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Differences in Stronger Versus Weaker Firefighters in Selected Measures of Power

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ABSTRACT

International Journal of Exercise Science 15(4): 552-560, 2022. Firefighters are required to perform a wide array of physically demanding job tasks, such as forcible entry, charged hose advances and victim extractions. An adequate level of muscular strength and power are required to successfully perform these tasks. The purpose of this study is to investigate the differences in stronger and weaker firefighters in measures of power. Archived data for twenty-seven (age = 34.3 ± 7.9 yr, body height = 176.3 ± 7.2 cm, body mass = 89.4 ± 15.7 kg) full-time firefighters were analyzed. Participants were placed into one of two groups [i.e., stronger (HIGH) (n = 13) and weaker (LOW) (n = 14)], based on their relative isometric mid-thigh pull (IMTPr) performance. Power measures included counter-movement jump (CMJ) height, and peak anaerobic power in watts (PAPW). Significant mean score differences were not discovered between HIGH and LOW IMTPr groups on any measures of lower-body power. Moderate positive correlations were observed between IMTP and CMJ (r = .519; p = .01). This study identified significant differences in absolute and relative strength between firefighters who were able to lift at least 2.0x their bodyweight versus those who were not. Additionally, absolute strength (as assessed by the IMTP) was significantly and positively correlated to CMJ height when compared to their weaker counterparts. These findings may provide insight into approaches for improving occupational performance and durability through the physical development of firefighters via strength and conditioning programs which focus on developing absolute strength, relative strength, and power.

KEYWORDS: Muscular strength, tactical fitness and nutrition, tactical athlete, isometric mid-thigh pull, fitness testing

INTRODUCTION

Muscular strength and power are essential for firefighters (FF) when performing numerous occupational tasks, such as forcible entry, hose operations, and vehicle extrication (7, 8, 9, 10, 14, 18, 19). The physiological demands of these activities are compounded by the need for these individuals to wear personal protective equipment (PPE) (13). This additional load increases the physical burden placed on the FF and negatively affects physical performance (2, 3, 13). This is of great importance considering even the smallest decrements in job performance within this profession may result in serious injury or death. For these reasons, developing muscular strength and power within this population is of significant importance (7, 8, 9, 10, 14, 18, 19). Little research has explored the relationships between lower-body strength and power within FF populations. Having a greater understanding of the relationship between these specific physical attributes may be useful in the development of strength and conditioning programs for improving occupational performance among these tactical athletes (18).

Numerous studies among athletic populations have demonstrated relationships between lower-body strength and power (7, 8, 9, 10, 14, 18, 19). However, fewer studies have examined these relationships within firefighter populations. Lower-body strength and power tests are frequently performed and have been examined within tactical athlete populations (7, 8, 9, 10, 14, 18, 19). Lindberg et al. (2015) found lower-body power, as measured by the standing broad jump, was significantly correlated ($p < 0.01$) to fireground tasks such as carrying hose baskets upstairs ($r^2 = 0.82$; $r = 0.41$) and hose pulling ($r^2 = 0.77$; $r = 0.38$) (10). Sell (2006) found the strongest relationship ($r = -0.58$) between time to completion on simulated firefighting task scenarios (SFTS) was vertical jump height performance (17). Within this study, SFTS consisted of job-specific tasks and specifically included forcible entry, stair climb, hose hoist, ladder extension, hose drag, ventilation exercise, attic crawl/crawling search, and victim rescue/drag (17). Additionally, participants' fitness were evaluated on an empirically-based task force-defined time. In addition to possessing optimal body composition, movement capacity and flexibility, muscular strength, and aerobic capacity, the study conducted by Sell (2006) determined that FFs who achieved a vertical jump height of greater than 17 inches were more likely to achieve a passing rate (95.60%) than those that jumped less than 17 inches (46.20%) (17).

