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Analyzing the Training Load Demands, and Influence of Sex and Body Mass, on the Tactical Task of a Casualty Drag via Surface Electromyography Wearable Technology

ROBERT G. LOCKIE‡1, MATTHEW R. MORENO†1, SPENCER C. DUCHENY†1, ROBIN M. ORR‡2, J. JAY DAWES‡3, KATHERINE BALFANY‡4,5

[1]Center for Sport Performance, Department of Kinesiology, California State University-Fullerton, Fullerton, CA, 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]Athos, dba Mad Apparel, Redwood City, CA, USA; [5]Department of Physical Medicine and Rehabilitation, University of Colorado-Anschutz Medical Campus, Aurora, CO, USA

†Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 13(4): 1012-1027, 2020. This study measured the training load (TL) demands associated with a military-specific casualty drag measured via surface electromyography (sEMG) wearable technology, and the influence of sex and body mass on these measures. Thirty-six college-aged participants (males = 25; females = 11) performed two trials of a 123-kg (91-kg dummy with 32-kg load) backwards casualty drag over 15 m. Time was recorded to calculate drag velocity, with the fastest trial analyzed. Prior to testing, participants were fitted with compression garments embedded with sensors to measure the vastus lateralis and medialis (quadriceps; QUAD), biceps femoris (BF), and gluteus maximus (GM) of both legs. The sEMG signal for each muscle was measured as a percentage of maximal voluntary contraction to calculate TL. The variables included TL (total, QUAD, BF, GM), and between-muscle ratios. The sample was also ranked and median split via body mass into heavier and lighter groups. Independent samples t-tests calculated differences between drag velocity and TL for the sex and body mass groups. Pearson's correlations calculated relationships between body mass and velocity with the TL variables (combined, males, females). Females and lighter participants experienced greater TL compared to males and heavier participants, respectively ($p < 0.01$). A slower drag velocity correlated with a greater total and QUAD TL for all participants, males, and females ($p \leq 0.03$, r = -0.65--0.80). Performing a slower casualty drag will increase TL demands, predominantly via QUAD stress. Training staff should develop the muscles important for the drag, especially for females and lighter males.

KEY WORDS: Army; body drag; EMG; military; tactical athlete; victim drag

INTRODUCTION

A soldier may need to complete a range of physically demanding tasks when they are deployed. These tasks can include moving under fire, carrying equipment, transferring ammunition, and casualty evacuation (15). A casualty drag is especially challenging, and this task involves dragging a fellow soldier from a hazardous environment to a safe location as quickly as possible. Due to the average body mass of soldiers and the combat loads they have to carry, when this task is simulated in training, the mass of the 'casualty' (a dummy suited with combat gear) can weigh 123 kg (91 kg dummy plus an additional 32 kg of gear) (9, 15). Performing a drag with this load has been found to stress an individual's strength and ability to produce force (9, 37, 42). Previous research has shown that maximal strength measured by the one-repetition back squat correlated with the time to drag a 79.5-kg dummy 10 m in Army Reserve Officer Training Corps and civilian university students (42). Lockie et al. (36) found that a greater 1RM hexagonal bar deadlift related to a faster time to drag 74.84-kg and 90.72-kg dummies over 9.75 m in civilian university students. As such, it can be surmised that an individual's ability to recruit appropriate muscles to produce force should relate to a more effective backwards casualty drag.

Accordingly, it is important that the ability to recruit appropriate muscles and produce force is developed during training, and monitored to ensure an appropriate training load (TL) is applied to the individual. TL is the stress placed on the body by the performed activity, and it is important to understand how the individual responds (via internal TL) to the imposed stress (32). Internal TL incorporates the psychophysiological responses occurring during the execution of an exercise (27). One example of internal load that could be measured relative to the stress imposed during a task such as the casualty drag is muscle activation via surface electromyography (sEMG). The use of sEMG can provide an indication of the relationship between muscle activation and force output during a particular action, information about movement strategy via muscle activation patterns (49), and more recently, TL (11, 41).

