NT, Tas) to level 8.6 / 43 ml/kg/min (WA).

Specific New Zealand comments include:

a. Uses too many non job-related tests such as push-up in one minute, grip strength, deadlift, and vertical jump. While such tests may measure muscular strength, muscle power or muscle endurance, they do it in a non-specific way and are thus invalid when measuring job-specific capabilities.
b. They suggest replacing job-specific tests such as the sledgehammer hit and dummy drag with the above non-specific tests. This would be open to legal challenge.
c. They suggest gender specific normal pass values yet firefighters have the same job requirements.
d. There is no evidence of validation or reliability of any of their tests in any of the literature I have seen to date.
e. There is no mention of what order the testing is to be done in which raises the question of reliability.

In summary, the PAA/CPAT is the most valid and reliable test of both an operational fire fighter and recruits ability to "do the job" and therefore unchallengeable in court. In terms of physical testing principles, it meets every criterion. The sooner the whole of Australia's fire fighting service do the same thing as the IAFF appears to have done and standardised it's testing, the better. At present it appears too may non-experts and too many "experts" appear involved and testing is very ad hoc, invalidated and unreliable. Someone or some organisation just needs the courage to bite the bullet and say PAA/CPAT is the way to go and do it. Nationally or at Queensland level, getting an expert panel together as CPAT did would solve all the issues. Saying that, I still feel, and the data from our study reported in the Appendix supports this, the "beep test" should be included in recruit screening. The service needs the very fittest to get involved and the same test measures the most important capacity of all (for health, thermoregulation and job performance reasons) in my opinion – the aerobic capacity.

Compare and contrast the QFRS McLachlan report of 2000 with the CPAT manual's outcomes on PAA/CPAT task criticalities, importance and perceptions of physical effort as determined by operational fire fighters.

The McLachlan report of 2000 also highlighted the importance of PAA test elements and strongly supports the results of the studies done by a panel of experts in the development of the CPAT in North America. The McLachlan report surveyed a total of 791 QFRS members, including 204 station officers and 583 operational fire fighters from all over Queensland and ranging from one to more than 16 years of service, all age groups and including six females. The report concluded that:

- *Excessive* to *moderate* effort was required for each of the PAA elements including a stair climb, hose drag, equipment carry, ladder raise and extension, forcible entry, search, rescue, and ceiling breach and pull.
- Task importance of *extremely* to *very important* was rated for each the PAA elements listed above.

These findings are in total agreement with the CPAT panel of experts findings.

Associate Professor, Peter Reaburn PhD
School of Health and Human Performance
Central Queensland University
Ph: 4930 6748
E-mail: p.reaburn@cqu.edu.au

APPENDIX A

Report of Research Project examining the relationship between Physical Ability Assessment (PAA) performance and both Beep Test and Treadmill running performance.

Purpose of the Study

To compare and contrast PAA performance of potential QFRS recruits and performance in both an aerobic capacity test on a treadmill and the multistage fitness test ("Beep Test").

Methodology

Participants: Ten (9 males, 1 female) healthy and physically active prospective QFRS recruits (age: 28±8.6 yr; body mass: 77.1±10.6 kg; height: 179.9±7.6 cm) volunteered to participate in the study. Each participant signed an informed consent document and completed a Physical Activity Readiness Questionnaire (PAR-Q) prior to participation.

Procedures: Each participant undertook three tests in succession. On day one, two tests were undertaken approximately two hours apart on the Rockhampton Fire Station grounds. Ambient conditions ranged from 28-32^{o}C temperature, 42-56% relative humidity, and 765-769 mmHg barometric pressure. The first test consisted of completion of the Multistage Fitness Test used in recruit testing for the QFRS. This test indirectly measures maximal oxygen uptake (VO_{2peak}) using progressive multistage 20-m shuttle runs to exhaustion (Leger and Lambert 1982). The number of shuttles was recorded for later data analysis and VO_{2peak} estimated from the number of shuttles completed using widely available tables.

The second test consisted of the Physical Ability Assessment (PAA) widely used in North America (Candidate Physical Ability Test - CPAT) as the physical ability component of the fire fighter hiring and recruiting process. The standardized test consists of eight separate and critical job related physical tasks performed in a continuous sequence that simulates fire scene events. The assessment must be completed within 10 minutes and 20 seconds and consists of a stair climb, hose drag, equipment carry, ladder raise and extension, forcible entry; search, rescue, and ceiling breach and pull. Throughout the test, participants wore long pants, a hard hat with chinstrap, work gloves and appropriate footwear with no open heel or toe. Watches and loose or restrictive jewellery were not permitted. Each participant wore a 22.7 kg (50-lb)

vest to simulate the weight of self-contained breathing apparatus and fire fighter protective clothing. An additional 11.4 kg (25-lb) is added to the candidate's shoulders during the stair climb event to simulate carrying a high-rise pack. Specific details of the test and each component of the test can be found in the CPAT manual. Heart rate (HR) was recorded continuously during the test, using short-range radio telemetry (Polar Sporttester, Polar Electro Oy, Kempele, Finland) and the highest HR during the CPAT test was recorded as HR_{peak}. Time taken (seconds) to complete the test and HR_{peak} were recorded for later data analysis.

