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Can Lower-Body Strength and Power Alleviate Load Carriage Performance Decrements (Tactical Deficit) in Simulated Law Enforcement Job Tasks?

ASHLEY M. BLOODGOOD‡1, JOSEPH M. DULLA†2, MEGAN B. THOMPSON†3,4, MATTHEW R. MORENO‡5, ROBIN M. ORR‡2, J. JAY DAWES‡3,4, and ROBERT G. LOCKIE‡6

[1]Department of Sport and Exercise Science, Park University, Gilbert, AZ, USA; [2]Tactical Research Unit, Bond University, Robina, Qld, AUSTRALIA; [3]School of Kinesiology, Applied Health and Recreation, Oklahoma State University, Stillwater, OK, USA; [4]Tactical Fitness and Nutrition Lab, Oklahoma State University, Stillwater, OK, USA; [5]Human Performance, Marine Corps Community Services, Camp Pendleton, CA, USA; [6]Center for Sport Performance, Department of Kinesiology, California State University, Fullerton, Fullerton, CA, USA

†Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 17(4): 1577-1594, 2024. Law enforcement agencies typically have recruits complete fitness assessments without personal protective equipment (PPE). PPE negatively impacts performance. Greater strength and power could alleviate performance decrements due to the extra load, termed the tactical deficit (TD). The purpose of this study was to examine whether lower-body strength or power related to the TD in civilians performing police tasks. Twenty participants (12 men, 8 women) completed baseline tests, including: standing broad jump (SBJ); relative SBJ; absolute and relative isometric leg/back dynamometer (LBD) and one-repetition maximum hexagonal bar deadlift (HBD). In two other sessions, participants completed four police tasks, either unloaded or loaded (PPE=~8-10 kg), in a counterbalanced order: vertical jump (VJ), 75-yard pursuit run (75PR), 74.84-kg body drag, and 500-yard run. The VJ was also used as a power metric, with peak anaerobic power and power:body mass (P:BM) derived. Paired samples t-tests investigated differences between unloaded/loaded conditions for each task for each sex. Independent samples t-tests compared the sexes. Pearson's correlations derived relationships between strength and power tests with each task TD for each sex. Load negatively impacted task performance ($p \leq 0.011$); males generally outperformed females ($p \leq 0.044$). Superior SBJ, relative SBJ, VJ, P:BM, and absolute and relative HBD related to a smaller 75PR TD (r=-0.582 to -0.838). Greater absolute and relative HBD related to a lower body drag TD (r=-0.576 to -0.618) in men. For women, the relative SBJ related to a smaller VJ TD (r=-0.727). Developing lower-body strength and power could offset TD in foot pursuit and dragging tasks for personnel.

KEY WORDS: 500-yard run, 75-yard pursuit run, body drag, hexagonal bar deadlift, police, personal protective equipment, PPE, standing broad jump, tactical, vertical jump

INTRODUCTION

Law enforcement can be a physically demanding occupation (8, 14), and the effective performance of job tasks is essential to not only the safety of the officer, but the community they are tasked to protect. Although the law enforcement profession can feature long bouts of sedentary activity (38), the high-intensity tasks that may be required of officers are essential for public safety. Some of the physically demanding tasks required of law enforcement officers include lifting or dragging objects or people, engaging in foot pursuits, or using force to apprehend a suspect (38). Many law enforcement agencies require the completion of job-specific fitness tests that assess the underlying characteristics necessary to successfully complete officer job tasks (20). These tests are typically administered without the presence of personal protective equipment (PPE) worn by law enforcement officers when on-duty. The lack of PPE during physical fitness testing for law enforcement personnel could potentially result in imprecise assessment of the physical characteristics and abilities necessary to complete job tasks, which generally occur on the job while under load.

Although the mandated PPE for officers may vary between departments, example load carriage requirements for law enforcement officers includes stab resistant body armor worn over the torso and a utility belt worn around the waist (2, 32). The belt typically comes equipped with a minimum of one firearm, two magazines, one flashlight, one radio unit, and two handcuffs (2, 32). This baseline PPE can add an additional 8-10 kilograms (kg) of mass to an officer (2, 12), on top of their own personal body mass. The PPE for law enforcement officers is often carried in the torso region with additional load distributed laterally within the belt (2, 12). The concentration of external load being placed in one central area of the body has implications for not only mobility (6, 32), but decrements in physical performance as a result of increased muscular fatigue (25).

Previous research has found PPE to have negative effects on occupation-specific movements and tasks. For example, PPE loads have been shown to decrease officer sprinting ability in short distances of approximately 9.1 meters (m) (13), countermovement vertical jump (VJ) height (6, 13), simulated body drag performance (34), and acceleration in vehicle exit maneuvers (6, 34). Additionally, wearing PPE increases the aerobic demands of officers as measured by a percentage of their maximal aerobic capacity during incremental running tasks on a treadmill under tactical load (6). Decreased performance in critical job tasks typically results in what could be termed a 'tactical deficit' (TD), which could be detrimental to the well-being of the officer. In the context of this research, TD refers to the decrease in performance that results from wearing a tactical load (i.e., PPE).

