THE HEALTH, FITNESS, AND ANTHROPOMETRIC CHARACTERISTICS OF FIREFIGHTERS ON THE NORTH COAST OF CALIFORNIA

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Abstract

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Limited research has been conducted on the health-related physical fitness level of rural firefighters on the northern coast of California. The geographic isolation of rural firefighters creates unique challenges, including staffing shortages placing individual firefighters under unusual physiological stress.

PURPOSE: The purpose of this study was to examine the health-related physical fitness status of rural firefighters.

METHODS: 20 male firefighters (mean±sd, age = 32±7 yr, height = 180±5 cm, body mass = 96±16 kg, fire service = 9±7 yr) on the northern coast of California performed body composition, strength, flexibility, and aerobic capacity tests. Data were compared with age-based normative data.

RESULTS: Fitness testing revealed that rural firefighters ranked above average on tests of upper body muscular strength (bench press) and aerobic capacity (VO2max) and average on tests of body composition (% fat) and flexibility (sit-and-reach). (Table 1)

CONCLUSIONS: Exercise programs for firefighters should focus on improving flexibility and body composition, while maintaining muscular strength and aerobic fitness to meet the demands of firefighting.

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Introduction

Firefighting is a physically taxing profession utilizing muscular strength, endurance, aerobic fitness, coordination, balance, and agility. Job tasks include use of demolition and extrication tools, hauling hoses and victim rescue. Making these tasks even more difficult, is the firefighting environment, marked by extreme temperatures, dangerous, unstable surroundings, and exposure to toxins. In addition to physical stresses, firefighting is mentally and psychologically demanding. These multiple stressors produce various health related problems. Conversely, as stated by Assistant Chief Sean Campbell, maintaining a high level a of physical fitness corresponds to better overall job performance and safety (Yoo, A., 2015).

While firefighters have to pass a physical entrance exam or ability test (AT), once passed they do not have to maintain physical fitness standards. Typically, ATs involve performing firefighting related tasks with a goal of minimizing time to completion. Perhaps the most common example of AT is the Candidate Physical Ability Test (CPAT), which consists of eight events: stair climb, hose drag, equipment carry, ladder raise and extension, forcible entry, maze search, rescue, and ceiling breach and pull (Joint Labor Management Wellness Fitness Task Force, 2007). Unfortunately, many firefighters are overweight or even obese, and most fire departments have no health programs aimed at mitigating this lack of fitness (National Fire Protection Association (NFPA), 2011). In fact, according to the NFPA (2011), only 30% of fire departments have such programs in place.

Arcata and Humboldt Bay fire departments face additional unique challenges. While Arcata and Eureka are considered urbanized clusters, the surrounding areas serviced by these departments is defined as rural (United States Census Bureau, 2010). As such, they face the same challenges offered by similar urban infrastructure, while relying on a much smaller population of both career and volunteer firefighters (S. Campbell, personal communication, 1/21/16).

Review of Literature

Description of Physical Characteristics

The focus of this review of literature will be the physical fitness related characteristics of firefighters. These characteristics will include all of the health- and fitness-related components of physical fitness as defined by the American College of Sports Medicine (ACSM). In addition, there will be a discussion of somatotyping as it applies to firefighters.

Health related components. According to the ACSM, there are five health-related components: Aerobic fitness, muscular endurance, muscular strength, body composition, and flexibility (Pescatello et al., 2014).

Aerobic fitness. VO_2Max is a measure of cardiorespiratory fitness and endurance (Pescatello et al., 2014). According to the Fire Service Joint Labor Management Wellness-Fitness Initiative (WFI) (2008), heart disease accounts for 45% of all on-duty deaths in US firefighters. Cardiac events outnumber all other cause mortality in firefighters (WFI, 2008). High rate of cardiovascular disease (CVD) and CVD related deaths has prompted national recommendations for minimal aerobic fitness levels (VO_2Max) in firefighters of 43ml/kg/min (NFPA, 2011). Longitudinal studies have demonstrated an inverse relationship has been found between aerobic fitness and risk of CVD (Ferreira et al., 2003).

Unfortunately, it is impractical to conduct measured maximal tests on every firefighter. As such, many researchers employ submaximal, predictive, field- and laboratory-tests as well as self-reported physical activity surveys (SRPA) in order to ascertain aerobic fitness. These alternate tests include the YMCA cycle ergometer protocol, the Bruce treadmill protocol, the Cooper 12-minute run, and the 1.5 mile run (Pescatello et al., 2014).

In their study, Jahnke et al. (2015) found an average VO_2Max for male, career firefighters of 43.3ml/kg/min. According to normative data obtained from the ACSM, this result ranks as fair (Pescatello et al., 2014). However, these results were obtained using a SRPA, and may be inaccurate. Researchers in another study found pre-intervention firefighter recruit VO_2Max values, as predicted by a cycle ergometer test, of 35ml/kg/min, a classification of poor or very poor according to the ACSM (Roberts et al. 2002; Pescatello et al., 2014). It is important to keep in mind that cycle ergometers tend to give lower VO_2Max values as compared to treadmills (Pescatello et al., 2014).

In general, studies with larger, more representative samples provided lower estimates of VO_2Max, as compared to studies with smaller samples. For example, in their studies, Jahnke et al. (2015) (n=625), Bauer et al. (2012)(n=957), and Vandersmissen et al. (2014)(n=605), researchers found VO_2Max values of 42ml/kg/min, 42ml/kg/min, and 43.3ml/kg/min respectively and are close to the NFPA recommended values. According to ACSM age/sex corrected norms, these values fall within 50-65%ile, or from average/fair-good. Conversely, smaller more specialized samples, tend to produce more positively skewed results. For example, in their study, Moore, Penry and Gunther (2014) (n=38) reported finding VO_2Max values of 48.4ml/kg/min, an ACSM ranking of excellent (Pescatello et al., 2014). Similarly, Sell (2011) (n=21) found VO_2Max values of 54.5, an ACSM ranking of superior (Pescatello et al., 2014) (see Table 1).

Table 1 Aerobic Capacity

Test	Protocol	Subjects	Results	Classification	References
VO_2max	Treadmill/bike	n=605(m) age=40.4(11.5)	43.3ml/kg/min	ACSM-good (65-70%)	Vandersmisser et al.(2014).
VO_2max	Cycle Ergometer	n=115(m=104, w=11) age=28.3(4.3)	pre=35(7) post=45(6) ml/kg/min	ACSM-pre= very poor (10%), post=fair/good (55-60%)	Roberts et al. (2002).
VO_2max	Walking Treadmill	n=38(m) age=31.2(7.7)	48.4(6.5)ml/kg/min	ACSM-excellent (80%)	Moore et al. (2014).
VO_2max	Treadmill	n=957(m), age=39.6(8.5)	MaxMets=12(1.9) 42(6.65)ml/kg*min	ACSM-fair (50%)	Baur et al.(2012).
VO_2max estimate	1.5 mile run	n=21(m) age 25.33(.79)	9.45(.14)min, 9.52mph, 54.55ml/kg/min	ACSM-excellent (90%)	Sell K. (2011).
VO_2max Estimate	Cooper 12 min run	n=20(m=17, w=3) age=34.5(6.1)	2181m(386.9), 37.47ml/kg/min	ACSM-very poor (25%)	Rhea et al. (2004).
VO_2max and submax	Bruce max, treadmill submax	n=30(m=21, f=9) age=31.9(6.4)	Submax=44.6(3.9) Max=45.7(7.2)	ACSM-60-65%	Delisle et al. (2014).
VO_2submax	Treadmill/ Stairmill	n=54(m=40, w=14) age=36.3(5.7)	treadmill=46.1(6.3) stairmill=45.3(6.7)	ACSM-good (70%)	Tierney et al. (2010).
VO_2submax	Cycle ergometer	n=95(m) volunteer age=37.5(10.6)	31.5(7.2)ml/kg/min	ACSM-very poor (5%)	Swank et al. (2000).
VO_2Max estimate	SRPA survey	n=625(m) age=39.4(8.8)	12 MET (42ml/kg/min)	ACSM-fair to good (50%)	Jahnke et al.. (2015).

Muscular endurance. Muscular endurance (ME) is a necessary part of effective firefighting. Firefighters can expect to work for lengthy periods of time, either manipulating charged hoses, throwing ladders, dragging victims to safety, or using heavy tools to breach walls and doors, or extricate victims from vehicles. ME is especially important in rural settings, where relief crews are in short supply.

There are several widely-accepted ways of measuring upper body ME including bench-press, curl-up, and push-up tests. In their study, Michaelides et al. (2011), found that success on the pushup test, a test of muscular endurance (Baumgartner, et al., 2002), was a good predictor of how well firefighters performed on firefighter task associated AT. In another study, researchers employed the YMCA bench-press protocol and determined both that firefighters scored well above average in ME (78-88%ile), ACSM classification of good to excellent, but also that female firefighters scored significantly higher than male firefighters (Magyari et al., 2010; Pescatello et al., 2014). In several other studies, researchers tested firefighter ME using push-up tests, performing push-ups until fatigue, and also found that when compared to age-sex corrected norms, firefighters scored excellent as defined by ACSM guidelines (Michaelides et al., 2008; Roberts et al., 2002; Sell, K. 2011; Pescatello et al., 2014). Sell (2011) also measured upper body ME using a partial curl-up protocol, and found that hotshot firefighters had above average ME, when compared to general populations.

In addition to widely accepted protocols such as the YMCA bench-press test, researchers have employed non-traditional ME tests, using weights intended to simulate the use of specialized firefighting equipment. In their study, Nacleiro et al. (2009) had firefighters complete as many repetitions as possible of a 40kg weight in 40 seconds.

Rhea et al. (2004), performed a similar test, asking participants to perform bench-press repetitions to fatigue using 45.5kg (see Table 2).

Table 2 Muscular Endurance

Test	Protocol	Subjects	Results	Classification	References
Upper body endurance	YMCA bench press test	n=535(m=502, w=33)	m=37.6 & 32.3, w=50.8 & 47.7	m=78% & 73%, w=86% & 88%	Magyari et al. (2010).
Upper body endurance	Push-ups to fatigue	n=38(m), age=32.25(6.07)	35.57(15.29)	ACSM-excellent	Michaelides et al. (2008).
Upper body endurance	Push-ups to fatigue	n=115(m=104, w=11), age=28.3(4.3)	pre=41(13), post=51(14)	ACSM-excellent	Roberts et al. (2002).
Upper body endurance	Push-ups, sit-ups, pull-ups	n =21(m), age=25.33(.79)	pushups-45.29(2.57), situps-59.9(1.24), pull-ups-12.57(.94)	ACSM-pushups-excellent curlups-above average pull-ups-no data	Sell K. (2011).
Max reps bench press	Maximum reps at 40kg in 40sec	n=14(m), age=29.3(4.2)	47.5(6.0)	Unknown	Naclerio et al. (2009).
Max reps bench and squat	Bench=45.5kg, squat=61.4kg, bent over row=20.5kg, biceps curl=13.6kg, shoulder press=11.4kg	n=20(m=17, w=3), age=34.5(6.1)	bench=37.9(12.2)reps, squat=39.4(29.4)reps, bent over row=35.1(13.8), curls=30.3(12.6), shoulder press=31.1(9.4)	No standards	Rhea et al. (2004).

Muscular strength. Similar to ME, higher levels of muscular strength, as measured by 1-Rep-Maximum (1RM) bench-press, were significantly related to success on AT (Michaelides et al., 2011). In addition to 1RM tests, many researchers assess overall muscular strength by measuring handgrip strength. Handgrip strength has been determined to be a valid and reliable method for determining muscular strength (ACSM, 2014). While strength is a prerequisite for many firefighting tasks, it is particularly important for victim rescue. In light of recent trends in the general population towards overweight and obesity, as well the increased health problems and reduced mobility in overweight and obese victims, muscular strength becomes increasingly significant to success as a firefighter (Center for disease control, 2015).