The measurement of TL in military tasks has become an important avenue of research and practical application in recent years, due to the physical challenges associated with training and the required job tasks. Indeed, initial entry training for a soldier is designed to mentally and physically prepare trainees for the military environment (52). As a result of the demands of initial entry training, many military organizations have started to use methods and technology more frequently associated with elite sport (18, 22). The integration between these processes has been done to ensure trainees experience the appropriate load to attain the desired adaptations during training, and to reduce the occurrence of injuries (31). The challenge for military populations is finding technology that can be used when in physical training attire or in uniform that can directly measure specific military tasks when performed in the field. One example of emerging technology that could viably have practical application in the military is sEMG wearable technology. This type of system evaluates activation and recruitment patterns of muscles during physical activity, and can use these measurements as an indicator of TL (11, 41). This would appear to have considerable value for military populations, as sEMG wearable technology can be worn under physical training attire or uniforms during training, and could be used to ascertain the TL demands and movement strategy via muscle recruitment patterns of specific tasks such as the casualty drag.

Moreover, if research indicates the value of using sEMG wearable technology during military tasks such as the casualty drag, this could inform future research studies into military task analysis. For example, previous research has indicated differences between the sexes in the TL experienced during basic military training as measured via other methods (rating of perceived exertion and heart rate) (47), and lower-body muscle ratios (e.g. quadriceps-hamstrings) in strength exercises (24). There could be specific differences between the sexes in TL and between-muscle ratios when performing the casualty drag. However, any TL differences between males and females in the casualty drag may not be purely due to sex. As females are generally smaller in stature than males (19), and dragging tasks relate to absolute strength (36, 42), the mass of the individual could be a distinguishing factor in the performance and stress experienced in the casualty drag. This analysis is pertinent given the potential implications of body mass to the performance of military tasks (17, 21, 55).

Therefore, the purpose of this study was to determine the TL demands and between-muscle ratios of a 15-m casualty drag with a 123-kg dummy using sEMG wearable technology. The 15-m drag distance was utilized as it has featured in previous military-specific research (9, 15). Casualty drag performance and the associated TL demands were analyzed relative to the sex and body mass of participants. Similar to previous research (36, 42, 46, 54, 57), college-aged, physically active men and women without previous military training were used as the sample population. It was hypothesized that TL would increase concurrently with the time needed to perform the casualty drag. Furthermore, it was hypothesized that females and smaller individuals, would experience a greater TL than males and heavier individuals, respectively.

METHODS

Participants

A convenience sample of 36 participants (age = 25.03 ± 3.62 years; height = 1.74 ± 0.10 m; body mass = 82.49 ± 20.92 kg), including 25 males (age = 25.16 ± 3.87 years; height = 1.78 ± 0.09 m; body mass = 88.93 ± 21.59 kg) and 11 females (age = 24.73 ± 3.13 years; height = 1.66 ± 0.08 m; body mass = 67.86 ± 8.58 kg) volunteered to participate in this study. The males and females in this study were of similar age and height to active-duty soldiers analyzed in the literature (9, 15), but were heavier than recruits at the start of basic training and active-duty soldiers (9, 15, 53, 59). Participants were recruited from the student population at the university via information sessions and word-of-mouth on campus. Similar to previous research, physically active and healthy volunteers were used as surrogates for a tactical population (36, 42, 46, 54, 57). The recruitment of civilians allowed for a proportion of males and females with different physical capabilities to be recruited (54). Additionally, previous research has demonstrated minimal learning effects with the casualty drag (15), which means that even for participants who were not active-duty soldiers, they should perform the casualty drag with consistency across trials. This was important, because for consistency no participant had been previously involved with any form of military or tactical training. Participants self-reported whether they completed the minimum recommended physical activity guidelines for cardiorespiratory and musculoskeletal fitness for adults as detailed by the American College of Sports Medicine (20). Participants were required to be free from any musculoskeletal disorders that could influence study participation (36). G*Power software (v3.1.9.2, Universität Kiel, Germany) confirmed post hoc that the sample size of 36 was sufficient for a correlation, point biserial model, and ensured the data could be interpreted with a moderate effect level of 0.44 (26), and a power level of 0.81 when significance was set at 0.05 (14). The institutional review board approved the study (HSR-18-19-586), all participants received a clear explanation of the procedures. This included the risks and benefits of participation, and written informed consent was obtained. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (44), and the recommendations of the Declaration of Helsinki (58).