The findings from these previous studies would suggest that it is important to train officers in a manner that allows necessary physiological adaptations to sustain the demands of their required PPE to ensure successful execution of job tasks. Although there is little debate that performance in physical tasks will become worse when performed with additional load, it could be theorized that better fitness could help alleviate some of these decrements. For example, strength and power are important fitness qualities that relate to law enforcement-specific job tasks, such as sprinting (5), jumping (4), and the body drag (24, 27). It could be expected that stronger and more powerful individuals may experience fewer performance decrements when performing acute tasks under load, such as with PPE intended for law enforcement officers. However, this has not been documented in the literature. Indeed, research is needed in determining whether muscular strength and power could reduce the TD experienced by an individual.

Therefore, the purpose of this research was to examine the effects of load carriage during sample policing tasks and investigate whether lower-body strength and power could lessen the TD in a civilian population age-matched to law enforcement recruits. The four policing tasks were chosen based on recruit training and testing guidelines, as well as the prevalence of these tasks in the field (1, 30). It was firstly hypothesized that men would be stronger and more powerful compared to women, necessitating the investigation of the sexes separately. It was further hypothesized that performance of the four policing tasks under load would result in lesser performance (i.e., decreased jump height, increased completion times) compared to the unloaded condition, resulting in a TD. Lastly, it was hypothesized that strength and power would correlate with the TD in both men and women whereby stronger and more powerful individuals would have a smaller TD in each task.

METHODS

Participants

A convenience sample of 20 college-aged, recreationally-active civilians (12 men, 8 women) were recruited for this study. Previous studies investigating the effects of PPE have used similar numbers of participants for analysis (12, 32, 35). Participant details can be viewed in Table 1, and participants were recruited from the student population at the university via information sessions or word-of-mouth. Similar to previous research (18, 36, 39), college-aged students were used as surrogates for a tactical population. The recruitment of civilians allowed for men and women with different physical capabilities to be recruited (36). Furthermore, fitness relationships relative to tasks performed with or without PPE should be similar whether performed by *ab initio* tactical personnel or civilians due to law enforcement agencies recruiting from the general population (18). Participants were recruited if they were: recreationally active, having trained in either aerobic or resistance exercise a minimum of two times a week for the past year; were free of upper- and lower-extremity injury within the past 6 months; and did not have any disabilities that influenced physical participation. The institutional review board approved this study (HSR-19-20-139). Participants received and signed a written informed consent detailing inherent risks, benefits, and an overview of the study, as well as read and signed a physical activity readiness questionnaire prior to their participation. The research also adhered to the recommendations of the Declaration of Helsinki (40) and the ethical guidelines set forth by the editorial board for the *International Journal of Exercise Science* (28).

Protocol

Three testing sessions were used for this study, and testing was conducted on the university campus. Participants wore their own athletic attire, abstained from intensive exercise in the 24-hour period prior to testing, were instructed to wear the same shoes for every session, and to maintain a consistent diet for the duration of the study. Following completion of the informed consent and health screening questionnaire in session one, the participant's anthropometric measurements including age, height, and body mass, were recorded. Height was measured barefoot using a wall-mounted stadiometer (Detecto, Webb City, MO, USA). Body mass was recorded by an electronic digital scale (Ohaus, Parsippany, NJ, USA). Participants then completed a dynamic warm-up, which involved 5 minutes cycling at a self-selected intensity on a stationary bicycle (Assault Fitness, Carlsbad, California), and 10 minutes of total-body dynamic stretching. After the warm-up was completed, the participants then completed a series of physical fitness tests to assess strength and power characteristics for session 1. These assessments included a standing broad jump (SBJ), isometric leg/back dynamometer (LBD), and a one-repetition maximum hexagonal bar deadlift (1RM HBD).

The SBJ provided an indirect measure of horizontal power, with the protocol adapted from previous research (27). Trials occurred alongside a tape measure fixed to the ground with adhesive tape. Each participant started with their toes on a marked piece of adhesive tape level with 0 centimeters (cm). With a simultaneous arm swing and crouch, the participant performed a maximal forward leap making sure to land with both feet. Participants were required to stick the landing with the trial being repeated if they lost balance after landing. The distance from the rearmost heel to the 0-cm line was measured as the SBJ distance to the nearest cm. The best of two trials was taken as the participant's final score with 2-minute rest periods occurring between each trial. Absolute and relative SBJ was recorded. Relative SBJ was calculated by dividing the SBJ distance against the body mass of each participant (27).

Isometric leg and back strength were measured using a LBD (Fabrication Enterprises, Inc., New York, USA), with procedures adapted from previous research (4, 24). The chain, which connects the scale on one end and a handle on the other, was adjusted so that the participant's knees were flexed at approximately 110°. While maintaining proper spinal alignment (i.e., neutral spine with no rounding of the back) and feet flat on the base of the dynamometer, the participants were instructed to keep the arms straight and pull the LBD handle upward as hard as possible by extending through the hips and knees. Absolute LBD strength was recorded as the amount of isometric force produced measured in kg. The participant performed two trials with the best trial being used for analysis. Relative strength was calculated with the formula: *relative LBD (kg/kg) = absolute LBD/body mass*.

The procedures for the 1RM HBD were adapted from the literature (17). The barbell used was a dual height hexagonal bar (American Barbell, San Diego, CA). Participants utilized the high handles of the dual height bar (17). No belts, chalk, or lifting straps were permitted. The participant began the testing by performing four warm-up sets with three minutes of rest in between: 10 repetitions at 50% of estimated 1RM, 5 repetitions at 70% of estimated 1RM, 3 repetitions at 85% of 1RM, and 1 repetition at 90%. Estimated 1RM was self-reported by the participant. After these warm-up sets, the weight was increased by 5% and another attempt at the load was given. This process continued until the subject failed to lift the load. A successful repetition was one where the participant stands erect within the frame of the barbell. A lift was deemed unsuccessful when the bar was lowered at any point in the ascent, or the subject failed to attain the standing position. Generally, no more than 5 attempts were required before the 1RM was reached. Relative strength was determined according to the formula: *relative 1RM (kg/kg) = 1RM HBD/body mass*.