It is well known that muscular strength is related to lower-body power (2, 3). However, few studies have examined the differences in stronger and weaker tactical athletes in relation to measures of lower-body power (2). Dawes et al. (2) reported significant differences in stronger police officers in the CMJ and peak anaerobic power in watts (PAPW) compared to their weaker counterparts. These authors also discovered significant ($p \leq 0.001$) low-to-moderate correlations between absolute isometric strength, countermovement jump (CMJ) height ($r = 0.388$), PAPW ($r = 0.606$) and power to body mass ratio (P:BM) ($r = 0.272$). It was discovered that relative isometric strength demonstrated stronger relationships to CMJ height ($r = 0.556$) and P:BM ($r = 0.642$) when compared to absolute isometric strength, but lower associations to PAPW ($r = 0.149$). However, these relationships should be further explored within other tactical populations (i.e., FF) to see if similar relationships exist. These findings may be useful in the development of specific training programs aimed at improving these muscular attributes with these populations.

Since muscular strength is an underpinning component of muscular power, it is valuable to explore the impact of strength on muscular power. These findings may be significant in the development of strength training and conditioning programs directed at improving performance within these populations. Therefore, the purpose of this study was to investigate the differences between stronger and weaker FFs, and to determine if a significant relationship exists between lower-body strength and power. It was hypothesized that lower-body power would significantly differ in stronger FFs as compared to their weaker counterparts. It was further hypothesized that there would be a significant correlation between lower-body strength and power. Additionally, the current study is supported by previous research which has reported significant positive relationships between muscular strength and muscular power in law enforcement populations (2). Previous findings regarding these relationships highlight the need to further examine relationships in additional tactical populations.

METHODS

Participants

Archived data for twenty-seven (age = 34.3 ± 7.9 yr, body height = 176.3 ± 7.2 cm, body mass = 89.4 ± 15.7 kg; HIGH (n = 13); age = 35.7 ± 5.6 yr, body height = 178.97 ± 4.2 cm, body mass = 88.8 ± 16.9 kg; LOW (n = 14); age = 33.1 ± 9.7 yr, body height = 173.8 ± 8.5 cm, body mass = 90.0 ± 15.0 kg;) full-time FFs from one department was analyzed. FFs that had not received a passing score on their annual physical abilities test, or were restricted from duty in any way, were not eligible to participate. All FFs read and signed an approved institutional review board consent document prior to participation (IRB# 18-52). The study conformed to the recommendations of the Declaration of Helsinki. Additionally, this research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (12).

The study was a cross-section design conducted at a fire agency in the United States. Fitness assessments were conducted in one testing session. Anthropometric (i.e., body height, (BH), body mass (BM)) as well as measures of strength and power (i.e., isometric mid-thigh pull test and counter-movement jump height (CMJ)) were used for this analysis.

Protocol

All participants performed the test battery while on duty. Testing was conducted at multiple sites, which were designated prior by the fire administration. All participants reported to their designated testing facility wearing athletic attire (i.e., shorts, t-shirt, and sneakers). All tests were performed in the following order:

Body Height (BH) and Body Mass (BM): Prior to testing, BH was measured using a freestanding portable mechanical height rod. BM for the FFs was measured using the Tanita TBF-300A (Tanita Corporation of America, Inc., Arlington Heights, Illinois).

Body mass index (BMI): BMI was calculated during analysis after converting the measurements of BH and BM into the appropriate metric units. BMI was calculated as weight in kilograms divided by the height in square meters (kg/m^2).

Counter Movement Jump (CMJ height): The CMJ was performed using the Just Jump System (Probotics, Inc. Huntsville, AL). Participants performed three consecutive CMJ trials. Each trial was separated by a 30 second-period. For the CMJ task, the participants were instructed to stand with their feet shoulder-width apart on the jump mat and perform three separate CMJ trials with maximal effort. Participants arm position were not standardized for this test and they were allowed to swing their arms during the eccentric and concentric phases of the CMJ. The average of the three trials were used for the analysis. This system has been determined reliable and valid for assessing CMJ height (15).