Protocol

One testing session was used for this study, and testing was conducted at the university. The participant signed the informed consent form and had their age, body height, and mass recorded. Participants were barefoot when they had their height and body mass measured. Body height was measured using a portable stadiometer (Detecto, Webb City, MO, USA), while body mass was recorded by electronic digital scales (Ohaus, Parsippany, NJ, USA). A thin-line metric tape measure (Lufkin, Apex Tool Group, Maryland) was used to measure waist and hip circumference to determine the size for the sEMG wearable technology (Athos, Redwood City, California). Waist circumference was measured in cm at the narrowest part of the waist just superior to the naval (48). Hip circumference was measured at the greatest posterior extension of the hip (48). Participants were then fitted with the appropriate garments. Males wore compression shorts, and females wore leggings. The shorts and leggings were each embedded with sEMG sensors that measured the vastus medialis (VM) and vastus lateralis (VL), biceps femoris (BF), and gluteus maximus (GM) for each leg. The sensors provided a bipolar differential sEMG measurement with an inter-electrode distance of 2.1 cm and were comprised of a conductive polymer. No skin or electrode preparation was performed at the site corresponding to each electrode as it aligned with recommended product usage (41). Participants then completed a standard dynamic warm-up, which involved cycling for 5 minutes at a self-selected intensity on a bicycle ergometer (Assault Fitness, Carlsbad, California), before completing ~10 minutes of full-body dynamic stretching.

After the warm-up, participants completed maximum voluntary isometric contraction (MVIC) assessments via manual muscle testing for each leg which was used to normalize the sEMG data (1, 2, 6). This followed manufacturer guidelines to ensure practicality of use for the technology. Furthermore, internal testing within the laboratory demonstrated that this normalization procedure for all muscles displayed similar results to MVICs performed on an isokinetic dynamometer ($r > 0.8$, $p < 0.01$) (2). To measure the quadriceps (QUAD; VM+VL) MVIC, participants sat on a table with their knees bent to 90°. The participant tried to extend the knee with maximal force while the researcher applied maximal resistance just above the ankle. To measure the BF MVIC, the participant lay prone on the table with the measured leg flexed at the knee to 90°. The researcher provided maximal resistance, pulling the shank away from participant as the participant simultaneously pulled their foot toward their buttocks. The participant stayed in the same position to measure the GM MVIC. The researcher provided maximal force downward on the participant's foot as the participant extended at the hip to drive the heel up. The participant performed three repetitions of each MVIC trial for 5 seconds each, with 60 seconds rest between trials (2).

All sEMG data was transmitted via Bluetooth technology embedded in a core that sat in the shorts or leggings. Data was sent to an iOS device (Apple Inc., Cupertino, California) with the software application where pre-programmed sessions logged the data. The technology processed the data independently and distributed a measurement of TL for combined muscle groups and a measure of integrated EMG (area under the curve of the rectified EMG signal). The integrated EMG for each muscle was measured as a percentage of MVIC and when combined, calculated the TL for the muscles. TL metrics were reported as arbitrary units (AU); a single 'AU' was equivalent to one muscle activating at 100% of the MVIC for one second. The variables included: QUAD, BF, GM, and total TL; and muscle ratios (QUAD:BF, GM:BF, and anterior-to-posterior [A:P; QUAD:BF+GM]).