Following completion of the 1RM HBD, participants were given a brief, 1-minute walk-through by the researcher, which is similar protocol to what law enforcement agency recruits receive during academy, in each of the four different occupational tests. Participants were also able to try on and wear the external occupational load (belt and weighted vest) for approximately 1 minute to familiarize themselves to the equipment before returning for testing sessions 2 and 3. Participants were also individually fitted for the belt and vest, and the sizes used by the participants were noted by the researcher.

The PPE used in this study was provided by a Southern California law enforcement agency and was identical in mass to duty gear used in the field. The equipment included a stab and small firearm caliber resistant adjustable vest (Second Chance Products, New Cumberland, PA) in small, medium, and large sizes to adjust to individuals of differing torso diameters (Figure 1). Standard Sam Browne utility belts (Aker, Chula Vista, CA) were provided in seven waist sizes (Figure 2 and Table 1). Belts were equipped with leather holsters and pouches that served as attachment sites to add extra mass equivalent to common gear carried by most officers. This extra mass was added using forged pieces of metal that equated to approximately 8-10 kg of total extra mass. This mass was selected because it has been used in previous research and is intended to replicate the mass of ammunition cartridges, hand cuffs, pepper spray, an extendable baton, a radio unit, replica taser gun, and high-power flashlight, and two low-caliber fire arms (2, 6). Previous research detailed that officers place the majority of their most important equipment anteriorly and laterally along the belt within easy reach (32). This configuration was mimicked in this study with the loaded pouches and holsters moved anteriorly and laterally across the belt. The PPE worn by each participant was weighed and recorded. Relative load for PPE was calculated as a percentage of body mass for each participant.

Figure 1. Sizes of ballistic vests (small: left; medium: middle; large: right).

Figure 2. Sam Browne belts.

Table 1. List of belt sizes ascending order.

Belt Sizes	Centimeters (cm)
Small	92
Small/Medium	101
Medium	106
Medium/Large	108
Large	116
Extra Large (XL)	118
Extra, Extra Large (XXL)	121

During sessions 2 and 3, participants wore athletic attire and completed four occupational tasks that are typical of law enforcement agency physical fitness testing. These two sessions were comprised of the same testing protocol, with the loaded condition requiring the participant to wear the PPE. The occupational tests included the VJ, 75-yard pursuit run (75PR), 74.84-kg (165-lb) body drag, and 500-yard (457.2-m) run. These tests are reflective of power, change-of-direction speed, strength, and high-intensity running, respectively (15, 30, 31), and have been validated a reflective of law enforcement patrol occupational demands (11). The VJ, body drag, and 75PR took place indoors, with the 75PR and drag occurring on a polished wood floor. The 500-yard run took place outdoors on an athletics track. Participants completed the tests in both an unloaded and loaded condition, with each condition taking place on different days. Sessions were separated by 48-56 hours depending on participant availability, and a counter-balanced approach was used to select which session featured unloaded or loaded conditions. For the VJ, 75PR, and body drag, two trials were completed for each condition, with 2-minute rest periods occurring between each trial and the best trial was used for analysis. For the 500-yard run, only one trial was completed (15, 19, 30).

A VJ test was implemented to provide an indirect measure of vertical power, in addition to measuring the qualities necessary for job tasks such as obstacle clearance and wall climbs (23, 30). A jump mat (Probotics Inc, Alabamba, USA) was utilized to measure jump height and followed established protocols (26). The participant initially started on the jump mat and was instructed to perform a countermovement jump, with no restrictions placed on the depth of the countermovement or arm swing. Jump height was calculated by the mat software based on the time spent in the air. Unloaded VJ measures were also used in the TD analysis as a measure of vertical power relative to job task performance under load. Peak anaerobic power measured in watts (PAPw) was calculated from the best unloaded trial using the equation from Sayers et al. (33): *Peak Power (watts; w) = (60.7 ·VJ height [cm]) + (45.3 ·body mass [kg]) - 2055.* PAPw was then calculated relative to the body mass of each participant via the formula: P:BM = PAPw/body mass (5).

The 75PR was designed to simulate a foot pursuit and involved five linear sprints about a square grid, while completing four, 135° direction changes across the grid (16, 30) (Figure 3). Participants also stepped over three barriers that were 2.44-m long and 0.15-m high that simulated roadside curbs during three of the five linear sprints, which was completed on a polished wooden floor. A pair of single-beam timing gates (Brower Timing Systems, Draper, Utah, USA) were placed at both the start and finish line and recorded time to the nearest 0.01 s

(31). Gate height was set at 0.63 m, and gates were positioned 1.84 m apart. Subjects started 0.5 m behind the start line to initiate timing at the first gate.