Peak Anaerobic Power in Watts (PAPW): The CMJ peak anaerobic power measured in watts (PAPW) was calculated for the best trial using the Sayers et al. (16) equation: PAPW = (60.7 CMJ height (cm)) + (45.3 ·body mass (kg)) – 2055). Additionally, PAPW relative to body mass was calculated to provide a power-to-body mass ratio (P:BM) using the following equation: P:BM = PAPW ·BM−1 (3, 11).

Isometric Mid-thigh-pull (IMTP): Participants completed three trials of a 5-second IMTP using a load cell (model LCR; OmegaDyne, Inc., Stamford, CT) secured to an eyebolt in a custom 1.219 m x 0.800 m platform via a carabiner. The opposing end of the load cell was attached to a 47 cm wide T-bar using a chain. Participants were instructed to stand with their feet shoulder-width apart on the platform with their knees bent at a 125-degree angle, their hips at a 140-degree angle, and a straight back, following the guidelines set forth by Comfort et al. (1). Participants were given a countdown, and then pulled maximally for 5 seconds. Participants were given a 30-second rest period between trials. The data were sampled and processed using a strain meter at 3 Hz (DP25B-S, Omega Engineering Inc., Norwalk, CT). The IMTP has been found to be a reliable and valid isometric test of upper and lower-body muscular strength (4). The best score of three attempts was converted to relative IMTP strength (IMTPr) by dividing body mass by IMTP score and used for this analysis.

Statistical Analysis
Prior to analysis, participants were divided into a HIGH or LOW group based on their IMTPr values. Participants able to lift at least 2.0x their body mass, were placed in the HIGH group (n = 13). While participants unable to lift 2.0x their body mass were placed in the LOW group (n = 14). The inclusion criteria for each group were established based on the findings and recommendations of previous research (2). Normality of the data was assessed by using the Shapiro-Wilk test. A multivariate analysis of variance (MANOVA) was utilized to determine if mean differences existed between the HIGH and LOW groups in CMJ performance and PAPW. Pearson's correlation was used to find relationships between measures of muscular strength (IMTP and IMTPr) and muscular power (CMJ, PAPW, and P:BM). The strengths of each correlation were classified as follows: 0 to 0.30, or 0 to -0.30 was considered small; 0.31 to 0.49, or -0.31 to -0.49 was considered moderate; 0.50 to 0.69 or -0.50 to -0.69 was considered large; 0.70 to 0.89 or -0.70 to -0.89 was considered very large; and 0.90 to 1.0 or -0.90 to -1.0 a near perfect correlation (2,3). Effect size calculations were also used to further determine if any worthwhile differences between groups were present. Effect sizes were calculated using Cohen's d and were interpreted using the Hopkins scale (6). Based on this scale, a d less than 0.2 was considered a trivial effect; 0.2 to 0.6 a small effect; 0.6 to 1.2 a moderate effect; 1.2 to 2.0 a large effect; 2.0 to 4.0 a very large effect; and 4.0 and above an extremely large effect. An alpha of $p \leq 0.05$ was adopted for all significance tests. Statistical analysis was performed using SPSS v24 (IBM, Armonk, NY).

RESULTS

Descriptive data for the entire sample is displayed in Table I. In Table II, descriptive statistics for both HIGH and LOW groups are displayed. Correlational data for all demographic, anthropometric, and strength measures in relation to power measurements are displayed in Table III. The MANOVA revealed significant differences between groups in IMTPr (F = 26.73; *p* = 0.00). However, no significant differences between groups in IMTP (F = 4.24; *p* = 0.06) were observed in this study. Results of the *d* calculations revealed a small effect size between groups in BH (*d* =0.12), BM (*d* =0.00), and CMJ height (*d* =0.02) and a moderate effect size between groups in IMTPr (*d* = 0.63). These results are displayed in Table II. Additionally, moderate positive correlations between IMTP and CMJ (r = .519; p = .01) were observed. No other significant differences were observed between HIGH and LOW groups in any measures of lower-body power. Significant moderate positive correlations between IMTP and BH, CMJ, and IMTPr were observed (p < 0.05). Significant moderate positive correlations between PAPW and CMJ were observed in this study (p < 0.05). Significant moderate negative correlations were observed between CMJ and BH, PAPW, and IMTP (p < 0.05).