Unfortunately, much of the research into firefighter strength relies on absolute values, as opposed to 1RM/body-weight. For example, researchers in two different studies found firefighters' 1RM for bench press to be 102.38kg and 96.12kg, and 1RM for squat to be 135.76kg and 110.15kg, respectively (Peterson et al., 2008; Michaelides et al. 2008). While there is some value to absolute figures, firefighters use heavy equipment with standardized weights, absolute values make it difficult to compare firefighters to general population norms. For example, the NSCA has developed normative data for absolute 1RM in Division I athletes (Baechle & Earle, 2008). However, whether firefighters can be compared to these norms is questionable. Setting aside the issue of average age in any given sample, the problem of which athletes to compare firefighters to remains. While it is possible to see commonalities between firefighting activities and some football-, baseball-, or basketball-related skills, it is impossible to directly compare one to the other. Similar to ME, either standardized tests of muscular strength need to be developed such that firefighters can be compared based on absolute values, or normative data needs to be developed so that firefighters can be compared to each other. In one study, researchers did calculate 1RM/body-weight ratios and found that their subjects averaged 1.4, a classification of excellent according to the ACSM (Nacleiro et al., 2009; Pescatello et al., 2014).

Handgrip strength is another common measure for assessing muscular strength. According to Assistant Chief Sean Campbell, handgrip strength is extremely important for firefighters in conducting their duties, maintaining control over tools, ladders and hoses (S. Campbell, personal communication, 1/21/16). In their studies, both Rhea et al. (2004) and Sell (2011), found firefighters' grip strength to be above the 95%ile when compared to age-sex corrected norms (Vianna et al., 2007). However, in another study, researchers found firefighter recruits only scored in the 60-70%ile (Roberts et al., 2002). While these results may seem incongruent, there are several explanations for the inconsistency. Sell (2011) only looked at hotshot firefighters, a highly trained, specialized force. Additionally, both the Sell (2011) and Rhea (2004) studies used fairly small samples (n=21 and n=20 respectively). In contrast, the Roberts study used a much larger sample (n=115). It is possible that the larger sample size is more indicative of the firefighting population as a whole. It is important to note, that in all these studies, firefighters scored above the population average (see Table 3).

Table 3 Muscular Strength

Test	Protocol	Subjects	Results	Classification	References
1RM	Bench press and squat	n=14(m) age=29.3(4.2)	107.4(12.2)Kg, 236.56Lbs., 1.4 relative to bodyweight	Cooper Institute-Excellent	Naclerio et al.. (2009).
1RM	Bench press 1rm, back squat 1rm	n=14(m) age=21.9(1.8)	pre: bench=102.38(27.85)kg, squat=135.76(31.19)kg ; post: bench=119.55(24.52)kg, squat=163.62(31.52)kg	No standards for 1RM	Peterson et al. (2008).
1RM	Bench press and squat	n=38(m), age=32.25(6.07)	bench press=96.12(21.99)kg, squat=110.15(24,44)	No values for 1RM	Michaelides et al. (2008).
5Rm bench press, 5Rm Back Squat, Handgrip Strength	NSCA guidelines for 5RM, dynamometer	n=20(m=17, w=3), age=34.5(6.1)	Bench press=217.6(50.7), Back squat=298(192.9), Handgrip=58.8(11.2)kg, bench and squat reported as kg, but must be lbs.	no standards for 5rm tests, above 95% for handgrip	Rhea et al. (2004).
Handgrip strength	Dynamometer	n =21(m), age=25.33(.79)	rt=63.48(1.74) lt=58.71(1.61)	above 95%	Sell K. (2011).
Handgrip strength	Dynamometer	n=115(m=104, w=11) age=28.3(4.3)	pre=102.9(8.7), post=105.4(18.7)	60-70%	Roberts et al. (2002).

Body composition. Body composition is important in determining safety and success for firefighters. Body-fat percentage (BF%) has been demonstrated to have a significant relationship to AT scores (Michaelides et al., 2008). In other words, as BF% increases so does the time to completion on ATs. Ample research on the relationship between BF% and speed exists. Researchers in one study demonstrated that in elite female sprinters, a 1% increase in BF% translated into an additional .11sec sprint time (Abe et al., 2011). In a separate study, researchers found both a positive correlation between lean body mass and speed, as well as a negative correlation between fat mass and speed in elite cross-country skiers (Enqvist et al., 2010). Intuitively, and for anyone who has observed or participated in firefighting confidence courses, this relationship is natural. Firefighters are often required to struggle through small irregular spaces, lower BF% allows them to be less bulky and more successful in negotiating these smaller spaces (CFFJAC, 2015). Assistant Chief Sean Campbell adds that BF% also appears to have a relationship to endurance. In his observations, leaner individuals tend to have better endurance, especially in bodyweight dependent tasks such as stair and ladder climbs (S. Campbell, personal communication, 1/21/16).

There are many valid, reliable ways of assessing body composition including skinfold assessment, bioelectrical impedance assessment (BIA), and whole body plethysmography (bod pod) (Kruger, R. et al., 2013; Dixon, C. et al., 2005). Skinfold assessment can be useful way of determining body composition across a population (Pescatello et al., 2014). Sell (2011) found hotshot firefighters averaged a BF% of 12.9%, which according to ACSM guidelines is classified as good (Pescatello et al., 2014). However, as mentioned previously, hotshot firefighters are a specialized force with specialized training and qualification tests, the firefighter equivalent to military Special Forces or police SWAT service. Roberts et al. (2002), found that firefighter recruits had a pre-intervention BF% of 17.5%, an ACSM classification of good (Pescatello et al., 2014). Recruits also represent a special population. While at the academy, physical fitness training is emphasized and required in order to graduate.

Unfortunately, as stated previously, very few departments require ongoing fitness training or assessments.

When similar assessments were made of more generalized firefighter populations, results were mixed. In two separate studies Michaelides et al., (2008; 2011) used BIA to establish BF%. In both studies investigators determined firefighter age-sex corrected BF% as poor, 21.8% and 23.1% respectively (Pescatello et al., 2014). Conversely, using bod-pod analysis, Rhea et al. (2002), found their subjects' BF% averaged at 16.6%, an ACSM rating of excellent (Pescatello et al., 2014). The disparities between these data may be caused by several factors. The sample size in Rhea's study was relatively small (n=20), allowing data to be more easily skewed by outliers. Another possible explanation for the discrepancy in BF% results could be the ages of the samples used. Average ages in both the Michaelides' studies (2008, 2011) were 32 and 33 respectively, conversely, studies with more positive results had participants with average ages 25 and 28 (Sell, 2011; Roberts et al., 2002). It is possible that younger samples tend to skew towards better/lower BF% as compared to older samples (see table 4).

Table 4 Body Composition

Test	Protocol	Subjects	Results	Classification	References
% Body fat	BIA (standing)	n=38(m), age=32.25(6.07)	21.78(6.22)%	ACSM-poor to fair	Michaelides et al. (2008).
% Body fat	BIA (standing)/BMI	n=73(m), age=33(7)	23.05(5.58)%, 29.55(3.67)kg/m*m	ACSM-poor to fair, overweight/obese	Michaelides et al. (2011).
% Body fat	Bod Pod	n=20(m=17, w=3), age=34.5(6.1)	16.6(3.9)%	ACSM-excellent	Rhea et al. (2004).
% Body fat	7 site skinfold and BMI	n=115(m=104, w=11), age=28.3(4.3)	pre=17.5%, post=15.7%	ACSM-good to excellent	Roberts et al. (2002).
% Body fat	3 site skinfold	n=21(m), age=25.33(.79)	12.93%(.49)	ACSM-good	Sell K. (2011).

Flexibility. According to Assistant Chief Sean Campbell, flexibility is extremely important for firefighter safety and success (S. Campbell, personal communication, 1/21/16). There are many occasions in both live-fire and training situations, when it is necessary to maneuver in restricted spaces. This can include either attempting to turn around when a path is blocked, or accessing tools or equipment in cramped working environments. Flexibility and the capacity to move through a full range-of-motion allows firefighters to react more quickly in a rapidly changing environment and maneuver through inhospitable, dynamic, settings.

The sit-and-reach, as well the modified sit-and-reach test are both considered valid methods of determining hamstring flexibility (Chung, P., & Yuen, K. 1999). In two different studies, researchers found average hamstring flexibility in firefighters to 20.9 in.

and 19.7 in. respectively (Michaelides et al, 2008; Sell, K., 2011). These scores represent excellent categories according to ACSM guidelines (Pescatello et al., 2014) (see Table 5).

Table 5 Flexibility

	Test	Protocol	Subjects	Results	Classification	References
	Hamstring and lower back flexibility	Sit and reach	n=21(m), age=25.33(.79)	19.17(.45)in. ; 48.6918(1.143)cm	ACSM-excellent	Sell K. (2011).
	Hamstring and lower back flexibility	sit and reach	n=115(m=104, w=11), age=28.3(4.3)	pre=34(7)cm, post=35(7)cm	ACSM-very good	Roberts et al. (2002).
	Hamstring and lower back flexibility	sit and reach	n=38(m), age=32.25(6.07)	20.9(7.5)cm	ACSM-needs improvement to fair	Michaelides et al. (2008).

Skill related components. According to the ACSM there are six skill-related components of fitness: Power, balance, reaction time, speed, agility, and coordination. Along with power, there will also be discussion of anaerobic capacity.

Power and anaerobic capacity. There are many ways to test power, explosive strength, and anaerobic capacity including the wingate protocol, vertical jump (VJ) and standing broad jump (SBJ), sprint tests, as well as variations on the step test. In one study, researchers found that hotshot firefighters power/explosive strength, as measured by the VJ, was average when compared to the general population of similar age and sex (Sell, K., 2011). Hotshot fire crews are considered an elite firefighting force who receive specialized training. As such, it is possible that regular structural firefighting crews would score lower on these measures, and consequently, lower than the general public. It is also possible that power may not be a particularly important skill for firefighters. Firefighting tests such as the CPAT may not select for those with higher than average power production.

Supporting this idea, in another study, researchers compared female firefighters' scores on a wingate test to a control group and found no significant difference in either peak- or average-power (Findley et al., 2002). While VJ and SBJ measure explosive strength/power, the wingate protocol is considered a valid method for measuring anaerobic power/capacity (Baechle & Earle, 2008). In their study, Lindberg et al., (2015) described firefighter mean SBJ to be 237 cm. Similar results were obtained by Peterson et al. (2008), who found that pre-intervention firefighters averaged 234 cm, and 243 cm. post-intervention.

Unfortunately, while it would be possible to calculate power produced by any given firefighter, or an average for a sample population based on calculations of distance and weight, there is nothing to compare these results to. SBJ normative data is only available for children up to age 18. Creation of either adult, or firefighter normative data would allow researchers to compare, rank, and categorize individual results. It is also possible that testing firefighters upper body power production or anaerobic capacity would be useful. In his comments, Assistant Chief Sean Campbell notes that many firefighters experience significant muscular "burn" while breaching walls, doors, and roofs (S. Campbell, personal communication, 1/21/16). Unfortunately, there is no data available for firefighter anaerobic capacity (see Table 6).