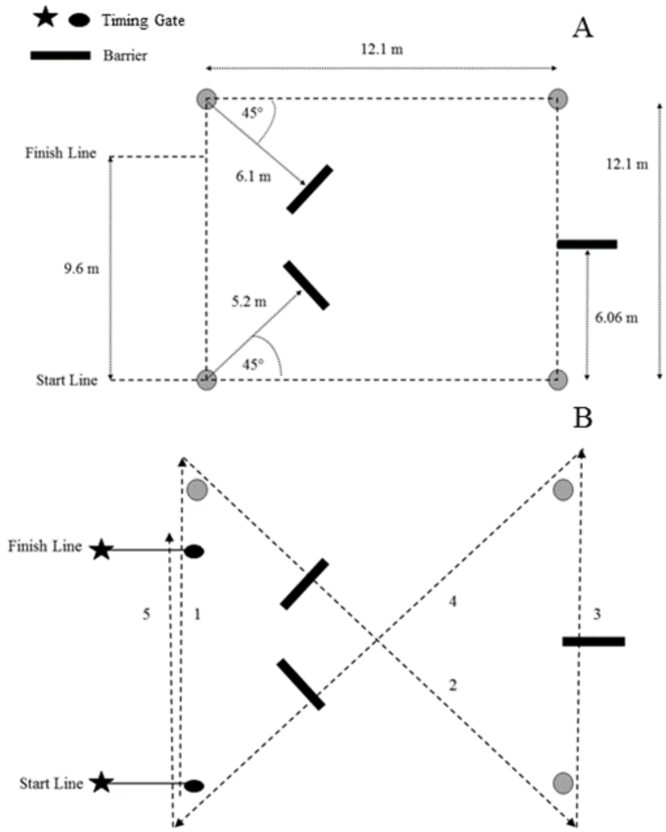

Figure 3. (A) 75-yard pursuit run dimension in meters. (B) Running direction numbered in order and timing gate placement.

For the body drag, a 74.84-kg dummy (Dummies Unlimited, Pomona, CA) was utilized. In addition to being a job-specific test, the body drag provided a strength-based task measure (17, 24). The procedures for the drag were adapted from state-mandated guidelines (15, 19, 22, 30). Adhesive tape was used to mark the start and finish lines for the 9.75-m dragging distance on polished wood flooring. The dummy was positioned face side up, with the head orientated towards the finish line, 0.3 m behind the starting line. The participant started by squatting and placing their arms under the dummy's arms and across the chest (Figure 4A). The participant was not allowed to grip or pull on any other part of the dummy as they lifted the dummy off the floor and into the starting position (Figure 4B). Then, the participant dragged the dummy backwards, with time not starting until the dummy's feet had crossed the start line. Time was stopped when the dummy's feet crossed the finish line and was recorded to the nearest 0.10 s. All times were recorded via stopwatch which followed state-mandated standards (30). Nonetheless, testing procedures were checked with three participants across multiple trials against time measured via a video recording (Apple, Cupertino, CA). Intra-class correlations showed that the stopwatch timing closely agreed with the video recording (r = 0.988, single measure = 0.986, average measure = 0.984, p < 0.001).

Figure 4. 74.84-kg body drag lifting position (A) and starting position (B).

The 500-yard (457.20-m) run was designed to simulate a long-distance foot pursuit (15, 19). Muscular endurance, anaerobic capacity, and aerobic capacity are physical characteristics that contribute to the 500-yard run (15). The distance was marked on an outdoor athletics track, and participants were instructed to run this distance as quickly as possible. Time was recorded via timing gates (Brower Timing Systems, Draper, UT, USA). Participants started 0.5 m behind the first set of timing gates to initiate timing, and time was recorded from when the participant broke the gate until they crossed the finish line at 500 yards.

Statistical Analysis
All statistical analyses were computed using the Statistics Package for Social Sciences (version 29.0; IBM Corporation, NY, USA) and Microsoft Excel (Microsoft Corporation™, Redmond,Washington, USA). Descriptive data (mean ± standard deviation [SD]) were calculated for all variables. Normality of the data for both sexes was evaluated by Kolmogorov-Smirnov test and visual analysis of Q-Q plots. As will be noted, the data was deemed to be normally distributed for both sexes, thus parametric statistics were used. Paired samples t-tests ($p < 0.05$) were run to derive differences between the unloaded and loaded conditions for the men and women. Following this, the TD was then calculated, with TD being expressed as a percentage via the following formula: *TD = ([Loaded Time or Jump Height ÷ Unloaded Time or Jump Height] x 100) – 100*. Independent samples t-tests ($p < 0.05$) were run to compare the differences between men and women in all variables. The between-sex comparisons were conducted to confirm the need to analyze the sexes separately. For all t-test analyses, effect sizes (d) were also calculated. Cohen's d was utilized (absolute value for the difference between the means divided by the pooled SD) (3). The d strength was defined as: <0.2: trivial; 0.2-0.6: small; 0.6-1.2: moderate; 1.2-2.0: large; 2.0-4.0: very large; and ≥4.0: extremely large effect (9).

Pearson's correlations ($p < 0.05$) were conducted to analyze relationships between absolute and relative isometric (LBD) and dynamic (HBD) strength, SBJ (distance and relative SBJ), and unloaded VJ (jump height, PAPw, and P:BM) with the TD for the VJ, 75PR, 74.84-kg body drag, and 500-yard run. Correlation strength was designated as per Hopkins (10): an r between 0 to ±0.3 was small; ±0.31 to ±0.49, moderate; ±0.5 to ±0.69, large; ±0.7 to ±0.89, very large; and ±0.9 to ±1 near perfect for relationship prediction.