Table 1. Descriptive statistics for entire sample of Firefighters (N = 27).

Variable	Minimum	Maximum	Mean ± SD
Age (yr)	23.0	54.0	34.3 ± 7.9
BH (cm)	154.5	185.4	175.9 ± 7.1
BM (kg)	60.0	128.7	89.4 ± 15.7
BMI (kg/m^2)	20.5	39.3	29.7 ± 4.9
CMJ (cm)	23.1	82.0	48.1 ± 15.1
PAPW (W)	2119.8	6921.7	4779.3 ± 1030.4
IMTP (kg)	175.3	505.3	356.0 ± 72.3
IMTPr (kg/BM)	1.1	2.9	1.9 ± 0.4

Table 2. Main effects for different variables between IMTPr HIGH and LOW groups.

Variable	HIGH (*n* = 13)	LOW (*n* = 14)	Effect Size (*d*)
Age (yr)	35.7 ± 5.6	33.1 ± 9.7	0.01
BH (cm)	179.0 ± 4.2	173.8 ± 8.5	0.12
BM (kg)	88.8 ± 16.9	90.0 ± 15.0	0.00
BMI (kg/m^2)	28.7 ± 6.2	30.3 ± 4.1	0.03
CMJ (cm)	51.2 ± 13.8	45.1 ± 16.1	0.02
PAPW (W)	4871.1 ± 1073.2	4921.3 ± 1231.34	0.05
IMTP (kg)	396.3 ± 54.7	318.5 ± 67.5	0.21
IMTPr (kg/BM)	2.2 ± 0.2*	1.5 ± 0.3	0.63

Data presented as mean ± SD. BM = body mass; CMJ = countermovement jump height; PAPW = peak anaerobic power in watts; IMTP = isometric mid-thigh pull; IMTPr = isometric mid-thigh pull relative strength. * Statistically different than LOW (p < 0.01)

Table 3. Correlations between demographic, anthropometric, power, and strength measures.

Variable	Age	BH (cm)	BM (kg)	CMJ (cm)	PAPW (W)	IMTP (kg)	IMTPr
Age	1	.055	-.055	-.280	.083	-.085	.071
BH (cm)	.055	1	.460*	.446*	.353	.627**	.392*
BM (kg)	-.055	.460*	1	-.197	-.058	.286	-.030
CMJ (cm)	-.280	.446*	-.197	1	.535**	.519**	.234
PAPW (W)	.083	.353	-.058	.535**	1	.157	.142
IMTP (kg)	-.085	.627**	.286	.519**	.157	1	.579**
IMTPr	.071	.392*	-.030	.234	.142	.579**	1

Note. * Significant relationship ($p \leq .05$) between the two variables; ** Significant relationship ($p \leq .01$) between the two variables; *** Significant relationship ($p \leq .001$) between the two variables.

DISCUSSION

The purpose of this study was to investigate the differences in stronger and weaker FFs in selected measures of power. The primary findings of this study were the significantly moderate positive correlations observed between IMTP and CMJ. No other significant differences were observed between HIGH and LOW groups in any measure of lower-body power. Overall, the findings of the current study suggest that absolute strength, rather than relative strength may have a greater impact on relative lower-body power as measured by the CMJ. Furthermore, when designing a strength and conditioning program for the tactical athlete a multi-faceted approach which includes achieving optimal body composition and developing power through lower-body strength training is recommended. The development of absolute lower-body strength may best prepare FFs for occupational tasks that require utilizing their lower-extremity muscles to generate enough force while pulling hoses, conducting forcible entries, dragging victims to safety, and completing similar occupational tasks.