Table 6 Power

Test	Protocol	Subjects	Results	Classification	References
Explosive strength	Vertical Jump	n=21(m), age=25.33(.79)	55.22(2.24)cm	Above 95%, paterson and peterson 2004	Sell K. (2011).
Explosive strength	Vertical Jump	n=72(m), age=33(7)	15.84(1.57)w/kg	No norms available for adults.	Michaelides et al. (2011).
Explosive strength	Vertical and broad jump	n=14(m) age=21.9(1.8)	Pre-Vertical=60.6(6.25)cm, Broad=234(17.82)cm ; Post-Vertical=66.22(6.33)cm, Broad=243.66(22)cm	No norms available for adults.	Peterson et al. (2008). .
Explosive strength	broad jump	n=38	237(54)cm	only data available under 18	Lindberg et al. (2015).
Anaerobic power	Wingate	n=10(w), age=29.8(2.1)	Peak power=451.6(69.6)W, mean power=314.1(32.7)W	no significant difference with control	Findley et al. (2002).
Anaerobic power	Wingate	n=150(w), age=27.1(4.5)	peak power=494(84.7)W, mean power=398.2(56.9)w	less than reference of adult women	Misner et al. (1988).
Anaerobic power	Step test	n=72(m), age=33(7)	403.12(101.42)W	No norms available	Michaelides et al. (2011).

Balance. While there have been some studies on the effects of various equipment on firefighter balance, there have been no attempts to create normative data describing firefighter balance in general. Additionally there are few studies exploring the relationship between balance and overall firefighter performance.

In one study, researchers studied the effects of leather vs. rubber boots on firefighter balance. The researchers found that firefighters using leather boots had better balance than those using rubber boots, and theorized that leather boots provided more support and prevented stabilizing muscles from tiring as quickly (Garner et al., 2013). Supporting this point, Kong et al. (2012) found that firefighters who participated in both aerobic and resistance training scored better on balance assessments than those who participated in neither, suggesting that enhanced muscular strength and endurance, do indeed improve balance. Balance may be an important aspect of a firefighter's capacity to perform his/her job safely and effectively, however, this relationship is still poorly understood (see Table 7).

Table 7 Balance

Test	Protocol	Subjects	Results	Classification	References
Leather vs. rubber boots	NeuroCom® Equitest System™ platform	n=12(m), age=33.42(6.47)	Balance worse in rubber boots	no norms	Garner et al. (2013).
Training effect on balance		n=23(m), age=28.2(6.7)	trained performed better	no norms	Kong et al. (2012).

Reaction time. The ability to react quickly to unexpected stimuli is vital for all emergency workers. There are few studies exploring firefighter reaction times. However, in one study, researchers used computer simulations to measure reaction times pre- and post-firefighting activities, and found faster reaction times post-firefighting (Greenlee et al., 2014). Researchers hypothesized that decrease in post-firefighting reaction time was, in part, due to heightened sympathetic response. Although reaction time is considered relatively untrainable (Baechle & Earle, 2008), it may become an important variable in firefighter selection. It is currently unknown how firefighters, as a whole, score on reaction time tests. Creating normative data for firefighter reaction time could assist in the process of determining which candidates are best suited for specific firefighter duties or firefighter duties as a whole (see Table 8).

Table 8 Reaction Time

Test	Protocol	Subjects	Results	Classification	References
Simulation	vCPT	n=20(m), age=25.7(5.2)	faster after bout of firefighting		Greenlee et al. (2014).

Speed, agility, and coordination. We could find no studies exploring firefighter speed, agility or coordination. This lack of information highlights the need for this and similar comprehensive studies, exploring current firefighter capabilities and pointing the way towards further research in these un-/under-explored areas. In an interview, Assistant Chief Sean Campbell specifically pointed to agility and coordination as being particularly important for firefighters (S. Campbell, personal communication, 1/21/16). According to him, the ability to change focus and direction as well as independently control limb movement is an important factor in working in the confined dynamic environments often associated with structure fires. It is possible that collecting and compiling normative data concerning these aspects of performance will give insight into what makes for effective, safe, firefighting technique.

Somatotype. All people have a genetic predisposition towards a specific body type. Somatotyping is a way categorizing people based on their body types. Specific athletic endeavors tend to favor certain body types. In general, continued participation in sports acts as a natural self-selecting factor. In other words, people with a natural genetic predisposition towards an activity continue progressing towards higher and higher levels of competition (Perroni et al., 2015; Nikolaidis et al., 2015). Simultaneously, those whose body types are not favorable towards success in a given activity tend to get weeded out.

The three classic exemplar somatotypes are endomorph, ectomorph, and mesomorph. Endomorphs tend to have high %BF, larger frames, and a rounder shape. The archetypical sumo wrestler is a good example of the endomorph body type. Conversely, ectomorphs tend to have very low %BF, small frames, and lean stick-like figures. Marathon runners and other endurance athletes tend to have ectomorph body types. Finally, mesomorphs tend to have low %BF like ectomorphs, however are characterized by muscular physiques and larger frames like endomorphs. Bodybuilders are a typical example of the mesomorph body type. Quite frequently, a person's physique will show characteristics of more than one somatotype, falling on the spectrum between body types. Ideal somatotype ranges for various athletic endeavors have been identified (Sharma & Dixit, 1985).

Just as somatotyping can help select genetically predisposed athletes for specific sports, somatotypes can be a useful tool in helping select the makeup of a team (Orhan et al., 2013). A very simple example of this selection process would be creating a basketball team. It is highly unlikely that a coach or general manager would draft a short player to be a center, similarly, it is unlikely that an obese person would be selected to be a shooting guard. A more refined version of this example can be used to select athletes depending on their morphometric suitability for a sport or position, or to fill a hole in a team's roster, rounding out its physical capabilities (Perroni et al., 2015).

These principles can be applied towards firefighting. Yokota, Berglund & Bathalon (2012) found that lean female soldiers were able to maintain a lower core body temperature than taller or shorter, fatter soldiers. Findings like this could be useful in predicting a firefighter's capacity to withstand the rigors of firefighting duties and while wearing protective gear. German researchers found that when comparing career firefighters, volunteer firefighters, and sports students both the professional and volunteer firefighters tended more towards endomorphy than the students, but were otherwise similar (Raschka, Bambusek & Turk, 2012). Little if any research has been conducted into either typical or optimal firefighter somatotype.

Statement of the Problem

There are many under-/un-explored areas of firefighter physical fitness components and anthropometric characteristics. While it seems logical that some skill-related physical fitness components like speed, agility and coordination all play a role in firefighter's effectiveness, no studies exploring this area were found. Similarly, almost no data exists for firefighter reaction time or balance. While there has been some exploration of firefighter power and anaerobic capacity, no normative data to compare it to exists.

There is significantly more research literature available concerning firefighter health related components. However, much of this data is problematic and have no normative data to be compared to. While there are standardized tests for ME, several studies employed unique protocols, with varying weights to test firefighter ME (Nacleiro et al., 2009; Rhea et al., (2004)). While the rationale for using these non-standardized weights is understandable as they represent common pieces of firefighting equipment, the results are impossible to compare or classify as these tests are unique to their individual studies, and there have been no norms developed for these tests.

Similarly, the area of optimal firefighter somatotype, or firefighter team somatotypes is wholly unexplored. Similar problems exist with muscular strength. There is no normative data for absolute values of strength and almost no studies report relative strength (1RM/BW). Additionally, no studies report percentile and classification values for muscular strength.

Finally, while there are many studies exploring individual aspects of firefighter fitness- and skill- related components of health, there are no studies which describe all aspects of a single cohort.

Statement of Purpose

The purpose of this study is to expand on the current research and attempt to conduct complete health- and skill- related fitness tests and to examine the anthropometric characteristics of rural firefighters, which includes:

1) Five-health related fitness components
2) Six-skill related components
3) Anaerobic (peak) power and (total) capacity assessments and
4) Somatotyping

Methods

Experimental Approach To The Problem.

The purpose of the study is to evaluate the physiological skill- and fitness-related components of health, as well as the anthropometric characteristics of rural firefighters. This project will be based on science and theory in the fields of Exercise Science in compliance with ACSM and NSCA recommendations and standards.

Subjects.

Expected subjects will be professional and volunteer firefighters from Arcata Fire Protection District (AFPD) and Humboldt Bay Fire (HBF). Expected ages of subjects is 20-59, with most falling between 20-45.

Subjects. Study subjects were professional (n=16) and volunteer (n=8) firefighters from Arcata Fire Protection District (AFPD) (n=20) and Humboldt Bay Fire (HBF) (n=4). Subjects' age was between 21-43 years.

Subject Testing

Testing order. All subjects filled out medical history forms as well as a Physical Activity Readiness Questionnaire (PAR-Q). Subjects were advised of, and signed both consent- as well as release of liability forms. Testing order was determined using NSCA and ACSM guidelines (Baechle & Earle, 2008; Pescatello et al., 2014): Non-fatiguing tests, agility tests, maximum power tests, maximum strength tests, sprint tests, muscular endurance tests, anaerobic capacity tests, and aerobic capacity tests. Testing was broken up into two sessions, separated by at least two days (48 hrs.).

On the first day of testing, subjects' blood pressure and anthropometric data (height, weight, girths, circumferences, skinfolds, %BF) were collected. These tests were followed by balance (eyes open, eyes closed), hand eye coordination, and flexibility assessments. After the non-fatiguing tests, subjects performed the pro-agility test, VJ and SBJ, 1RM max on bench-press**,** lat pull-down followed by upper body ME, and finally a wingate test. On the second day of testing, subjects performed a 10yd sprint, followed by 1RM on leg press/squat, lower body ME using the same protocol as upper body ME test, and finally a 1.5 mile run protocol for aerobic capacity.

Testing Procedures. All Testing took place in the Humboldt State University Human Performance Lab (HPL) or on the football field. In order to avoid interrater reliability issues, all anthropometric data was collected by the same proctor. Height was measured using a Seca mechanical wall mount stadiometer (Seca 216, Chino, CA). Weight was measured on a beam balance scale (437 Physician's Scale, Detecto, Webb City, MO). Girths were measured using anthropometer (Model 01290, Lafayette Instrument Co. Lafayette, IN). Circumferences were measured folowing standard ACSM guidelines (Gullick Anthropometric Tape, North Coast Medical, Gilroy, CA). Skinfolds were measured following ACSM protocols (Lange Skinfold Calipers, Beta Technology, Santa Cruz, CA). %BF will also be assessed using BIA (Quantum X, RJL Systems, Clinton Township, MI). Subjects will lie on a nonconductive surface with their right shoe removed. After calibration, and assuring that the subject is not wearing any jewelry or other conductive materials, electrodes were placed on the right foot and right hand. Reactance and resistance values were recorded and translated into %BF.

Single leg balance assessment: subjects will stand on non-dominant leg (support leg when kicking). Timer will start when dominant foot leaves the ground and stopped when the subject puts their foot down (cutoff at 60 sec.) First test were with eyes open, second test with eyes closed. Hand eye coordination: alternate-hand wall ball toss, subjects will stand 3 ft. from a wall and bounce a tennis off the wall catching it with the alternate hand. This process was repeated as many times as possible in 30 seconds. Flexibility was assessed following YMCA sit and reach protocol, using a Accuflex I (Novel Products Inc., Rockton, IL). Subjects were instructed to warm up for several minutes by walking on a treadmill, after which they will place bare feet against a sit-and-reach box. With knees locked flat on the floor subject will reach as far as possible with overlapped hands and hold for two seconds. This process was repeated three times, with the best score recorded. Handgrip was assessed for both hands on a dynamometer (Jamar, Sammons Preston Rolyan, Bolingbrook, IL).

VJ was measured on a standing vertical jump measure (Vertec, Perform Better, Warwick, RI). Vertec was adjusted to each individual so that bottom blade is 12 inches above subjects fingertips when fully extended above the head. Using one quick countermovement subject will jump as high as possible. Three attempts were allowed, with the highest value being recorded. SBJ were measured on a floor lying long jump tester (Long Jump Tester, Power Systems, Knoxville, TN).