RESULTS

According to the Kolmogorov-Smirnov tests for the men, 23 out of 26 variables were normally distributed (p = 0.122-0.200), which was confirmed by observation of the Q-Q plots. For women, all variables were normally distributed (p = 0.102-0.200), which were again confirmed by the Q-Q plots. Accordingly, parametric statistics were used in this study. Descriptive data and between-sex comparisons for age, height, body mass, absolute PPE load, relative PPE load, and the strength and power tests are shown in Table 1. Age was not significantly different between the sexes. Males were significantly taller, had a greater body mass, and higher PPE load compared to females (all large effects). Females had a significantly higher relative PPE load compared to males, with a large effect. Males were significantly stronger and more powerful in all tests except for the relative SBJ (moderate-to-very large effects) when compared to their female counterparts.

Data for the unloaded and loaded conditions and the TD is displayed in Table 2. The unloaded VJ was included in both Tables 1 and 2 as it was used as a general metric for vertical lower-body power, in addition to a law enforcement-specific test. For the males, paired samples t-tests indicated that the additional load resulted in a significantly lesser VJ height (p < 0.001; d = 1.81; large effect), and slower 75PR (p = 0.011; d = 0.88; moderate effect), 74.84-kg body drag (p < 0.001; d = 1.36; large effect), and 500-yard run (p = 0.013; d = 0.86; moderate effect). For the females, the added PPE led to a significant decrease in VJ height (p = 0.003; d = 1.54; large effect), and slower 75PR (p = 0.006; d = 1.39; large effect) and 500-yard run (p = 0.007; d = 1.34; large effect) times. There was no significant difference between the unloaded and loaded body drag for females (p = 0.877; d = 0.06; trivial effect). The males outperformed the females in all the law enforcement specific tests, with large-to-very large effects. The female participants did have a significantly lower TD for the 74.84-kg body drag compared to the men. There were no significant between-sex differences in the TD for the VJ, 75PR and 500-yard run.

Table 1. Descriptive characteristics (mean ± SD) for all subjects combined, men and women, and between-sex comparisons for age, height, body mass, personal protective equipment (PPE) load, relative PPE load (PPE as percentage of body mass), standing broad jump (SBJ), relative SBJ, vertical jump (VJ), peak anaerobic power measured in watts (PAPw), relative PAPw (P:BM), isometric leg/back dynamometer strength (LBD), relative LBD, one-repetition maximum hexagonal bar deadlift (1RM HBD), and relative HBD.

Variable	All (N = 20)	Males (n = 12)	Females (n = 8)	p	d	d Strength
Age	23.10 ± 2.81	23.25 ± 3.30	22.88 ± 2.03	0.779	0.13	Trivial
Height (m)	1.69 ± 0.08	1.73 ± 0.07	1.63 ± 0.04*	0.004	1.53	Large
Body Mass (kg)	70.76 ± 10.14	76.23 ± 8.43	62.55 ± 6.21*	0.001	1.79	Large
PPE Load (kg)	8.26 ± 0.27	8.37 ± 0.27	8.09 ± 0.18*	0.016	1.21	Large
Relative PPE Load (%)	11.87 ± 1.49	11.10 ± 1.15	13.03 ± 1.12*	0.002	1.66	Large
SBJ (cm)	201.05 ± 37.50	218.50 ± 34.02	174.88 ± 26.33*	0.007	1.40	Large
Relative SBJ (cm/kg)	2.86 ± 0.50	2.88 ± 0.50	2.82 ± 0.53	0.793	0.12	Trivial
VJ (cm)	53.79 ± 11.05	60.31 ± 7.33	44.00 ± 8.05*	<0.001	2.14	Very Large
PAPw (watts)	4415.33 ± 975.98	5059.28 ± 614.11	3449.39 ± 464.32*	<0.001	2.87	Very Large
P:BM (watts/kg)	62.13 ± 9.01	66.54 ± 6.37	55.50 ± 8.54*	0.004	1.52	Large
LBD (kg)	138.15 ± 39.81	157.92 ± 35.21	108.50 ± 26.07*	0.003	1.55	Large
Relative LBD (kg)	1.94 ± 0.44	2.07 ± 0.41	1.74 ± 0.43	0.101	0.79	Moderate
1RM HBD (kg)	127.91 ± 38.07	148.25 ± 34.53	97.40 ± 16.94*	0.001	1.75	Large
Relative HBD (kg)	1.79 ± 0.40	1.94 ± 0.38	1.58 ± 0.34*	0.044	0.99	Moderate

* Significantly (p < 0.05) different from the men.

Table 2. Descriptive characteristics (mean ± SD) for all subjects combined, men and women, for the loaded, unloaded, and tactical deficit (TD) between-sex comparisons vertical jump (VJ), 75-yard pursuit run (75PR), 74.84-kg body drag, and 500-yard run (500R).