On a separate occasion close to day one of testing, each participant attended the Human Performance Laboratory at Central Queensland University, to complete the third and final test of the project – a treadmill run to volitional exhaustion to measure VO_{2peak} and HR_{peak} using standardized methods. Briefly, following familiarization with the treadmill, heart rate monitor (Polar) and gas analysis equipment (Medgraphics CPX), each participant commenced treadmill running at between 8-10 km/hr and ran continuously on the treadmill while speed was increased 1 km/hr each minute until volitional exhaustion after which each participant warmed down for five minutes at a self-selected speed. HR_{peak} was determined as the highest heart rate achieved during the last minute of exercise and VO_{2peak} as the highest recorded 30-second rolling average of oxygen uptake during the last minute of exercise. Criteria for achievement of VO_{2peak} were no increase in VO_2 despite an increase in running speed, an RER value of greater then 1.10, and volitional exhaustion. HR_{peak} and VO_{2peak} values were recorded for data analysis.

Data Analysis. In order to determine oxygen consumption (VO_2) during the PAA, regression analysis was undertaken using an *Excel* function (Microsoft) for each subject's heart rate – VO_2 relationship during the treadmill test of maximal oxygen uptake. Once a regression equation was determined for this relationship, VO_{2peak} for the PAA was determined. Relationships and differences between a number of variables (Beep test shuttles, estimated VO_{2peak} for the beep test, PAA time to completion, PAA HR_{peak}, PAA VO_{2peak}, treadmill HR_{peak} and treadmill VO_{2peak}). Relationships between variables were determined using Pearson product moment correlations and differences between variables determined using a paired, two-tailed Student's t-test. Statistical significance was accepted at the 0.05 level.

Results

Table one below shows the results (mean and standard deviation) of each of the tests conducted.

Table 1: Mean and standard deviations of each of the variables measured during the PAA, Beep Test and Treadmill test.

* Two of the 10 subjects failed to complete the test within the 10 min 20 sec time period allowed but time to completion was recorded and analysed.

significantly different to both treadmill (p=0.02) and PAA (p=0.001)

Variable	Result
Maximal oxygen uptake (ml/kg/min)	
PAA	44.7±5.0
Beep Test	51.7±4.5 #
Treadmill	47.5±4.5
Heart rate (bpm)	
PAA	187.9±10.8
Treadmill	189.6±11.2
Beep test (shuttles)	84.9±17.8
*PAA time to completion (seconds)**	601.1±126.8

VO_{2peak} values for the beep test were significantly greater than the VO_{2peak} values recorded for either the PAA or treadmill tests. The VO_{2peak} for the PAA was 94% of that observed during the treadmill test but not statistically different.

Correlation analysis was undertaken to examine the relationship between variables of interest. Significant relationships were observed between HR_{peak} during the PAA and treadmill tests ($r=0.68$, $p<0.01$), VO_{2peak} observed during the PAA and treadmill tests ($r=0.63$, $p<0.05$), and the number of Beep test shuttles and time to completion of the PAA($r=-0.76$, $p<0.01$).

Discussion

The purpose of this study was to compare and contrast PAA performance of potential QFRS recruits and performance in both an aerobic capacity test on a treadmill and the multistage fitness test ("Beep Test") used by the QFRS as part of their recruiting process. The results of this study suggest that, while the multistage fitness test (Beep Test) might predict PAA performance as suggested by the significant correlation between PAA completion time and the number of shuttles completed in the Beep test, two of the 10 participants who passed the

minimum requirement of the Beep Test were not able to meet the required PAA completion time of 10 minutes and 20 seconds. Indeed one of the participants achieved a Beep Test score of 11.8 but completed the PAA test in 10 minutes and 40 seconds, strongly suggesting that the PAA measures more capacities than just aerobic capacity that is measured by the Beep test.

The results of this study also suggest that the PAA test, as suggested by the estimated VO_{2peak} of 44.7±5.0 ml/kg/min is not as aerobically stressful as the Beep test where the same participants recorded a VO_{2peak} of 51.7±4.5 ml/kg/min. This result would strongly suggest that the PAA test measures different job-related qualities than the Beep test that is designed to indirectly measure VO_{2peak} in a cost-effective and time-effective manner.