1RM was determined following NSCA testing guidelines for warm up and 1RM testing.. Bench press was assessed on a standard bench press (Hammer Strength Bench Press, Life Fitness, Rosemont, IL), lateral pulldown was assessed on Lat pulldown machine (Hammer Strength Lat Pulldown, Life Fitness, Rosemont, IL), Squat was assessed in a squat rack (Hammer Strength Squat Rack, Life Fitness, Rosemont, IL), and leg press was assessed using a linear leg press (Hammer Strength Linear Leg Press, Life Fitness, Rosemont, IL).

ME test was conducted by calculating 65% of 1RM, subjects will perform as many reps as possible, to fatigue followed by a 30 second rest period after which they will again perform as many reps as possible to fatigue for a total of 4 sets (Baechle & Earle, 2008, Heyward, V., & Gibson, A., 2014).

Speed was assessed using a 10 yd. dash protocol on an outdoor football field using an electronic timing system (Brower TC Wireless Timing System, Utah). Starting in a three point stance, subjects will respond to the electronic timer system to start, and proceed to sprint 10 yds. In a straight line. Subjects will perform three attempts with a three minute resting time in between attempts, with the best time recorded. Agility was measured using the pro-agility protocol (Brower TC Wireless Timing System, Utah) starting from a three point stance, subjects will respond to the electronic timer system to start, run 5 yds. to the left, touch the ground with his left hand, turn, run 10 yds. to the right, touch the ground with his right hand, turn, and sprint through the original starting line. Subjects were given three attempts with three minute resting periods between attempts. The fastest time was recorded. Reaction time was recorded on both the agility and from the electronic timer system (Brower TC Wireless Timing System, Utah).

Wingate test:Data collection for each 30-sec Wingate test (Model 894Ea, Monark, Sweden) was captured with Monark Wingate software (Monark Anaerobic Test Software

Version 3.2.1.0). Resistance for each subjects was calculated and displayed in absolute terms (body weight in kg multiplied by 8.0%) Peak power was defined as the highest power output during the test averaged over 5 consecutive sec during the 30-sec test. Power output was expressed in absolute values (Watts). Absolute mean power was determined from the average power output of 6 successive 5-sec periods in the 30-sec test. Minimum power was determined from the lowest power output during the test averaged over 5 consecutive sec. Fatigue index was calculated as a percentage of peak power minus minimum power divided by peak power and multiplied by 100.

1.5 mile run: 1.5 mile run on a motorized treadmill (Platinum Club Series Treadmill, Life Fitness, Rosemont, IL) Wearing a heart rate monitor (Polar 800CX, Polar, Finland) and a stride sensor (Polar S3+, Polar, Finland), the subject will run 1.5 miles on a treadmill at 0% grade at their fastest speed (mph).

Data Analysis. All data was analyzed using IBM® SPSS® Statistics Version 23 (IBM, Armonk, New York). All the data was tested for their normal distribution (Kolmogorov-Smirnov test). Data was interpreted in a descriptive manner. Where possible, the data was compared with normative data for the general population and divided into categories based on physical fitness. These descriptive data was used to generate reference value (like Norm) tables by classifying the top 30%ile as high, the next 40%ile as medium, and the bottom 30%ile as low, based on their %ile rankings.

Limitations

Due to the unpredictable nature of emergency work, tests median, minimum and maximum values, and split into high, medium and low ranges based on a 30-40-30%ile ranking. Additionally, results will be classified into categories as compared to ACSM and Cooper Institute data, where possible A total of 24 healthy male firefighters volunteered for this study, 16 professional and 8 volunteers with a mean age of 33.6 ± 8.7, and a mean experience level of 8.4 ± 6.7 yrs. All subjects participated in anthropometric measurements; however, due to the inherent difficulties of scheduling emergency first responders, not all subjects were able to participate in all aspects of health- and/or skill-related component testing. Of the 24 total subjects, 21 completed the balance, coordination, and flexibility assessments, as well as the vertical jump, grip strength, bench press 1RM, bench press endurance tests; 20 completed the SBJ as well as the Lat. pull-down 1RM and endurance tests; 18 completed the wingate protocol (anaerobic capacity); 14 tested 1RM and endurance on the leg press; 12 subjects completed the agility and speed tests; 12 were assessed for reaction time and aerobic capacity (1.5 mile run); 4 completed squat 1RM and endurance tests.

Assumptions

Job duties and activities outside of the fitness testing will not greatly affect test results. Participants will give their best effort and perform to the best of their capability

Results

All results results are reported as the mean (± standard deviation), median, minimum and maximum values, and split into high, medium and low ranges based on a 30-40-30%ile ranking. Additionally, results were classified into categories as compared to ACSM and Cooper Institute data, where possible A total of 24 healthy male firefighters volunteered for this study, 16 professional and 8 volunteers with a mean age of 33.6 ± 8.7, and a mean experience level of 8.4 ± 6.7 yrs. All subjects participated in anthropometric measurements, however, due to the inherent difficulties of scheduling emergency first responders, not all subjects were able to participate in all aspects of health- and/or skill-related component testing. Of the 24 total subjects, 21 completed the balance, coordination, and flexibility assessments, as well as the vertical jump, grip strength, bench press 1RM, bench press endurance tests; 20 completed the SBJ as well as the Lat. pull-down 1RM and endurance tests; 18 completed the wingate protocol (anaerobic capacity); 14 tested 1RM and endurance on the leg press; 12 subjects completed the agility and speed tests; 12 were assessed for reaction time and aerobic capacity (1.5 mile run); 4 completed squat 1RM and endurance tests.

Anthropometric Characteristics

Firefighters' anthropometric measurements are found in Tables 9-10, and Figure 2. Subject mean height was 71.1 ± 2.3 in. and mean weight was 194.0 ± 25.9 lbs. The mean %BF of the firefighters was 16.1 ± 5.7.

Table 9 Anthropometric Characteristics

Measurement	Mean	SD
Height	71.1 in.	2.3 in.
Weight	194.0 lbs.	25.9 lbs.
%BF	16.1%	5.7%
Age	33.6	8.7

To produce the somatogram, the following mean skinfold measurements values were recorded: 14.5 ± 7.2 mm (triceps), 18.7 ± 9.6 mm (subscapular), 19.5 ± 10.5 mm (suprailiac), and 11.8 ± 4.5 mm (medial calf). Bone breadth measurements taken at the epicondyles of the humerus and femur produced the following mean values: 7.4 ± 0.4 cm (humerus) and 10.3 ± 0.6 cm (femur). Circumference measurements taken at the biceps and calf produced the following observed mean values: 36.5 ± 2.5 cm (biceps) and 39.2 ± 3.3 cm (calf). Subjects' mean somatotypic measurements are found in Table 10. The mean firefighter somatotype, described as endomorphy - mesomorphy - ectomorphy, found was: 5.0 ± 1.9 - 6.1 ± 1.0 - 1.1 ± .8, and a height-weight-ratio (HWR) of 40.3 ± 1.8.

Table 10 Anthropometric Measurements

	Triceps (mm)	Sub. Scap.(mm)	Suprailiac (mm)	Medial Calf (mm)	Humerus (cm)	Femur (cm)	Biceps (cm)	Calf (cm)
Mean	14.5	18.7	19.5	11.8	7.4	10.3	36.5	39.2
SD	7.2	9.6	10.5	4.5	0.4	0.6	2.5	3.3
Median	13	17.5	19	11	7.5	10.1	36.5	39
Min	33	46	45	20	8.5	12.3	42.6	47.5
Max	3	5	4	4	6.5	9.2	32	34

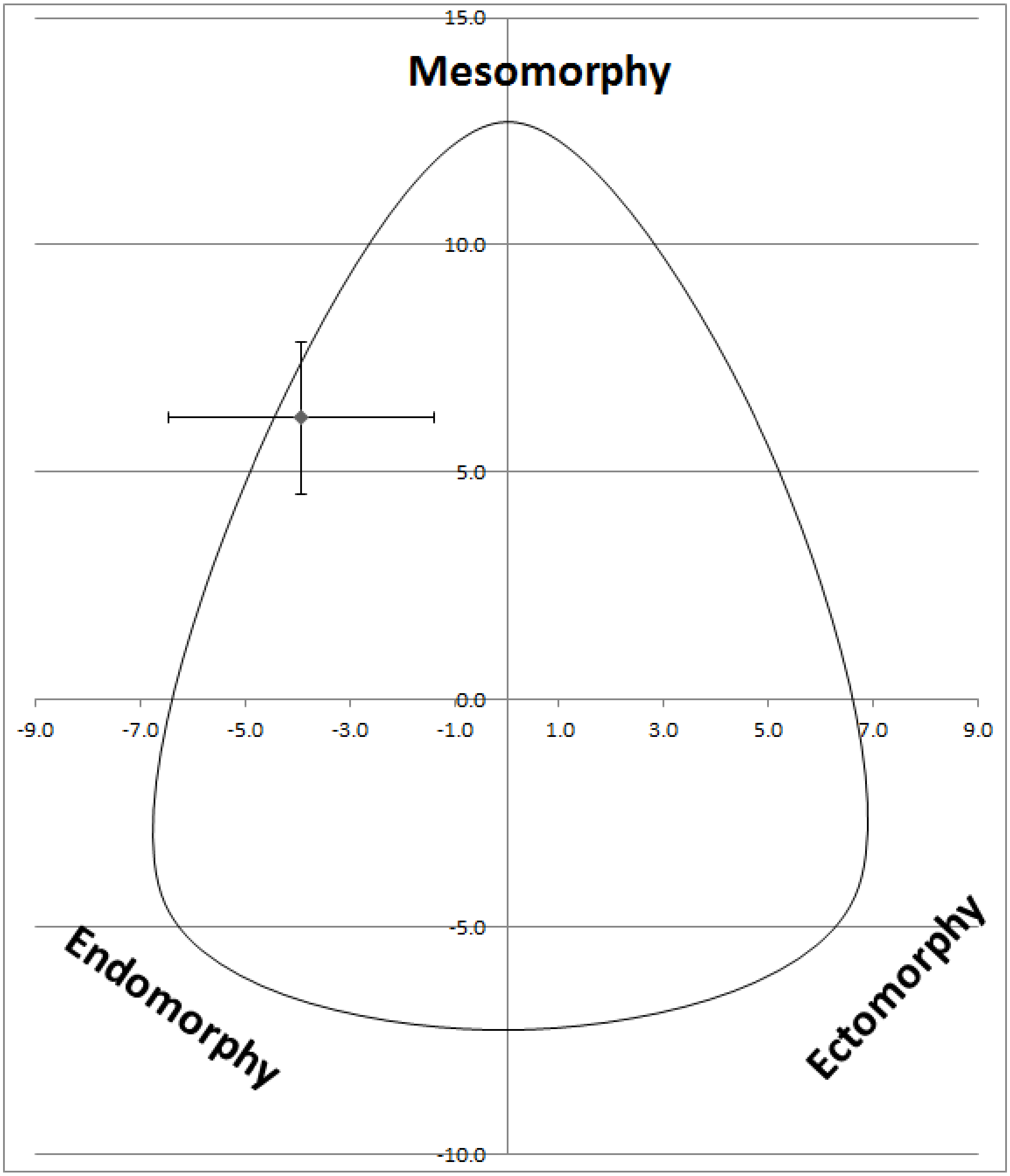

Figure 1 Somatogram showing mean firefighter somatotype (±SD)

Health-Related Fitness Characteristics

%BF, BMI, VO2Max, Flexibility. Firefighter health-related fitness characteristics are found in tables 11-13. As reported above, subject %BF was 16.1 ± 5.7. Median %BF was 16%, minimum %BF was 5.9% and maximum %BF was 24.4%. %tile rankings were split into high>19.2%, medium=11.4-19.1%, low<11.3%. Mean BMI was calculated 27.1 ± 3.1, a classification of overweight. Median BMI was reported as 26.1, minimum BMI was 22.4, maximum BMI was 32.5. %tile rankings were split into high>28.8, medium=25.6-28.7, and low<25.5.