Variable	All (*N* = 20)	Males (*n* = 12)	Females (*n* = 8)	*p*	*d*	*d* Strength
Unloaded VJ (cm)	53.79 ± 11.05	60.31 ± 7.33	44.00 ± 8.05*	<0.001	2.14	Very Large
Loaded VJ (cm)	47.04 ± 9.48	52.71 ± 6.72§	38.55 ± 5.96§*	<0.001	2.20	Very Large
TD VJ (%)	12.12 ± 6.61	12.39 ± 6.91	11.71 ± 6.84	0.831	0.10	Trivial
Unloaded 75PR (s)	17.57 ± 1.32	17.02 ± 1.06	18.38 ± 1.30*	0.019	1.17	Large
Loaded 75PR (s)	18.71 ± 1.78	17.97 ± 1.61§	19.81 ± 1.50§*	0.019	1.18	Large
TD 75PR (%)	6.49 ± 5.87	5.57 ± 6.18	7.88 ± 5.46	0.402	0.39	Small
Unloaded Body Drag (s)	6.65 ± 2.55	4.98 ± 0.76	9.16 ± 2.18*	<0.001	2.82	Very Large
Loaded Body Drag (s)	7.17 ± 2.06	5.89 ± 1.08§	9.10 ± 1.65*	<0.001	2.42	Very Large
TD Body Drag (%)	11.46 ± 15.37	18.57 ± 13.86	0.80 ± 11.08*	0.007	1.38	Large
Unloaded 500R (s)	92.89 ± 13.76	85.97 ± 10.39	103.27 ± 11.80*	0.003	1.58	Large
Loaded 500R (s)	104.42 ± 19.55	94.46 ± 12.12§	119.36 ± 19.52§*	0.002	1.61	Large
TD 500R (%)	12.40 ± 11.74	10.44 ± 12.36	15.33 ± 10.86	0.376	0.42	Small

§ Significantly ($p < 0.05$) different from the unloaded condition. * Significantly ($p < 0.05$) different from the men.

Table 3. Pearson's correlations for the tactical deficit (TD) for the vertical jump (VJ), 75-yard pursuit run (75PR), 74.84-kg body drag, and 500-yard run (500R) with the standing broad jump (SBJ), relative SBJ, vertical jump (VJ), peak anaerobic power measured in watts (PAPw), relative PAPw (P:BM), isometric leg/back dynamometer strength (LBD), relative LBD, one-repetition maximum hexagonal bar deadlift (1RM HBD), and relative HBD in male civilians (*n* = 12).

Variables		VJ TD	75PR TD	BD TD	500R TD
SBJ	*r*	0.364	-0.603*	-0.451	-0.207
	p	0.244	0.038	0.141	0.518
Relative SBJ	*r*	0.250	-0.582*	-0.319	-0.131
	p	0.432	0.047	0.312	0.685
VJ	*r*	-0.282	-0.635*	-0.285	-0.279
	p	0.375	0.026	0.369	0.380
PAPw	*r*	-0.104	-0.437	-0.278	-0.233
	p	0.747	0.155	0.381	0.487
P:BM	*r*	-0.284	-0.601*	-0.209	-0.217
	p	0.371	0.039	0.514	0.498
LBD	*r*	0.410	-0.304	-0.244	-0.016
	p	0.185	0.336	0.445	0.962
Relative LBD	*r*	0.376	-0.422	-0.242	-0.030
	p	0.228	0.172	0.448	0.925
1RM HBD	*r*	-0.152	-0.689*	-0.576*	-0.382
	p	0.638	0.013	0.050	0.220
Relative 1RM HBD	*r*	-0.232	-0.838*	-0.618*	-0.429
	p	0.469	0.001	0.032	0.164

* Significant ($p < 0.05$) relationship between the two variables.

For the male participants, there were significant large, negative correlations for the SBJ, relative SBJ, VJ, P:BM, and absolute and relative HBD with the 75PR TD (Table 3). For the body drag TD, there were significant moderate, negative correlations with absolute and relative HBD. These data suggested that stronger and more powerful males had a smaller deficit for the 75PR, and stronger males had a smaller TD for the body drag. For the female participants (Table 4), there was a significant very large, negative correlation between relative SBJ and the VJ TD. This relationship indicated that females who were more powerful relative to their body mass had a smaller deficit for the VJ. There were no other significant relationships between the strength and power tests with the TD for any other tasks.

Table 4. Pearson's correlations for the tactical deficit (TD) for the vertical jump (VJ), 75-yard pursuit run (75PR), 74.84-kg body drag, and 500-yard run (500R) with the standing broad jump (SBJ), relative SBJ, vertical jump (VJ), peak anaerobic power measured in watts (PAPw), relative PAPw (P:BM), isometric leg/back dynamometer strength (LBD), relative LBD, one-repetition maximum hexagonal bar deadlift (1RM HBD), and relative HBD in female civilians (n = 8).

Variables		VJ TD	75PR TD	BD TD	500R TD
SBJ	r	-0.556	0.258	0.029	-0.459
	p	0.152	0.538	0.945	0.253
Relative SBJ	r	-0.727*	0.353	0.232	-0.276
	p	0.041	0.392	0.580	0.508
VJ	r	-0.621	0.082	0.199	-0.440
	p	0.100	0.846	0.636	0.275
PAPw	r	-0.372	-0.120	-0.082	-0.580
	p	0.365	0.776	0.847	0.131
P:BM	r	-0.660	0.081	0.204	-0.417
	p	0.075	0.848	0.628	0.303
LBD	r	-0.306	-0.380	-0.405	-0.195
	p	0.461	0.353	0.319	0.643
Relative LBD	r	-0.500	-0.216	-0.204	-0.144
	p	0.207	0.607	0.628	0.734
1RM HBD	r	-0.206	0.548	0.442	-0.148
	p	0.624	0.159	0.273	0.727
Relative 1RM HBD	r	-0.406	0.537	0.508	-0.049
	p	0.318	0.170	0.199	0.908

* Significant (p < 0.05) relationship between the two variables.