After the MVICs had been conducted, the participants then completed the casualty drag. All drag trials were performed on a polished wooden floor, with adhesive tape marking the start and finish lines for the 15-m dragging distance. Prior to performing the 123-kg casualty drag, participants completed a warm-up 15-m drag with a 75-kg dummy. Two trials were then completed for the 123-kg casualty drag, with five minutes rest provided between trials. The methods for the casualty drag were adapted from Foulis et al. (15). A 91-kg dummy (Dummies Unlimited, Pomona, California), with 32 kg of additional load via a weighted vest (5.11 Tactical, Irvine, California) and weight bags (Dummies Unlimited, Pomona, California) to provide a total load of 123 kg, was used for the casualty drag. The dummy was placed lying on the ground, and participants were positioned on the start line. Grabbing the handles on the vest, the participants dragged the dummy backwards as quickly as possible over the required 15-m distance. Time was recorded via stopwatch by a researcher trained in the use of stopwatch procedures (36, 37, 40, 43) with data captured via this method known to be reliable (23). Timing was initiated from the first movement of the participant, and timing stopped when the feet of the participant passed the finish line. Similar to the methods of Foulis et al. (15), if participants were unable to drag the dummy 15-m in 30 seconds, the distance that the dummy was dragged was measured. However, all participants were able to complete their casualty drag trials within 30 seconds. Velocity was calculated for the casualty drag by dividing the distance covered by the time taken to cover this distance (15, 43), and was measured in meters per second (m/s). The wearable technology recorded data for the duration of all casualty drags.

Statistical Analysis

All statistical analyses were computed using the Statistics Package for Social Sciences (Version 26.0; IBM Corporation, New York, USA). Descriptive statistics (mean ± standard deviation [SD]) were calculated for each variable. The sample was split into male (n = 25) and female (n = 11) groups, and the total sample was also ranked in body mass and median split into heavier (n = 18) and lighter (n = 18) groups. This median split approach has been used in previous studies (7, 39). Independent samples t-tests ($p < 0.05$) were used to compare the male and female groups, and the lighter and heavier groups, in age, height, body mass, casualty drag velocity and the TL variables. Effect sizes (Cohen's *d*) for the between-sex and between-body mass group comparisons were also calculated from the difference between the means divided by the pooled standard deviations (12). 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 (26). Pearson's correlations were used to determine relationships between body mass and casualty drag velocity with the TL variables ($p < 0.05$). The total sample was analyzed, and then the sexes were analyzed separately. The correlation strength was designated as: an r between 0 to ±0.3 was considered 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 (25). Stepwise linear regression analyses ($p < 0.05$) were conducted for casualty drag velocity and TL with sex and body mass as covariates. Similar to previous research, this approach was done due to the exploratory nature of this section of the analyses (37). Lastly, scatter plots were also produced in Microsoft Excel (Microsoft Corporation™, Redmond, Washington, USA) for select variable pairs for further relationship analyses.

RESULTS

For the between-sex comparisons (Table 1), equal variances were assumed for all variables except for GM TL. Males were taller and heavier, and performed the casualty drag faster than females. Females had a greater TL for total, QUAD, BF, and GM, and there were no significant between-sex differences in the muscle ratios. All differences in TL had large effects. When the sample was split into heavier and lighter groups (Table 2), there were 17 males and one female in the heavier group. Eight males and 10 females were placed in the lighter group. For the between-body mass group comparisons, equal variances were assumed for all variables except total TL, QUAD TL, GM TL, and QUAD-BF. The heavier group were taller, heavier (as expected), and performed the casualty drag faster. The lighter group experienced a greater total TL, QUAD TL, and GM TL. These three TL differences, in addition to the non-significant difference for BF TL, had moderate effects.

Table 1. Descriptive data (mean ± SD) for civilian males and females in age, height, body mass, casualty drag velocity, TL (total, QUAD, BF, and GM), and muscle ratios (QUAD:BF, GM:BF, and A:P).