Table 11 %BF and BMI

	%BF	Classification (CI)	BMI	Classification (ACSM)
High >	19.2	55%tile	28.8	Overweight
Medium	19.1-11.4	55-95%tile	28.7-25.6	Overweight
Low <	11.4	95%tile	25.5	Overweight
Mean	16.1	75%tile	27.1	Overweight
SD	5.7	N/A	3.1	N/A
Median	16	75%tile	26.1	Overweight
Minimum	5.9	99%tile	22.4	Normal
Maximum	24.4	25%tile	32.5	Obesity, Class I

Using the ACSM equation for estimation of energy expenditure during common physical activities, subjects' VO_2Max was calculated from their 1.5 mile run time/speed, with a mean value of 47.4 ± 4.0 ml/kg/min. Median VO_2Max was 48 ml/kg/min, minimum VO_2Max was 36.2 ml/kg/min, maximum VO_2Max was 57.1. %tile rankings were split into high>51.6 ml/kg/min, medium=44.3-51.5 ml/kg/min, and low<44.2 ml/kg/min.

Table 12 VO2Max

	VO2Max(ml/kg/min)	Classification (ACSM)
High >	51.6	90%tile
Medium	51.5-44.3	60-90%tile
Low <	44.2	60%tile
Mean	47.4	76%tile
SD	4	N/A
Median	48	79%tile
Minimum	36.2	18%tile
Maximum	57.1	97%tile

Subjects' mean flexibility was observed at 29.1 ± 8.8 cm. Median flexibility was 30 cm, with a maximum value of 41.5 cm, and a minimum value of 5 cm. Flexibility %tile rankings were split into high>33 cm, medium=27-32 cm, and low<26 cm.

Table 13 Flexibility

	Flexibility(cm)	Classification (ACSM)
High >	33	Very Good
Medium	27-32	Fair-Very Good
Low <	26	Fair
Mean	29.1	Good
SD	8.8	N/A
Median	30	Good
Minimum	5	Needs Improvement
Maximum	41.5	Excellent

Muscular fitness. Muscular fitness was measured using 1RM (muscular strength) and an endurance protocol using 65% of 1RM for as many reps as possible across 4 sets. Additionally, absolute values for 1RM were divided by individual body weight to produce a strength to weight ratio.

Muscular strength. Muscular strength results can be found in tables 14-16. Mean bench press 1RM was recorded as 201 ± 50 lbs. Median bench press 1RM was 195 lbs., with a maximum value of 355 lbs. And a minimum value of 125 lbs. %tile rankings were separated into high> 215 lbs. Medium =180-214 lbs. and low<179. Bench-press to body weight (1RM/BW) ratio was calculated with a mean value of 1.05 ± .25. Median Bench-press 1RM/BW was 1.1, with maximum value of 1.45 and a minimum value of .58. %tile rankings were split into high>1.2, medium=.96-1.1, and low<.95. Lateral pull-down 1RM mean value was observed as 209.8 ± 45.5 lbs. Median lateral pull-down was 195 lbs. with a maximum value of 280 lbs. and a minimum value of 110 lbs. %tile rankings were split into high>250 lbs. medium=185-249 lbs., and low<184 lbs. Lateral pull-down 1RM to body weight ratio was calculated as 1.05 ± .38.

Table 14 Upper body muscular strength

	Bench Press (lbs)	1RM/BW	Classification (CI)	Lat Pull-down (lbs)	1RM/BW
High >	215	1.2	87%tile	250	1.2
Medium	214-180	.96-1.1	55-86%tile	185-249	1.1-.83
Low <	179	0.95	54%tile	184	0.82
Mean	201	1.05	71%tile	209.8	1.05
SD	50	0.25	N/A	45.5	0.38
Median	195	1.1	78%tile	195	1.1
Minimum	125	.58	1%tile	110	0.51
Maximum	355	1.45	99%tile	280	1.7

Grip strength results can be found in table 15. Mean cohort muscular strength as measured by handgrip dynamometry for the right hand was 95.5 ± 19.4 lbs. Median grip strength was 96 lbs. with a maximum value of 127 lbs., and a minimum value of 62 lbs. Right hand grip strength %tile split was high> 105 lbs., medium= 86-104 lbs., and low< 85 lbs. For the left hand, mean handgrip strength was measured at 92.8 ±19.7 lbs. Left hand median grip strength was 95 lbs., with a maximum value of 127 lbs., and a minimum value of 58 lbs. Left hand grip strength %tile rankings split was high>101 lbs., medium= 85-100 lbs., low> 84 lbs. Mean handgrip strength/BW (G/BW) ratio was calculated as .98 ± .23. Median G/BW was .94, with a maximum value of 1.48, and a minimum value of .6. G/BW %tile ranking was split into high> 1.04, medium=.9-1.03, and low< .89.

Table 15 Handgrip strength

	Right (lbs.)	Left (lbs.)	R+L/BW
High >	105	101	1.04
Medium	86-104	85-100	.90-1.03
Low <	85	84	0.89
Mean	95.5	92.8	0.98
SD	19.4	19.7	0.23
Median	96	95	0.94
Minimum	62	58	0.6
Maximum	127	127	1.48

Lower body strength as measured by the leg press had a mean value of 937.3 ± 219.3 lbs. Median leg press value was 913.5 lbs. with a maximum value of 1285 lbs. And a minimum value of 582 lbs. %tile rankings were split into high>814 lbs. medium=774-813 lbs. and low<773 lbs. Mean 1RM/BW ratio was calculated as 4.8 ± 1.2. Median 1RM/BW value was 4.8, with a maximum value of 7.1 and a minimum value of 2.7. %tile were split into high>5, medium=4.3-4.9, and low<4.2. ranking above the 90%tile, or well above average, as compared to ACSM norms (Pescatello et al., 2014). Lower body strength as represented by the squat had a mean value of 277.5 ± 127.4 lbs. Median squat value was 275 lbs. with a maximum value of 315 lbs. and a minimum value of 245 lbs. Squat %tile ranking were split into high>295 lbs., medium=255-294 lbs, and low<254 lbs. Mean squat 1RM/BW produced a value of 1.52 ± .17. Median squat 1RM/BW was 1.5, with a maximum value of 1.7, and a minimum value of 1.3. 1RM/BW %tile rankings were split into high>1.6, medium=1.4-1.5, and low<1.3.

Table 16 Lower body muscular strength

	Leg-Press 1RM(lbs)	Leg-Press/BW	Squat 1RM (lbs.)	Squat 1RM/BW
High >	814	5	295	1.6
Medium	813-774	4.9-4.3	255-294	1.4-1.5
Low <	773	4.2	254	1.3
Mean	937.3	4.8	277.5	1.5
SD	219.3	1.2	127.4	.17
Median	913.5	4.8	275	1.5
Minimum	582	2.7	245	1.7
Maximum	1285	7.1	315	1.3

Muscular endurance. Muscular endurance results can be found in tables 17-20. Upper Body muscular endurance (UBME) as measured while performing an endurance protocol on the bench-press provided subjects' mean scores of 26.6 ± 5.6 reps. Median bench-press endurance repetitions score was 27.5 reps, with a maximum value of 34 reps, and a minimum value of 15 reps. Bench-press endurance %tile rankings were split into high>31 reps., medium=25-30 reps., and low<24 reps. Bench-press endurance mean total load was calculated as 2363 ± 658 lbs. Median bench-press endurance total load was 3540 lbs, with a maximum value of 5440 lbs., and a minimum value of 1200 lbs. Bench-press endurance total load %tile rankings was split into high>3900 lbs., medium=3301-3899 lbs., and low<3300 lbs. Mean bench-press endurance as measured by total load/body weight (TL/BW) was calculated as 18.7 ± 6.5. Median TL/BW was found to be 18.5, with a maximum value of 31.5, and a minimum value of 5.5. TL/BW %tile rankings was split into high>22, medium=17.7-21.9, and low<17.6.

Table 17 Bench-press endurance

	Total reps.	Total load(lbs)	Total load/BW
High >	31	3900	22
Medium	25-30	3301-3899	17.7-21.9
Low <	24	3300	17.6
Mean	26.6	3512	18.7
SD	5.6	1041	6.5
Median	27.5	3540	18.5
Minimum	15	1200	5.5
Maximum	34	5440	31.5

UBME as measured by the lat. pull-down produced a mean of 30.7 ± 6.6 total reps. Median lat. pull-down endurance was 30 reps, with a maximum value of 44 reps, and a minimum value of 22 reps. Lat. pull-down endurance %tile rankings were split into high>35, medium=27-34, and low<26. Mean lat. pull-down endurance total load, was measured at 4179.1 ± 1287.4 lbs. Median lat. pull-down endurance total load was 4073.8 lbs, with a maximum value of 7260 lbs. And a minimum value of 1644.5 lbs. Lat. pull-down endurance total load %tile rankings were split into high>4725 lbs., medium=3681-4724 lbs., and low<3680 lbs. Mean lat. pull-down endurance as measured by TL/BW was calculated as 22.3 ± 8.3. Median TL/BW was 20.6, with a maximum value of 43.4, and a minimum value of 7.5. TL/BW %tile rankings were split into high>25.3, medium=19.5-25.5, and low<19.4.

Table 18 Lat. pull-down endurance

	Total reps.	Total Load (lbs)	Total Load lbs./BW
High >	35	4725	25.3
Medium	27-34	3681-4724	19.5-25.2
Low <	26	3680	19.5
Mean	30.7	4179.1	22.3
SD	6.6	1287.4	8.3
Median	30	4073.8	20.6
Minimum	22	1644.5	7.5
Maximum	44	7260	43.4

Lower-body muscular endurance (LBME), as measured by the leg-press was found to have a mean value of 42.7 ± 14.9 total reps. Median leg-press LBME was measured at 42 reps, with a maximum value of 69 reps, and a minimum value of 21 reps. Leg-press LBME %tile rankings were split into high>48 reps, medium=36-47 reps, and low<35 reps. LBME as measured by total load, produced a mean value of 23,803.3 ± 11943.7 lbs. Median total load was 23393.5 lbs., with a maximum value 51274 lbs., and a minimum value of 5535 lbs. Total volume %tile rankings were split into high>30221 lbs, medium=15561-30220 lbs., and low<15560 lbs. LBME as measured by TL/BW was calculated as 124.3 ± 66. Median LBME TL/BW was 126.8 with a maximum value of 284.9, and a minimum value of 23.5. LBME TL/BW %tile rankings were split into high>144.8, medium=81.6-144.7, and low<81.5.

Table 19 Leg press endurance

	LP Total reps	LP Total load (lbs)	LP Total load/BW.
High >	48	30221	144.8
Medium	36-47	15561-30220	81.6-144.7
Low <	35	15560	81.5
Mean	42.7	23803.3	124.3
SD	14.9	11943.7	66
Median	42	23393.5	126.8
Minimum	21	5535	23.5
Maximum	69	51274	284.9

LBME as measured by the squat produced a mean value of 38.3 ± 10.8 total reps. Median squat LBME total reps was 41 reps, with a maximum value of 48 reps, and a minimum value of 23 reps. Squat LBME %tile rankings were split into high>43, medium=39-42, and low<38. Mean squat LBME total load was 6886.3 ± 2274.3 lbs. Median squat LBME total load was 6667.5 lbs., with a maximum value of 9840 lbs., and a minimum value of 4370 lbs. Squat LBME %tile rankings were split into high>7095 lbs., medium=6240-7094 lbs., and low<6239 lbs. LBME as measured by TL/BW produced a mean result of 38.6 ± 14.4. Median squat TL/BW was 40.7, with a maximum value of 53.4, and a minimum value of 19.5. Squat TL/BW %tile rankings were split into high>44.6, medium=36.9-44.5, and low<36.8.