DISCUSSION

The goal of this study was to ascertain whether lower-body dynamic and isometric strength or power could attenuate TD (i.e., performance decrement due to PPE load carriage) within law enforcement-specific tasks. It was initially hypothesized that men would be stronger and more powerful compared to women in this sample. In support of other studies documenting between-sex differences in law enforcement-specific fitness tests (19, 22, 23), this hypothesis was proven correct. However, there were no differences between the sexes regarding the TD, even though the males had a higher absolute PPE load, while the females had a higher relative PPE load. This may be indicative of the load of PPE affecting both sexes similarly. It was then hypothesized that performance in the VJ, 75PR, 74.84-kg body drag, and 500-yard run would decrease when performed under load. Similar to other studies (6, 7, 13, 34), this hypothesis was generally found to be correct. The only task where the PPE did not appear to have a significant impact was for the 74.84-kg body drag performed by women. It was lastly hypothesized that stronger, more powerful participants would perform better in police job tasks while under load (i.e., a smaller TD). In contrast to the hypothesis, the majority of relationships between strength and power with TDs were not significant. However, there were select significant relationships. For men, absolute and relative SBJ, VJ, P:BM, and absolute and relative 1RM HBD related to the 75PR TD. Absolute and relative HBD significantly related with the 74.84-kg body drag TD. For women, relative SBJ had a significant relationship to the VJ TD. Although preliminary, the significant relationships have implications for how PPE could alter job task performance and how select strength and power characteristics could mitigate certain TDs.

Both men and women in this study had better unloaded VJ performance when compared to another study that utilized the VJ to assess lower-body power in a civilians (males: 60.31 ± 7.33 cm vs 58.90 ± 10.60 cm; females: 44.00 ± 8.05 cm vs 40.59 ± 7.77 cm) (31). There were no significant relationships between the VJ TD with any of the strength and power tests for the men. The VJ was used in lieu of more dynamic law enforcement tasks that require vertical power, such as a wall climb (23, 30). It is possible that a more complex task could have exhibited different relationships between TD and strength and power if PPE was worn during the climb. However, specifically for women, there was a significant relationship between relative SBJ and VJ TD. These data suggested that women in this study who had a greater relative SBJ had a smaller decrement in performance when under load during the VJ. SBJ and VJ both utilize the stretch shortening cycle necessary to complete jumping movements (37). These similarities could somewhat explain the relationship between the relative SBJ and VJ TD. Additionally, the females in this study had better relative SBJ performance than a previous study using absolute SBJ (174.87 ± 26.32 cm vs 162 ± 28 cm) in a civilian population (31). The current results suggest that the females in this study may have had the necessary relative lower-body power to aid in attenuating the TD for the VJ. The results from this preliminary analysis may suggest that female personnel who develop greater relative lower-body power could attenuate some of the PPE impacts on an explosive task, such as a VJ. Noting these findings and considering that both VJ and SBJ performance decreased when wearing PPE, the data presented here further supports the development of lower-limb power for women during law enforcement training (23).

Select power (SBJ, relative SBJ, VJ, and P:BM) and strength measures (absolute and relative 1RM HBD) showed moderate-to-large negative relationships to the 75PR TD in the men. These data suggest that men who had higher levels of dynamic strength and power had a smaller decrement in performance for change-of-direction speed task (i.e., 75PR) when PPE was added. Underlying physical characteristics that are necessary for faster performance in the 75PR are strength and power (31). Post et al. (31) found that relative lower-body strength (as measured by an isometric mid-thigh pull) and power (as measured by VJ and SBJ) had large, negative relationships to the 75PR (r = -0.41 to -0.66). It could be suggested that men who possess higher levels of dynamic strength (as measured by absolute and relative HBDL) and power (as measured by SBJ, relative SBJ, VJ, and P:BM) could have a smaller TD in change-of-direction job tasks, such as a foot pursuit. This is important when put into context of officers needing to accelerate, decelerate, change direction, and/or sustain running speed in order to pursue suspects. Thus, lower-limb strength and power development could not just benefit job task performance in male personnel (4, 5, 24), but could also improve their ability to maneuver while running and wearing PPE.

For females, there were no relationships shown between strength and power measures and the 75PR TD. When compared to other studies that have utilized the HBD (17), females in this study had poorer absolute (109.94 ± 22.35 kg vs 97.40 ± 16.94 kg) and relative (1.70 ± 0.38 kg/kg vs 1.57

± 0.34 kg/kg) strength levels. The women in the current sample may not have been strong enough to attenuate the effects of PPE load during the 75PR. Future studies should utilize a greater sample of females, and include stronger females than those in this study, in an attempt to see if greater strength and power could attenuate TD in change-of-direction speed tasks such as the 75PR.