	Males (*n* = 25)	Females (*n* = 11)	*p*	*d*	*d* strength
Age (years)	25.16 ± 3.87	24.73 ± 3.13	0.75	0.12	Trivial
Height (m)	1.78 ± 0.09	1.66 ± 0.08*	<0.01	1.41	Large
Body Mass (kg)	88.93 ± 21.59	67.86 ± 8.58*	<0.01	1.28	Large
Velocity (m/s)	1.49 ± 0.26	0.83 ± 0.16*	<0.01	3.06	Very Large
Total TL (AU)	56.01 ± 15.30	94.73 ± 27.84*	<0.01	1.72	Large
QUAD TL (AU)	27.23 ± 9.65	44.37 ± 14.82*	<0.01	1.37	Large
BF TL (AU)	16.82 ± 8.03	29.54 ± 11.27*	<0.01	1.30	Large
GM TL (AU)	11.96 ± 4.32	20.82 ± 7.34*	<0.01	1.47	Large
QUAD:BF	1.07 ± 0.80	0.92 ± 0.58	0.57	0.21	Small
GM:BF	0.88 ± 0.58	0.76 ± 0.32	0.53	0.26	Small
A:P	0.97 ± 0.40	0.91 ± 0.25	0.64	0.18	Trivial

* Significantly ($p < 0.05$) different from the males.

Table 2. Descriptive data (mean ± SD) for civilian males and females median split into heavier and lighter groups in age, height, body mass, casualty drag velocity, TL (total, QUAD, BF, and GM), and muscle ratios (QUAD:BF, GM:BF, and A:P).

	Heavier (*n* = 18)	Lighter (*n* = 18)	*p*	*d*	*d* strength
Age (years)	25.72 ± 4.34	24.33 ± 2.68	0.26	0.39	Small
Height (m)	1.79 ± 0.09	1.70 ± 0.09*	<0.01	1.00	Moderate
Body Mass (kg)	94.88 ± 22.64	70.11 ± 7.97*	<0.01	1.46	Large
Velocity (m/s)	1.52 ± 0.29	1.06 ± 0.32*	<0.01	1.51	Large
Total TL (AU)	55.43 ± 13.20	80.25 ± 30.98*	<0.01	1.04	Moderate
QUAD TL (AU)	25.97 ± 6.82	38.97 ± 16.02*	<0.01	1.06	Moderate
BF TL (AU)	17.57 ± 8.48	23.85 ± 12.06	0.08	0.60	Moderate
GM TL (AU)	11.90 ± 3.42	17.44 ± 8.09*	0.01	0.89	Moderate
QUAD:BF	0.90 ± 0.65	1.16 ± 0.98	0.30	0.31	Small
GM:BF	0.78 ± 0.33	0.90 ± 0.65	0.48	0.23	Small
A:P	0.92 ± 0.26	0.99 ± 0.44	0.60	0.19	Trivial

* Significantly ($p < 0.05$) different from the heavier group.

When all participants were pooled in the correlation analysis (Table 3), body mass significantly related to casualty drag velocity (large relationship), total TL, QUAD TL, and GM TL (all moderate relationships). These correlations indicated that a greater body mass related to a faster velocity and lower TL. When considering casualty drag velocity relationships for all participants, a faster velocity related to lower total TL, QUAD TL (both very large relationships), BF TL, and GM TL (both large relationships). For the male and female analyses, there were no significant relationships between body mass with casualty drag velocity and the TL variables. There were significant relationships between casualty drag velocity and total and QUAD TL. For both males and females, a faster velocity related to a lower TL, and strength of these relationships were large-to-very large. There were no significant correlations for the ratios.

Table 3: Correlations between body mass and casualty drag velocity with TL (total, QUAD, BF, and GM) and muscle ratios (QUAD:BF, GM:BF, and A:P) in civilian males and females.