Table 20 Squat endurance

	Squat Total reps	Squat Total load (lbs)	Squat Total load/BW.
High >	43	7095	44.6
Medium	39-42	6240-7094	36.9-44.5
Low <	38	6239	36.8
Mean	38.3	6886.3	38.6
SD	10.8	2274.3	14.4
Median	41	6667.5	40.7
Minimum	23	4370	19.5
Maximum	48	9840	53.4

Skill-Related Fitness Characteristics

Firefighter skill-related fitness characteristics are found in tables 21-23.

Power & Anaerobic capacity. Firefighter power, as measured by the VJ recorded mean values of 21.6 ± 7.3 in. Median VJ value was 22 in. with a maximum value of 27 in. and a minimum value of 15 in. %tile ranking were split into high>24 in., medium=21-23 in., and low<20 in. Firefighter power, as measured by the SBJ recorded a value of 84.7 ± 10 in. Median SBJ value was 84 in. with a maximum value of 105 in. and minimum value of 57.5 in. %tile rankings were split into high>89 in. medium=81-88 in. and low<80.

Table 21 Vertical jump and standing broad jump

	VJ(in.)	SBj(in.)
High>	24	89
Medium	23-21	88-81
Low<	20	80
Mean	21.6	84.7
SD	7.3	10
Median	22	84
Min	15	57.5
Max	27	105

Testing of subjects' anaerobic capacity produced mean peak power(PP) values of 934.6 ± 290.03 W. Median PP was 941.2 W, with a maximum value of 1325.8 W, and a minimum value of 499.7 W. %tile rankings were split into high>1022.6 W, medium=884.4-1022.5 W, and low<884.3 W. Mean peak power per body-weight (PP/BW) was calculated as 10.7 ± 3.5 W/kg. Median PP/BW was 10.8 W/kg, with a maximum value of 14.2 W/kg, and a minimum value of 5.3 W/kg. %tile rankings were split into high>12.3 W/kg, medium=9.8-12.2 W/kg, and low<9.7 W/kg. Mean Average power (AP) was measured as 653.7 ± 136.5 W. Median AP was 655.6 W, with a maximum value of 963.7 W, and a minimum value of 348 W. %tile rankings were split into high>696.9 W, medium=621-695 W, and low<620.8 W. Mean average power per body-weight (AP/BW) was determined to be 7.5 ± 1.6 W/kg. Median AP/BW was found to be 8.3 W/kg, with a maximum value of 9.1 W/kg, and a minimum value of 3.7 W/kg. %tile rankings were split into high>8.5 W/kg, medium=7.04-8 W/kg, and low<7.03 W/kg. Mean power decrement (%decline) 57.9 ± 9.8% decline in power. Median %decline was 57.5%, with a maximum value of 85.4%, and a minimum value of 43.7%. %tile rankings were split into high>59.6%, medium=52.5-59.5%, and low<52.4% (see Table 22.)

Table 22 Anaerobic capacity

	PP(W)	PP(W)/BW(kg)	AP(W)	AP(W)/BW(kg)	%decline
High>	1022.6	12.3	696.9	8.5	59.6
Medium	1022.5-884.4	12.2-9.8	695-621	8-7.04	59.5-52.5
Low<	884.3	9.8	620.8	7.03	52.4
Mean	934.6	10.7	653.7	7.5	57.9
SD	290.03	3.5	136.5	1.6	9.8
Median	941.2	10.8	655.6	8.3	57.5
Min	499.7	5.3	348	3.7	43.7
Max	1325.8	14.2	963.7	9.1	85.4

Balance, Reaction Time, Speed, Agility, & Coordination. Participant's mean balance score was 36.4 ± 21 sec. Median balance values collected were 34.6 sec. with a maximum value of 60 sec. and a minimum value of 9.33 sec. %tile rankings were split into high>59.7 sec., medium=16.4-59.6 sec., and low<16.3 sec. Reaction time(RT) was observed with a mean value of .29 ± .04 sec. Median RT was measured as .29 sec., with a maximum value of .35 sec., and a low value of .23 sec. %tile rankings were split into high>.33 sec., medium=.28-.32 sec., and low<.27 sec. Mean score on the 10 yd. dash(speed) was 2.4 ± .3 sec. Median speed was 2.4 sec., with a maximum value of 3.12 sec., and a minimum value of 2.13 sec. %tile rankings were split into high>2.41 sec., medium=2.32-2.4 sec., and low<2.3 sec. Firefighter mean time for the pro-agility course (agility) was 5.8 ± .4 sec. Median agility value was 5.7 sec., with a maximum value of 6.46 sec., and a minimum value of 5.3 sec. %tile rankings were split into high>5.94 sec., medium=5.46-5.95 sec., and low<5.45. During the wall-ball coordination test, subjects demonstrated a mean score of 41.1 ± 6.9 tosses. Median coordination score was 40 tosses, with a maximum value of 54 tosses and a minimum value 28 tosses. %tile rankings were split into high>46 tosses, medium=38-45, and low<37.

Table 23 Skill related characteristics

	Balance(sec)	RT(sec.)	Speed(sec.)	Agility(sec.)	Coordination(tosses)
High<	59.7	0.33	2.41	5.94	46
Medium	59.6-16.4	.32-.28	2.4-2.32	5.95-5.46	45-38
Low	16.3	0.27	2.31	5.45	37
Mean	36.4	0.29	2.4	5.8	41.1
SD	21	0.04	0.3	0.4	6.9
Median	34.6	0.29	2.4	5.7	40
Min	9.33	0.23	2.13	5.3	28

Discussion

As stated previously, there are no comprehensive studies collecting descriptive information on the entirety of firefighter health and fitness as a cohort. A study by Sell (2011), is one of the few studies attempting to thoroughly explore firefighter fitness, in which 21 hotshot, wildland firefighters were tested. Where possible results will be compared to Sell's results. In addition to the Sell study, results will be compared to general public norms (ACSM), and to Cooper Institute fit for duty emergency responder norms.

Anthropometric Characteristics

A unique aspect of the current project is the measurement and description of firefighter somatotype. Figure 3 illustrates typical somatotypes for some athletic fields and a reference somatotype for the general public. The somatotype produced from this data shows subjects can generally be described as endo-/meso-morphic. Firefighters tend to be heavier (endomorph) and more muscular (mesomorph) than the general reference point. When compared to athletes, firefighters most resemble wrestlers and football players, exhibiting a low levels of bodyfat, but with a heavier set body. This body-type description fits with the %BF and BMI findings which suggest that although firefighters have a high BMI they maintain better than average %BF. In other words, firefighters tend to be large but muscular.

It is worth pointing out the fairly large standard deviation found for mean firefighter somatotype, suggesting that individual firefighters have a wide variety of body types. Perhaps by identifying an "ideal" firefighter somatotype, further research could help narrow the focus of firefighter recruitment efforts, either in building balanced teams, or in predicting candidate success at firefighting related tasks. A possible avenue towards this goal might be attempting to find correlation between specific somatotypes and success (probably as measured by time) on firefighting tasks. In fact, it may be possible to identify both an ideal overall firefighter body-type, and to associate certain specific body-types with specific firefighting tasks. Understanding task-specific somtotyping, may be another useful tool in building balanced, safe, successful teams. Perhaps, task specific somatotyping can assist in assigning firefighters to the tasks for which they are best physically suited. Finally, somatotyping can be used to inform firefighter training and exercise programs. If a firefighter exhibits particular skill at, or affinity for a task, their somatotype can inform their training goal (eg gain muscle mass, lose body fat, become lighter, etc.) Overall, somatotyping is an underutilized tool that may inform hiring, task assignment, and training goals.

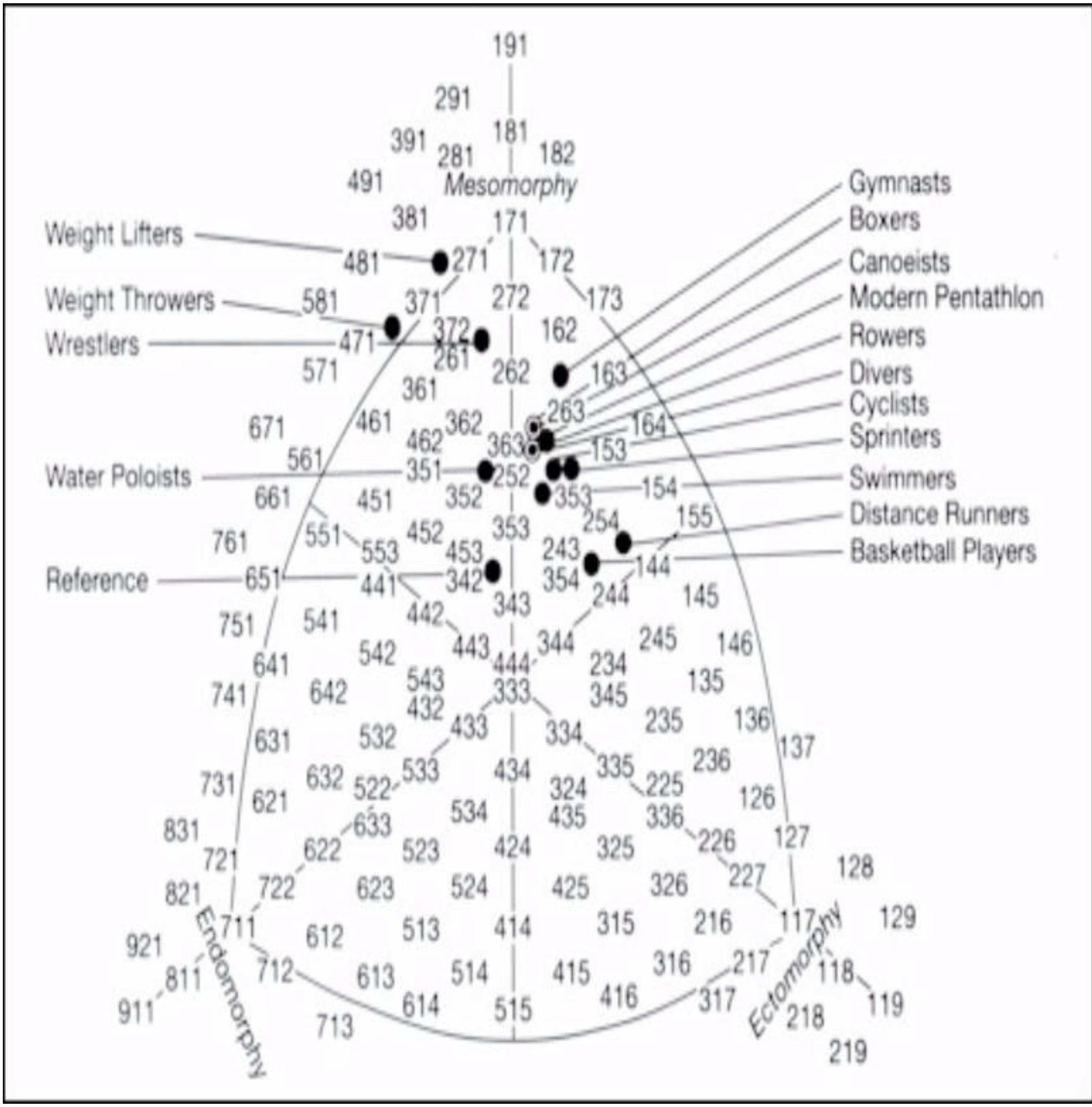

Figure 2 Somatogram showing common athlete and a general reference somatotype

Health Related Characteristics

%BF/BMI. An interesting finding was the incongruence between %BF and BMI. Mean firefighter %BF was 16.1%. While this value was higher than the 12.3% found by Sell, it still ranked above the 70%ile and classified as good relative to general population norms (Sell, 2011; Pescatello et al., 2014); Compared to norms developed by the Cooper Institute, subjects' mean %BF was at the 50%tile and classified as fair compared to the general public (Cooper Institute, 2007). Additionally, even the high %BF %tile was within normal healthy parameters (Pescatello et al., 2014). However, mean BMI was classified as overweight, and even the lowest %tile group was categorized as overweight (Pescatello et al., 2014). It has been postulated that BMI is not an appropriate measure of body composition for all populations and that researchers must take several factors into consideration when citing BMI (CDC, 2011**)**. For example, it has been demonstrated that male athletes may have as much as 50% less subcutaneous body fat when compared to non-athletes with similar BMI, producing similar BMIs in individuals with substantially different %BF and health outlooks than average adults (Wallner-Leibman, et al., 2013). It is possible that BMI may not be an appropriate method for assessing body composition in firefighters. Instead, %BF or possibly circumferences would give a better understanding of an individual firefighter's health. Additionally, exploring the differences between career and volunteer firefighters may yield some interesting results.