Fire fighters perform numerous tasks that require high levels of muscular strength, and both muscular and cardiovascular endurance. The PAA replicates the CPAT widely used in North America and shown by a panel of experts within the United States as a valid and reliable measure of fire fighting physical qualities. Operational fire fighter must be able to carry and climb ladders while wearing heavy protective clothing and breathing apparatus, lift, drag and control charged fire hoses, swing an axe or sledgehammer to gain to gain or clear entry, lift, drag or carry victims to safety, and perform these tasks continuously or intermittently until an emergency is resolved. The PAA test is designed to identify individuals who have these physical attributes to perform the job of a fire fighter.

The required job skills of modern fire fighters are complex and rigorous. Fire fighting is considered one of the most physically demanding and hazardous of all civilian occupations (Gledhill & Jamnik, 1992). During both training drills and actual fire suppression activities, firelighters perform numerous tasks that require high levels of muscular strength, and both muscular and cardiovascular endurance.

Importantly, an adequate level of aerobic power or VO_{2peak} is widely recognised as critical for safe and effective firefighting (Davis, Dotson & Santa Maria, 1982; Gilman & Davis, 1993; Gledhill & Jamnik, 1992; Peate, Lundergan & Johnson, 2002; Sothman, Saupe, Jasenof & Blaney, 1992; Swank, Adams, Barnard, Berning & Stamford, 2000b). Furthermore, fire suppression activities take place in thermally stressful environments where high levels of radiant heat combined with wearing heavy protective clothing and breathing apparatus prevent heat loss via evaporative cooling (Richardson & Capra, 2001; Smith, Petruzzello, Kramer & Misner, 1997; Smith & Petruzzello, 1998). A high level of cardiorespiratory fitness has also long been associated with improved exercise-heat tolerance (see Cheung, McLellan & Tanaglia, 2000 for review), again highlighting the importance of a high VO_2max

in operational firefighters. Finally, high levels of aerobic fitness are associated with decreased mortality and cardiovascular disease and to improved cardiovascular disease risk factors such as lower cholesterol levels, lowered blood pressure, and improved glucose tolerance and insulin sensitivity (Blair, Kohl, Barlow, Paffenbarger, Gibbons & Macera, 1995; US Department of Health and Human Services, 1996). However, previous research has shown that the leading occupation-related cause of premature termination of service for operational fire fighters is cardiovascular disease and that the same cohort has increased cardiovascular disease rates than the general population (National Fire Protection Association, 1997; Swank, Adams, Barnard, Berning, Ottersbach, & Bowerman, 2000a). Furthermore, recent data has shown that 41.7% (professional fire fighters) and 47.6% (volunteer fire fighter) of United States on-duty fire fighter fatalities were due to myocardial infarctions and the majority of these fire fighters had a prior history of cardiovascular disease (Fahy & Leblac, 2002).

Taken together, the above factors strongly suggest that aerobic capacity, as indirectly but efficiently and cost-effectively measured by the Beep test, should remain a crucial component of the QFRS recruiting process. Moreover, while the PAA test also stresses the aerobic system to approximately 94% of VO_{2peak}, it validly and reliably measures the job-related tasks of fire fighting. Importantly, both the CPAT manual and the QFRS Physical Fitness Survey Analysis (McLachlan, 2000) highlighted that the each of the PAA tasks were rated by fire chiefs in North America and 204 QFRS station officers and 583 QFRS operational firefighters as requiring maximal or moderate physical effort and extremely or very important in importance.

In summary, the results of this analysis strongly suggest the need to retain the multistage fitness test (Beep test) as a cost-effective means of measuring the all-important aerobic capacity of QFRS recruits. Furthermore, while the PAA test also stresses the aerobic system, it more validly and reliably measures the critical job-related tasks of operational fire fighters and should thus be included in the QFRS recruiting process.

References

Adams, T., Yanowitz, F. et al. (1986). A study to evaluate and promote physical fitness among firefighters. *Journal of Sports Medicine and Physical Fitness* 26(4): 337-345.

Blair, S.N., Kohl, H.W. III, Barlow, C.E., Paffenbarger, R.S. Jr., Gibbons, L.W. & Macera, C.A. (1995). Changes in physical fitness and all-cause mortality: a prospective study of healthy and unhealthy men. *Journal of the American Medical Association* 273: 1093-1098.

Cheung, S.S. and McLellan, T.M. (1998). Heat acclimation, aerobic fitness, and hydration effects on tolerance during uncompensable heat stress. *Journal of Applied Physiology* 84(5): 1731-1739.

Cheung, S.S., McLellan, T.M. & Tenaglia, S. (2000). The thermophysiology of uncompensable heat stress: physiological manipulations and individual characteristics. *Sports Medicine* 29(5): 329-359.