		All Participants (n = 36)		Males (n = 25)		Females (n = 11)	
		Body Mass	Velocity	Body Mass	Velocity	Body Mass	Velocity
Velocity	r	0.52*	-	0.34	-	-0.29	-
	p	<0.01		0.10		0.39	
Total TL	r	-0.38*	-0.80*	-0.15	-0.65*	0.01	-0.66*
	p	0.02	<0.01	0.48	<0.01	0.97	0.03
QUAD TL	r	-0.37*	-0.78*	-0.24	-0.68*	0.17	-0.73*
	p	0.03	<0.01	0.26	<0.01	0.62	0.01
BF TL	r	-0.18	-0.58*	0.17	-0.28	-0.12	-0.35
	p	0.29	<0.01	0.41	0.18	0.73	0.30
GM TL	r	-0.45*	-0.64*	-0.32	-0.26	-0.11	-0.52
	p	0.01	<0.01	0.12	0.21	0.76	0.10
QUAD:BF	r	-0.19	-0.13	-0.33	-0.34	0.18	-0.39
	p	0.26	0.45	0.10	0.96	0.60	0.24
GM:BF	r	-0.19	-0.05	-0.32	-0.21	0.15	-0.34
	p	0.27	0.78	0.13	0.33	0.66	0.31
A:P	r	-0.08	-0.09	-0.18	-0.25	0.36	-0.31
	p	0.65	0.59	0.38	0.22	0.28	0.35

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

For the regression analyses, only sex was involved in the predictive relationships for casualty drag velocity (r = 0.80, r^2 = 0.64, p < 0.01), total TL (r = 0.68, r^2 = 0.46, p < 0.01), QUAD TL (r = 0.58, r^2 = 0.34, p < 0.01), BF TL (r = 0.55, r^2 = 0.31, p < 0.01), and GM TL (r = 0.62, r^2 = 0.38, p < 0.01). Nevertheless, scatter plots were produced to further investigate the relationships between casualty drag velocity and body mass for the males and females relative to total and QUAD TL (as these two TL variables had the most significant relationships). The scatter plots for casualty drag velocity are shown in Figure 1; Figure 2 displays the plots for body mass. Within both figures, it can be seen that males are generally pooled towards the right (faster drag velocity and greater body mass, respectively). However, in Figure 1 there are faster females that experienced a lesser total and QUAD TL compared to slower males. Additionally, Figure 2 shows that there are certain heavier females that experienced a lesser total and QUAD TL than lighter males.

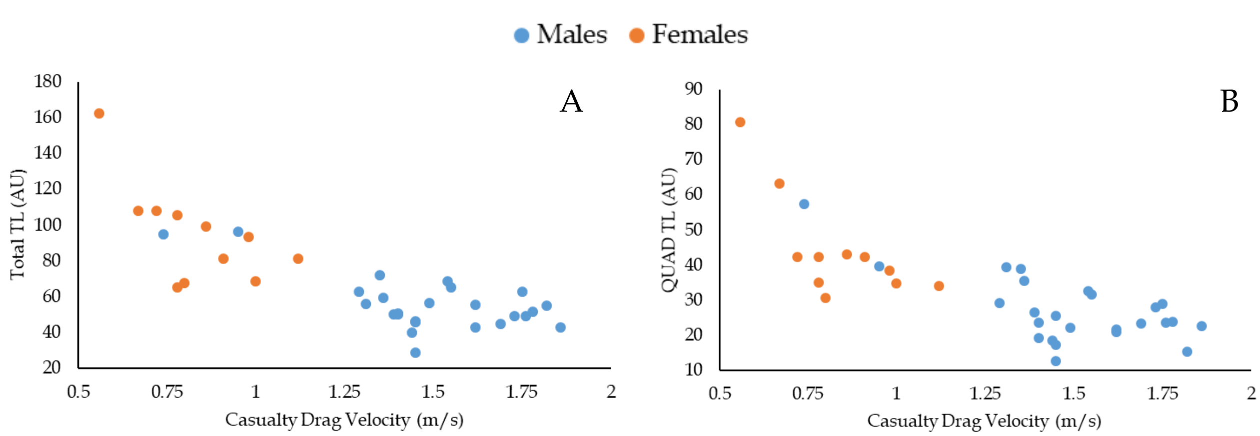

Figure 1. Scatter plots depicting the relationship between velocity with total (A) and QUAD (B) TL for the casualty drag in civilian males (n = 25) and females (n = 11).