VO2Max. The health risks associated with firefighting are exacerbated by the extreme conditions associated with fires. During the course of this study, as part of a university initiated community service project, HPL staff were able to participate in a live-fire training exercise. These training sessions were, in part, to help HPL staff understand the specific physical rigors of firefighting and to help develop training regimens aimed at increasing stress and exercise tolerance (Yoo, A., 2015). During this training session we found structure fire temperatures in excess of 600^{o}F**.** The equipment needed to survive such harsh conditions creates additional stress. In their study Bruce-Low, Cotterrell & Jones (2007), found that wearing turnouts (insulated, protective pants and jacket) and self-contained-breathing apparatus (SCBA) increased HR by 64.8 BPM over resting. Along with increased heart rates, firefighters also experience higher than normal levels of sweating, resulting in lowered blood plasma levels, higher blood viscosity, higher blood pressure, and lower stroke volume, all contributing to overall stress on the cardiovascular (CV) system (Smith et al. 2001; Smith et al. 2001). Acknowledging this stress, it is imperative that firefighters maintain high levels of cardiovascular fitness.

Mean VO_2Max value for the cohort was 47.4 ml/kg/min, a ranking above the 75%ile and classified as good when compared to the general public (Pescatello et al. 2014), and above the 75%tile with a classification of good according to Cooper Institute norms (Cooper Institute, 2007). This value is above the nationally recommended value of 43 ml/kg/min (NFPA, 2011). Even the low %tile grouping started above the recommended value, meaning that every subject in the medium group already surpasses professional guidelines. Additionally, the Standard deviation for VO_2Max was only 4 ml/kg/min, suggesting that generally, firefighters scores were close to the mean, and consequently most firefighters' aerobic fitness is classified as good or better.

However, the value found in the current project is low when compared to the 54.55ml/kg/min described by Sell (Sell, 2011). The difference in results can at least partially be attributed to age differences between the groups of participants. The average age of participants in the Sell study was just above 25 yrs., while for this project it was over 33 yrs. Regression equations used to predict VO_2Max in individuals account for age as a negative factor, indicating that as people age, they become less aerobically fit (Pescatello et al., 2014). Overall, results suggest that firefighter aerobic fitness is good, but firefighters should continue working to maintain aerobic capacity.

Flexibility. Mean firefighter flexibility value described in this study is categorized as good according to ACSM normative values (Pescatello, et al., 2014). This classification is lower than that found by Sell (2011), whose subjects were classified as excellent, and Roberts (2002) which described their subjects as very good according to ACSM guidelines (Pescatello et al. 2014). Conversely, other researchers have described firefighters with below average flexibility (Michaelides et al. 2002). While flexibility is an important component of fitness, the diverse nature of these results suggests that low-back/hamstring flexibility may not be as important to firefighting tasks as shoulder- and shoulder-girdle flexibility. During several interviews, as well as training sessions, Assistant Chief Sean Campbell illustrated the point that firefighters frequently have to manage both themselves and their equipment through narrow, restricted spaces, often while crawling (S. Campbell, personal communication, 1/21/16). It may be the case that assessing shoulder range-of-motion and shoulder-girdle mobility are more appropriate measures of firefighter flexibility.

Muscular Fitness.

As discussed in the introduction, muscular fitness is extremely important for firefighter safety and success. In addition to protective gear, firefighters carry an assortment of tools. For the purpose of this study, we weighed the protective equipment and tools used by firefighters, and found the total weight for turnouts, SCBA, and irons (halligan, hammer or axe) is 75 pounds: turnouts-31lbs, SCBA-29lbs, irons-15 lbs. In addition to this equipment, firefighters may carry several other pieces of equipment, including wire cutters, screwdrivers, knives, as well as power-, and extraction-tools (power tools-circular saw 22lbs, extraction tool 25lbs). In conjunction with these tools, firefighters must also handle both pressurized and unpressurized hoses, as well as manipulate ladders. Whether manipulating the aforementioned equipment, or participating in other duties, most firefighting tasks require strength (victim rescue), endurance (ladder/stair climbing), or some combination of the two (charged hose management, wall breaching, tool management, etc.). Maintaining these skills necessitates maintaining a certain level of muscular fitness.

Muscular Strength. Subjects' mean upper-body strength, as assessed by 1RM for bench press was 201 lbs. Unfortunately, there is no normative data for raw bench press scores for the general public, firefighters, or emergency responders. This figure is somewhat lower, although still in line with results described in other studies. Researchers in two different studies found firefighter mean bench press 1RM at 211 lbs. and 224 lbs. (Michaelides et al., 2008; Peterson et al., 2008). It is possible to attribute the stronger performances described in the aforementioned studies to age related decline in strength. The participants in both the Michaelides and Peterson studies trended younger than the subjects in this current project.

The mean bench press 1RM/BW ratio of 1.05 is ranked above the 70%tile according to norms developed by the Cooper Institute, and is classified as good (Cooper Institute, 2007). The 1.05 1RM/BW ratio is lower than the figure of 1.4, a classification of excellent and a ranking above the 85%tile, described in a similar study (Naclerio et al. 2009). Again, the comparative study used a younger sample population than the current project, and some of the differences in strength may be attributed to age related decline in strength.

Another measure of muscular strength evaluated subjects' handgrip strength. The mean handgrip values of 95.5 lbs ± 19.4 (right), and 92.8 ± 19.7 lbs. (left). These values are below the age and sex corrected mean of 121.5 ± 22.2 lbs.(right) cited by Mathiowetz (1985), the same data the Jamar company uses. These results are also below the mean values described by Massy-Westropp (2011) of 103.5 ± 21.4 lbs, and Sell (2011) of 139.8 ± 3.8 lbs. for right-hand grip strength, 129.3 ± 3.5 kg for left-hand grip strength. The hand grip results are in opposition to the results of the bench-press which places firefighters above average in strength as compared to the general population. It is possible that firefighting duties may have interfered with getting accurate handgrip strength results. Considering firefighters' use of hand- and power-tools, as well as the reality of managing hoses and ladders, these results suggest that firefighters might well consider grip strength/forearm strength training. Additionally, it may be useful to investigate firefighter grip endurance as opposed to maximum grip strength. Since strength and endurance often display an inverse relationship, it is possible that firefighters may display below average grip strength but a capacity to maintain volitional contraction far longer than the genera- public.

Muscular Endurance. There is an ample amount of data allowing researchers to classify and categorize results from testing protocols such as the YMCA bench-press, partial curl-up, or push-up test. Unfortunately, tests like the push-up test do not produce actionable data. In other words, while it is possible to use data from a push-up endurance test to determine a subject's fitness level, it is impossible to build an exercise program built on those results. As a result, a protocol designed to result in an actionable training program was used (description in Appendix B).

To test muscular endurance, a non-traditional protocol utilizing repeated sets at 65% of 1RM with 30 sec. rest intervals was employed. While this protocol makes it difficult to compare subjects to previously gathered normative data, it was chosen due to its usefulness in creating actual training protocols. Using calculations described in Appendix B, the testing protocol can be used to create an optimized training program. The endurance protocol used during this project allows researchers to evaluate a subject's fatigue ratio: the relationship between the number of reps, the weight moved and the subject's 1RM, can be used to create a set descending weights. Training using descending sets derived in this manner produces larger training volumes, an important factor in endurance training (Baechle, & Earle (Eds.), 2008). With the development of normative data from this current project and other similar projects, it will be possible, in the future, to use results from the 65% repeated sets protocol to evaluate a subjects' muscular endurance. Perhaps, adoption of a single, universal, task specific ME test could lead to useable data, describing how firefighters compare to each other if not to the general populace. If true norms or descriptive data for this kind of testing can be compiled, a ME test could be useful in the selection, training, and evaluation of firefighters. A recruit or applicant would immediately be classified according to their ranking as compared to other firefighters. Additionally, a very specific, data driven, optimized training program could be created out of these test results.

Skill Related Characteristics

Power and Anaerobic Capacity. Mean firefighter VJ score was 21.6 in., a ranking above the 75%tile as compared to the Cooper Institute norms for the general public, and a classification of good, bordering on excellent (Cooper Institute, 2007). The VJ result is almost identical to the 21.7 in. described by Sell (2011). However, mean VJ was lower than the result described by Peterson (2008), which found mean firefighter VJ at 26.1 in., a classification of excellent and a ranking above the 90%tile. Mean firefighter SBJ was 84.7 in., unfortunately there are no established norms for adult SBJ, although this result is lower than the values cited by both Peterson, 95.9 in. (2008), and Lindberg, 93.3 in. (2015).

Anaerobic capacity was measured using a wingate protocol, allowing researchers to observe both the peak power achieved as well as the decline in that power output over time. Additionally, power/bodyweight ratios allow researchers to look at relative, as opposed to absolute, power production capacity. Mean PP was 934.6 W a ranking above the 95%tile when compared to available normative data (Maud & Shultz, 1989). Mean PP/BW was found to be 10.8W/kg, a ranking above the 85th%tile when compared to available normative data (Maud & Shultz, 1989). Mean AP found was 653.7 W, a ranking above the 85%tile when compared to available norms (Maud & Shultz, 1989). Mean AP/BW 7.5 W/kg, a ranking above the 55%tile when compared to available norms (Maud & Shultz, 1989). Finally, mean firefighter %decline was 57.9%, a ranking above the 95%tile when compared to available norms (Maud & Shultz, 1989). It appears that firefighters have above average capacity to produce both explosive power, however, they also appear to produce average AP/BW, and display a large %decline. Results pairing high PP with high %decline are compatible with what is known about muscular fitness, where strength and endurance tend to have an inverse relationship. Unfortunately there is no normative data ranking minimum power and minimum power/body weight, making it difficult to distinguish whether the high %decline represents the natural drop off expected when starting at a higher resistance, weight, or power output. There has been some research comparing power to fat-free-mass as well as overall body weight, which may be an interesting avenue of research for the future. Additionally, there has been some criticism of the available normative data, it was collected in 1989, over 25 years ago, used a small population (n=186, m=112, f=74) of college aged men and women. However, updated normative data is unavailable. It is entirely possible that, much like certain sports (long jump, power-lifting, etc.), firefighting is somewhat self-selective for high peak PP or explosive power but not necessarily sustained efforts. There are several scenarios imaginable where it may be an advantage to have a quick, powerful reaction, although sustaining that effort may not be necessary. Additionally, it may be the case that, similar to RT, power and anaerobic capacity are affected by firefighting duties, and proximity to live fire situations. It is possible that sympathetic nervous system response may enhance (or diminish) firefighter power and anaerobic capacity.