It was hypothesized that lower-body power would significantly differ in stronger FFs compared to their weaker counterparts. However, this hypothesis was not supported by the findings of the current investigation. Based on the results of this study, it was discovered that no significant differences in lower-body power exist between stronger and weaker tactical personnel. These results contrast those commonly reported in tactical research. For instance, Dawes et al. (2019) and Lindberg et al. (2015) reported that stronger tactical athletes jumped higher than their weaker counterparts (2, 10). Further support was provided in an investigation conducted by Dawes et al. (2015), who examined the relationship between selected measures of power and linear sprint speed ability [e.g., CMJ height, PAPW, power-to-body mass ratio (P:BM), and sprint speed over 5-m, 10-m, and 20-m] among members of a part-time Special Weapons and Tactics (SWAT) team (3). In both instances, these researchers reported significant correlations between all of the selected speed distances and power measures. PAPW is also a popular method for measuring lower-body power within tactical populations (2, 3). However, there were no significant differences in PAPW between groups within this investigation. The findings from this study are meaningful based on previous findings, the modifiable contributors to occupational performance (i.e., absolute and relative strength) that were identified, and should be considered by administration, tactical strength and conditioning staff, and other support staff when determining the most important aspects of health and wellness and/or strength and conditioning programs for FFs (2).

It was hypothesized that a significant correlation would exist between lower-body strength and power. The findings of this investigation partially support this supposition, as it was discovered that significant moderate correlations did exist between IMTP and CMJ height. However, no significant relationships between relative strength (IMTPr) and any measure of lower-body power were observed in this study. Although relationships between absolute lower-body strength and power are supported by previous research, these results contradict previously reported findings assessing relationships between relative strength and power production in tactical populations (2, 3, 13). It may be worthwhile to consider that many occupational tasks performed by "tactical athletes" do not resemble that of traditional athletic populations, thus mechanisms to achieve similar tasks (e.g. producing power via a CMJ) may not always be the same. Therefore, the authors posit a simple explanation for the observed findings within this study. Within athletic populations, success or development of sport-specific skills may be determined by the ability to adequately master certain physiological qualities (e.g. coordination, utilizing the stretch-shortening-cycle, etc.) (11). However, within tactical populations, the ability to produce force, irrespective of its relation to an individual's body mass, appears to be a primary contributor to power production. Consequently, these findings suggest that stronger tactical athletes are also more powerful tactical athletes, so the development of absolute lower-body strength should be prioritized within firefighter populations.

While the results of this study highlight the importance of absolute and relative strength for FFs, it is not without limitations. Based on the archival nature of the data collected, the authors were limited to only measuring isometric lower-body strength. In the future, it may be beneficial for researchers to utilize dynamic measures of strength (e.g., back squat, deadlift, etc.) and their relationships to lower-body power in this population. Furthermore, upper-body strength (e.g., grip strength, etc.) may be a limiting factor in performance of the IMTP. It may be beneficial for future research to investigate the relationships between both upper and lower-body strength to determine their impact on occupational performance. Additionally, future research may find the utilization of force platforms beneficial for assessing strength and power metrics, but also for identifying specific mechanisms for force- and power-production within the firefighter population. Finally, although they considerably improve data interpretation and outcome estimations between multiple groups, quartiles are most beneficial when there are at least 30 observations per parameter. Thus, a larger sample size is recommended if a similar statistical analysis approach is to be taken.

In conclusion, the findings of the present study suggest that absolute and relative lower-body strength can be utilized to create HIGH/LOW performer groups within tactical, but specifically, FF populations. Tactical Strength and Conditioning Coaches (i.e., TSAC-F) can utilize this information to support the incorporation of training methods that will increase each of these qualities within this population. Notably, the ability to rapidly produce force, may have influenced performance in these measures. Therefore, it is recommended that other forms of resistance training such as plyometrics are integrated into strength and conditioning approaches within this population. These types of exercises emphasize the development of reactive strength and eccentric loading via short ground contact times, in addition to traditional weight training.

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