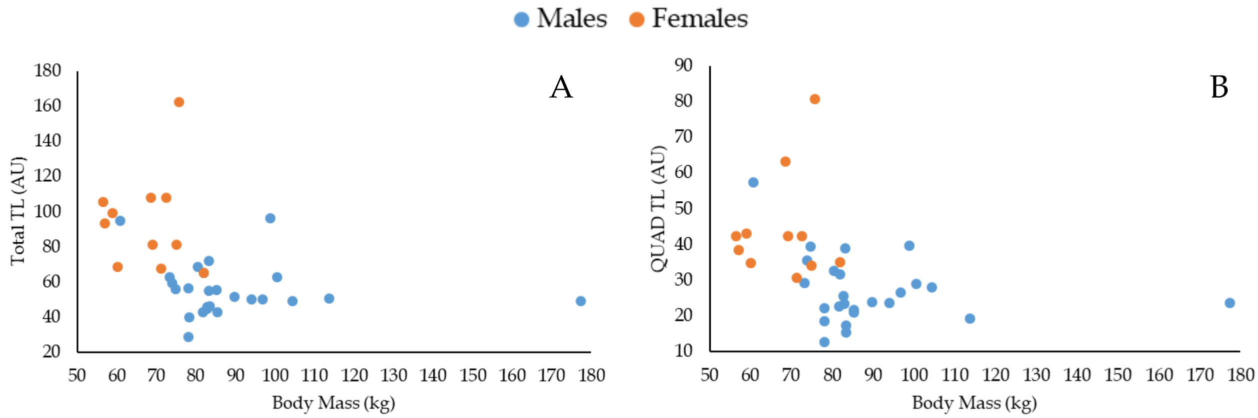

Figure 2. Scatter plots depicting the relationship between body mass with total (A) and QUAD (B) TL for the casualty drag in civilian males (n = 25) and females (n = 11).

DISCUSSION

This study investigated the TL demands and between-muscle ratios of a 15-m casualty drag with a 123-kg dummy using sEMG wearable technology. The analysis was conducted relative to the sex and body mass of participants. As was hypothesized, males performed the casualty drag faster than females, and experienced lesser TL as measured by sEMG wearable technology. However, when considering the body mass results, it may not be the sex of the individual that influences the TL experienced during the casualty drag but rather body mass as lighter males and females experienced a greater TL compared to their heavier counterparts. Given that females are generally lighter than males, discerning which of these two factors has the greatest influence on the task. As such, using sEMG wearable technology to measure a tactical task such as the casualty drag, and some potential application in basic training for military populations may better inform training requirements as opposed to considerations of sex and body mass alone.

As stated, the females experienced a significantly greater TL (total, QUAD, BF, and GM) during the casualty drag compared to males. This was expected, especially considering the physiological differences between men and women relative to muscle mass, and overall body mass (3, 28). Body mass was not equated between the males and females in order to show actual differences between the sexes in the casualty drag, and no individual can change their mass when performing this task. Several studies have indicated the males generally perform better than females in fitness-related tasks for law enforcement (4, 10, 38), firefighter (5), and military (51, 56, 59) populations. This study supported these findings. The data from the current study also has potential implications for basic training in military populations, with females often times at greater risk of injury due to higher experienced TL (30, 35, 47). The sEMG wearable technology clearly showed greater muscle TL for females compared to males for the same task. Furthermore, the regression analyses indicated that sex predicted total TL (explained variance = 64%), QUAD TL (explained variance = 34%), BF TL (explained variance = 31%), and GM TL (explained variance = 38%). In accordance with the existing research (30, 35, 47), and with the TL data from this study, females who aim to enter the military should ensure they develop their strength and physical conditioning to the best of their ability. Nindl (45) has provided a detailed review of literature as to what should be the training foci of females entering the military. Furthermore, the appropriate application of training modalities (e.g. resistance training, aerobic conditioning) and load over a 24-week period can improve the strength, muscular endurance, and aerobic capacity of females specific to military tasks such as a maximal lift, repetitive lift, and ruck march (46). This is vital considering many females will enter the military service at a physical disadvantage relative to males (30, 35, 47, 51, 56, 59). However, any inherent sex differences may not completely explain these findings. Indeed, there were some individual female participants, typically those who were faster in the casualty drag or who were heavier, that did not experience a greater total and QUAD TL compared to some of the males. This could be related to the previous training history of these females; greater strength measured by a maximal hexagonal bar deadlift has been related to a faster 9.75-m drag with 74.84-kg and 90.72-kg dummies in college-aged men and women (36). Additionally, heavier females could have body mass advantages in completing the casualty drag.