Balance. While there are no norms for balance, there is some important information to be gleaned from the results found during this project. Mean firefighter balance was recorded at 36.4 ± 21 sec., a seemingly large standard deviation. Large standard deviations suggest data with a large range of values as compared to the mean. In other words, firefighter balance is far from uniform, with some firefighters demonstrating excellent balance and others demonstrating poor balance. Another data point evidencing this wide disparity, can be seen in the wide range covered by the “medium” group, which is described as everyone with scores from 16.4-59.6 sec. As stated previously, balance appears to be affected by muscular endurance. It might be a worthwhile avenue of research to explore the relationship between lower-body muscular endurance scores (total reps or total volume) and balance. It might be beneficial for firefighters to focus on lower-body muscular endurance as a way of improving performance in both of these components.

Reaction Time. There is very little data available on reaction time. It is logical to believe that in a dynamic and dangerous environment, reaction time would not only be important, but could be the difference between life and death. All the research points to two things: first, reaction time is fairly untrainable; second, reaction time decreases (improves) under the stress of real firefighting tasks, perhaps due to autonomic nervous system activation (Greenlee et al., 2014). Testing reaction time, and reaction time improvement post-firefighting tasks, could improve overall firefighter safety. It may be useful to look for a link or relationship between pre- and post-firefighting activity reaction time. One possibility is that reaction times improve proportionally, and all firefighters see about the same improvement. However, it may be the case that like strength training, people with better (faster) reaction time are near their given limit and have less room for improvement. Until this relationship is clarified, it is difficult to ascertain exactly how to test firefighter reaction time. While testing pre-firefighting task reaction time is simpler, it may not reveal an individual firefighter's response in live fire situations, and may produce misleading results.

Speed, Agility, and Coordination. Speed, agility, and coordination represent some of the least understood and explored areas of firefighter fitness. There was no normative data to compare firefighter 10yd. dash time to. While no research was found on firefighter sprint speed, it is possible that linear speed may not be particularly important for firefighting. The complex, irregular, and fluid nature of the physical environment within a structure fire does not lend itself to linear sprinting. Research indicates that athletes require 60 meters to achieve full speed (Jeffreys, 2013). The likelihood that firefighters would be afforded the space to achieve a sustained straight line run is low. It may, in fact, be that firefighting naturally selects against speed, or that speed has little to no correlation to success as a firefighter. Possible future research may focus on the relationship, if any, between speed and specific firefighting tasks. Additionally, it may be useful to examine acceleration rather than speed.

However, as discussed above, agility and coordination are considered critical skill-components for firefighter safety (S. Campbell, personal communication, 1/21/16). On the whole, fires exhibit certain behavior patterns, however, individual fires are very unpredictable, with a wide range of factors (including fuel type, airflow, humidity, layout/floor plan, etc.) determining how they progress over time. Responding to the dynamic nature of a live fire situation often requires both mental and physical agility. Firefighters may need to change tactics mid task, similarly firefighters may need to change inertia and direction mid task, most dramatically in life or death/escape situations. Coordination is another factor in firefighter safety. The capacity to direct manual tasks both with and without looking can be a critical skill related to firefighter safety. Some skills require only a general level of coordination (eg breaching walls, aiming charged hose lines, etc.). Other skills may require a much higher level of coordination, and may in fact be the difference between life and death. For example, a firefighter caught in a tangle of wires may need to produce and use a wire cutter in order to extricate themselves from the locale. Under normal circumstances this may not seem like much of a task. However, given the likelihood that this happens in a environment with low to no visibility, possibly a confined space, and almost certainly in proximity to fire, it becomes apparent that a high level of coordination can be the difference between success and failure. It may be informative for departments to test firefighters on coordination, and either use coordination scores as part of their entrance requirements. Additionally, coordination scores could be used in assessing which firefighters might be best suited for entering a structure likely to have the equivalent of a “wire maze” or other, similar obstacles.

Conclusion

Firefighter scores were compared to available norms for specific tests, but normative data was not available for all tests. Firefighters displayed better than average body composition, above average mean VO_2Max, and good flexibility. Muscular fitness was found to be either below average (handgrip strength) or above average (BP/BW). Firefighter power was found to be above average, while anaerobic capacity was well above average. These findings suggest that firefighters need to continue working to maintain aerobic capacity and anaerobic capacity/power, while working to improve certain aspects of muscular fitness.

By collecting this descriptive data, we hope to encourage others to collect similar data, and eventually to have this data compiled as normative data. This data could then be used to compare current, active firefighters to recommended fitness levels, areas for improvement could be identified, and prescriptions for improvement in these areas could be codified. Also, it may be possible to expand or update the current ATs to include areas previously ignored. For example, based on results explored in this review of literature, inserting a flexibility assessment to either the CPAT or fire academy entrance evaluation might be a valuable addition. Similarly, if an optimal somatotype range can be determined, it could be used to build more effective firefighter teams. This type of information could be invaluable for creating safer, more effective firefighting teams.

However, little if any research has been conducted into either typical or optimal firefighter somatotype.

This study also highlights the need for more, useful, normative data to be collected and compiled by organizations such as the ACSM. While the ACSM provides some data, there should at least be general population norms developed for all the components of health and fitness.

Hopefully, this project will both continue and be replicated. With enough descriptive data collected, true normative data could be compiled, providing actionable benchmarks in each area of fitness. The capacity to evaluate and rank individual firefighters, as well as diagnose areas of weakness or strength, allows for specific individualized training regimens, building more cohesive and balanced teams, and, most importantly, increase firefighter safety. “It’s all about going home at the end of the day.”

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APPENDIX: INFORMED CONSENT

Humboldt State University Department of Kinesiology

Consent to Participate in Research

Developing Specific Physical Fitness Tests and Training Programs for Local Firefighters

Purpose and General Information

You are being asked to participate in a research study conducted by Young Sub Kwon, Ph.D. (Principle Investigator) and Kyra Han (Graduate student). The purpose of this research is to evaluate how to develop specific physical fitness tests and exercise training programs for local firefighters. You are being asked to participate because you are firefighter who are healthy and between the ages of 20-59 years. Your data will not be shared with your employers.

This form will explain the study, including possible risks and benefits of participating, so you can make an informed choice about whether or not to participate. Please read this consent form carefully. Feel free to ask the investigators or study staff to explain any information that you do not clearly understand.

What will happen if I participate?

This proposed project will be developed based on science and theory in the fields of Exercise Science. All testing will take place in the Human Performance Lab (HPL) at

Humboldt State University (HSU). When scheduling takes place, you will be asked to refrain from using caffeine and alcohol for 24 hours before each testing and training session. If you agree to be included in this study, you will be asked to read and sign this consent form. Upon signing, the following will occur:

- The study will be described in detail and your questions will be answered, then you will fill out all pre-screening forms in a private room in the Human Performance Lab. You will be introduced to the study, the purposes and procedures, and the risks and benefits. Following this introductory information, a Health History and Activity Questionnaire, Physical Activity Readiness Questionnaire (PAR-Q), the Firefighter Activity Survey will be completed, and Firefighters Assessment and Training Satisfaction Survey will be completed after tests. The investigators will provide a detailed description of the protocol both verbally and in writing. You will be encouraged to ask questions.
- The period of this study is from March 1, 2015 thru February 29, 2016. Your fitness will be assessed and training programs will be developed throughout this time period. Muscular fitness, cardiorespiratory endurance, flexibility, body composition, speed, power, agility, and reaction time assessments will be completed.
- The risk of breaching confidentiality will be minimized by using only professional personnel to perform all study activities, identification numbers instead of names, and rooms at times when others will not need access. A private room is available for discussion and testing, and all study data will be kept in a file cabinet in the P.I.'s office. All data will continue to be coded so that your identity is not revealed throughout the duration of the research.
- The length of time the participation will take around 2 hours.

What are the possible risks or discomforts of being in this study?

Every effort will be made to protect the information you give us. Every effort will also be made to minimize any risk by allowing proper warm-up and having a certified strength and conditioning specialist conducting all of the testing. As with any research, there may be unforeseeable risks. These risks include muscle soreness, muscle fatigue, and common injuries and issues associated with exercise, For more information about risks, contact the Principal Investigator, Young Sub Kwon, Ph.D

How will my information be kept confidential?

Your name and other identifying information will be maintained in files, available only to authorized members of the research team for the duration of the study. For any information entered into a computer, the only identifier will be a unique study identification (ID) number. Any personal identifying information and record linking that information to study ID numbers will be destroyed when the study is completed. Information resulting from this study will be used for research purposes and may be published; however, you will not be identified by name in any publications.

What other choices do I have if I don't participate?

Taking part in this study is voluntary so you can choose not to participate. The investigators have the right to end your participation in this study if they determine that you no longer qualify for various reasons such as health or injury issues, not following study procedures, or absenteeism.

Will I be paid for taking part in this study?

There will be no compensation.

Can I stop being in the study once I began?

Yes, you can withdraw from this study at any time without consequence.

Protected health information (PHI)

By signing this consent document, you are allowing the investigators and other authorized personnel to use your protected health information for the purposes of this study. This information may include: resting blood pressure, height, weight, age, %body fat, and health and fitness related items on the questionnaires. In addition to researchers and staff at the Human Performance Lab (HPL) at Humboldt State University (HSU) and other groups listed in this form, there is a chance that your health information may be shared (re-disclosed) outside of the research study and no longer be protected by federal privacy laws. Examples of this include disclosures for law enforcement, judicial proceeding, health oversight activities and public health measures.

Right to Withdraw

Your authorization for the use of your health information shall not expire or change unless you withdraw or change that information. Your health information will be used as long as it is needed for this study. However, you may withdraw your authorization at any time provided you notify the Humboldt State University investigators in writing. To do this, please contact to:

Young Sub Kwon, Ph.D.

707-826-5944 from Monday thru Friday 8am - 5pm. (or at 505-350-4345 after hours).

Ysk15@humboldt.edu

Department of Kinesiology

Humboldt State University

Please be aware that the research team will not be required to destroy or retrieve any of your health information that has already been used or shared before your withdrawal is received.

Refusal to Sign

If you choose not to sign this consent form, you will not be allowed to take part in the project.

What if I have questions or complaints about this study?

The investigator will answer any question you have about this study. Your participation is voluntary and you may stop at any time. If you have any questions, concerns, or complaints about this study, please contact Young Sub Kwon, Ph.D. If you would like to speak with someone other than the research team, you may call the chair of the Institutional Review Board (IRB) for the Protection of Human Subjects, Dr. Ethan Gahtan, at eg51@humboldt.edu or (707)826-4545. The IRB is a group of people from Humboldt State University and the community who provide independent oversight of safety and ethical issues related to research involving human subjects.

Liability

No compensation for physical injury resulting from participating in this research is available.

What are my rights as a research projects

If you have questions about your rights as a participant, report them to the Humboldt State University Dean of Research, Dr. Rhea Williamson, at Rhea.Williamson@humobldt.edu or (707) 826-5169

Consent and Authorization

You are making a decision whether to participate in this study. Your signature below indicates that you read the information provided (or the information was read to you). By signing this Consent Form, you are not waiving any of your legal rights as a research subject.

I have had an opportunity to ask questions and all questions have been answered to my satisfaction. By signing this Consent form, I agree to participate in this study and give permission for my health information to be used or disclosed as described in this Consent Form. A copy of this Consent Form will be provided to me.

Sincerely,

Young Sub Kwon, Ph.D.
707-826-5944

I have read an opportunity to ask questions and all questions have been answered to my satisfaction. By signing this consent form, I agree to participate to this study and give permission for my health information to be used or disclosed as described in this consent form.

A copy of this consent form will be provided to me.

____ ____________

Signature of participant Date