A body drag is an essential job task for law enforcement officers (15, 19, 27). Males in this study were faster (4.97 ± 0.76 s vs. 5.71 ± 1.64 s), and females (9.16 ± 2.18 s vs 7.38 ± 1.87 s) were slower, than that of a previous study that investigated 74.84-kg body drag performance (17). Interestingly, females showed no significant differences in BD performance between the unloaded and loaded conditions. As the females performed the BD slower in this study compared to that from Lockie et al. (17), this could partially explain the lack of difference between the unloaded and loaded conditions. Additionally for women, there were no significant relationships between strength and power measures and the 74.84-kg body drag TD. The lack significance could in part be due to the females in this study being weaker (17) and not as powerful (21) than previous women in the literature. Females that completed a 1RM HBD in a study by Lockie et al. (17) lifted more than the females in the current study (109.94 ± 22.35 kg vs 97.40 ± 16.94 kg). Additionally, female law enforcement recruits had higher VJ PAPw compared to females in this study (3505.64 ± 920.81 watts vs 3449.39 ± 464.32 watts) (21). The women in this study may have found the 74.84-kg body drag difficult regardless of the presence of PPE as the body drag requires greater absolute strength (i.e., moving the dummy) than relative strength (i.e., wearing the PPE) (29) and impacts shorter and lighter individuals to a greater extent (22), making them slower in completion times in either condition. Even with the small sample in the current study, these data emphasize the need for absolute strength development in women to perform physically-demanding policing job tasks, such as body drags.

The data for the men indicated a negative correlation with absolute and relative 1RM HBD with the 74.84-kg body drag TD. Interestingly, absolute and relative LBD had no significant relationships with the BD TD, which could suggest that in the current sample dynamic strength influenced dragging performance more than isometric strength. Nonetheless, men who had higher absolute and relative dynamic strength tended have a smaller TD when needing to move the absolute mass in the 74.84-kg body drag. Lockie et al. (17) found that absolute (r = -0.666) and relative (r = -0.619) strength correlated to two separate body drags (74.84 kg and 90.72 kg dummies) in recreationally-trained males and females, which was a similar population to this study. Likewise in male specialist police, Orr et al. (29) reported correlations between absolute (r = 0.747) and relative (r = 0.568) deadlift strength and an 85-kg dummy drag. Noting that in both of the latter mentioned studies, absolute strength was more strongly correlated than relative strength, this could partially explain why, in this study absolute strength was significantly correlated to the body drag TD while relative strength was not. Again, noting the overall significant decrease in BD time with PPE. This may suggest that officers with higher levels of absolute strength may not only be able to move an absolute mass (i.e. moving a body to safety) more efficiently (18, 24), but they could also be able to do so while tolerating the additional load of PPE.

There were no relationships established between strength and power measures and the 500-yard run TD for either sex. PPE impedes mobility (6) and gait kinematics (32) which could decrease running efficiency (13). Nevertheless, the lack of significant findings from this study relative to TD could be due to the 500-yard run being a more aerobically-based task (15), which may limit the influence that strength and power have on TD during an extended run. Lockie et al. (15) found that law enforcement recruits who possessed greater muscular endurance (i.e., push-ups, sit-ups, mountain climbers, and pull-ups) performed better in the 500-yard run. However, none of these tests are traditional measures of maximal strength and power, such as those used in this study. Even so, law enforcement officers should be cognizant that PPE will lead to an increase in fatigue and make them slower (6), regardless of the resulting TD. Officers should ensure they optimize their fitness to the best of their ability, with the knowledge that wearing their PPE will make their job tasks more difficult.

There are research limitations that require discussion. Actual law enforcement personnel were not recruited for this study due to variability in work schedules making it difficult to complete a multiple-day study and to prevent possible injury that could prevent them from working. Again, the use of civilian participants has been done in previous tactical research (18, 36, 39), so there is value to the current results. Nonetheless, law enforcement recruits or officers may have more experience with load carriage and the PPE, which could affect the strength and power relationships with the TDs for the different job tasks. If possible, it could be beneficial to replicate this study with law enforcement personnel. Further, the participants in this study were relatively young (~23 years of age), and older officers may not have the same job task performance metrics or TDs when compared to the study participants. Future studies could investigate the strength and power relationships with the TD from police tasks in older, career officers. The sample size was relatively small (*N* = 20; 12 men, 8 women), and this could have influenced the results. Regardless, there have been studies with similar sample size numbers that have found similar results to the current research (12, 32, 35). Future research could replicate the current research with more participants. Another limitation was not using some of the actual policing items (i.e., pepper spray, flashlight, magazines, etc.) and the replicated items not being perfectly scaled to actual weight of the original policing items. Actual equipment was not able to be used given that they were to be carried by civilian participants on a college campus. Nonetheless, the overall weight of the PPE implemented in this study still coincided with that of mandated PPE load of officers (~8-10 kg) (2, 12). However, it should also be noted that the PPE worn by participants in this study is not necessarily exactly representative of what is required for every officer across the more than 17,000 different law enforcement agencies, as all agencies individually determine the authorized PPE worn by their personnel. Agencies should assess the impact their specific PPE has on the TD for their personnel during occupational tasks.

In conclusion, higher levels of absolute and relative power (i.e., SBJ, relative SBJ, VJ, and P:BM) and dynamic strength (i.e., HBD and relative HBDL) resulted in a smaller 75PR TD for males. Additionally, higher absolute and relative dynamic strength also resulted to smaller 74.84-kg body drag TD for males. For females, the relative SBJ related to a smaller VJ TD. These results together suggest that while being essential to job task performance, dynamic strength and power could also aid in mitigating TD for the VJ for women, and 75PR and 74.84-kg body drag for men.

It should be noted that these results were influenced by the physical capacities of the participants in this study (e.g., the females in this study were relatively weaker compared to similar populations). When extrapolated to police populations, the current results could affect officer safety in the field. Females, in general, are at a physical disadvantage compared to males both with and without the presence of PPE. The data from this study provides further support to the need for law enforcement personnel to increase strength and power to successfully complete police job tasks, especially while wearing mandated PPE.

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