Davis, P., Dotson, C. & Santa Maria, D. (1982). Relationship between simulated firefighting tasks and physical performance measures. *Medicine and Science in Sports and Exercise* 14: 65-71.

Donovan, K. and McConnell, A. (1999). Firefighters' self-contained breathing apparatus (SCBA): the effects of SCBA mass upon exercise duration during treadmill walks in the laboratory. *Fire Engineers Journal*. November: 28-33.

Fahy, R.F. & LeBlanc, P.R. (2002). Firefighter fatalities 2001. *NFPA Journal* July/August: 68-76.

Gilman, W.D. & Davis, P.O. (1993). Fire fighting demands aerobic fitness. *NFPA Journal* March/April: 68-73.

Gledhill, N. & Jamnik, V.K. (1992). Characterization of the physical demands of firefighting. *Canadian Journal of Sport Science* 17(3): 207-213.

Havenith, G., Inoue, Y. et al. (1995a). Age predicts cardiovascular, but not thermoregulatory, responses to humid heat stress. *European Journal of Applied Physiology*. 70: 88-96.

Havenith, G., Luttikholt, V. et al. (1995b). The relative influence of body characteristics on humid heat stress response. *European Journal of Applied Physiology*. 70: 270-279.

Leger, LA, and Lambert, J (1982). A maximal multistage 20-m shuttle run test to predict VO_2 max. *European Journal of Applied Physiology* **49**: 1–12.

Leger, L. and Gadoury, C. (1989). Validity of the 20 m shuttle run test with 1 min stages to predict VO2 max in adults. *Canadian Journal of Sport Sciences* 14(1): 21-26.

Louhevaara, V., Soukainen, J. et al. (1994). Development and evaluation of a test drill for assessing physical work capacity of fire fighters. *International Journal of Industrial Ergonomics.* 13: 139-146.

McLachlan, B. (2000). Physical Fitness Survey Results. Report from Management Information Analyst, Strategic Planning and Policy Unit, Queensland Fire and Rescue Authority, September, 2000.

National Fire Protection Association (1997). *1582: Standard of medical requirements for firefighters* Quincy, MA: NFPA.

Paliczka, V., Nichols, A. and Boreham, C. (1987). A multi-stage shuttle run as a predictor of running performance and maximal oxygen uptake in adults. *British Journal of Sports Medicine.* 21(4): 163-165.

Peate, W.F., Lundergan, L. & Johnson, J.J. (2002). Fitness self-perception and VO_2max in firefighters. *Journal of Occupational and Environmental Medicine* 44(6): 546-550.

Pyke, F., Rickard, R. et al. (1987). Research into practice: physical fitness and firefighting. *Journal of Occupational Safety.* 3(1): 16-21.

Richardson, J.E. & Capra, M.F. (2001). Physiological responses of firefighters wearing level 3 chemical prortective suits while working in controlled hot environments. *Journal of Occupational and Environmental Medicine* 43(12): 1064-1072.

Smith, D.L., Petruzzello, S.J., Kramer, J.M. & Misner, J.E. (1997). The effects of different thermal environments on the physiological and psychological responses of firefighters to a training drill. *Ergonomics* 40(4): 500-510.

Smith, D. & Petruzzello, S.J. (1998). Selected physiological and psychological responses to live-fire drills in different configurations of firefighting gear. *Ergonomics* 41(8): 1141-1154.

Sothmann, M., Saupe, K. et al. (1990). Advancing age and cardiorespiratory stress of fire suppression: determining a minimum standard for aerobic fitness. *Human Performance* 3: 217-236.

Sothmann, M., Saupe, K., Jasenof, D. & Blaney, J. (1992). Heart rate response of firefighters to actual emergencies: Implications for cardiorespiratory fitness. *Journal of Occupational Medicine* 34: 797-800.

St Clair-Gibson, A., Broomhead, S. et al. (1998). Prediction of maximal oxygen uptake from a 20-m shuttle run as measured directly in runners and squash players. *Journal of Sports Sciences.* 16(4): 331-335.

Swank, A.M., Adams, K.J., Barnard, K.L., Berning, J.M., Ottersbach, M. & Bowerman, J. (2000a). A comparative analysis of cardiovascular disease risk factors for volunteer firefighters. *Clinical Exercise Physiology* November: 199-203.

Swank, A.M., Adams, K.J., Barnard, K.L., Berning, J.M., & Stamford, B.A. (2000b). Age-related aerobic power in volunteer firefighters, a comparative analysis. *Journal of Strength and Conditioning Research* 14(2): 170-174.

US Department of Health and Human Services. (1996). *Physical activity and health: a report of the surgeon general.* Atlanta, GA: USDHHS, Centers for Disease Control and Prevention.