Greater body mass can be advantageous to the performance of military-specific tasks, especially those that require absolute strength (e.g. lifting, carrying, and dragging tasks) (21, 55). Greater body mass also means individuals will generally generate more ground reaction force during gait (16), which could also influence the ability to generate force during a dragging task. In accordance with this, body mass was also analyzed in this study. The lighter group, which included eight males and 10 females, experienced a greater TL (total, QUAD, BF, and GM) compared to the heavier group. Absolute strength is important for backwards dragging tasks (36, 42), as individuals are attempting to move fixed loads. Although body mass did not predict casualty drag TL, larger individuals would likely be more efficient when performing the backwards casualty drag. This is notable, as a decrease in the internal load experienced during a casualty drag would be important if a soldier needs to perform other tasks in succession, such as moving under fire and seeking cover. There was one participant in this study that was much heavier than other participants (Figure 2), but their data was kept as a means to demonstrate the value of body mass when performing a drag. Nonetheless, it is acknowledged that active-duty soldiers are much smaller than this individual (9, 15), because they must also be able to perform other tasks (e.g. ruck marches, movement under fire) for which greater body mass would be less advantageous. Given the importance of the casualty drag if it needs to be performed in the field (9, 15), females and lighter men should perform absolute strength training that would help them become as efficient as possible in this task. This would be especially important for females, given that they are generally smaller in stature and mass compared to males (3, 28). This should ideally reduce the TL demands of any dragging activities they may need to perform, providing the soldier with a reserve for other important tactical tasks during training or deployment. Nonetheless, it should be noted that body mass could always be a limiting factor when performing a casualty drag, even if the individual is completing strength training. As a result, strength training must be a focus of smaller individuals, as they have the physical disadvantage of lighter body mass.

A novel aspect to this study was the use of sEMG wearable technology to measure the demands of the casualty drag. This is pertinent, given the need for military populations to use appropriate technology to monitor the performance of their recruits and soldiers during training (18, 22, 31). Part of the benefits for this technology is that it is non-invasive and practical, providing no restrictions on the performance on military tasks such as the casualty drag. As expected, TL demands increased the longer an individual had to perform the casualty drag. Internal TL incorporates the physiological response to an imposed demand from activity occurring during the execution of an exercise (27). The TL derived from muscle activation provides a new internal load metric (11). Further to this, the sEMG wearable technology appeared to provide a useful measure of the stress imposed by the casualty drag, as total TL increased with a slower drag velocity. Previous research has utilized this technology to measure body weight squats and push-ups (1) and isokinetic knee flexion and extension (41). This is the first study to measure a military-specific task such as the casualty drag. Although more research is required, there appears to be potential value in utilizing sEMG wearable technology to measure military tasks, especially during basic training due to the practicality of this equipment. This could have important implications for those individuals at risk of injury due to excessive TL (30, 35, 47).

The potential value of this technology is further highlighted by the QUAD TL results. QUAD TL significantly related to casualty drag velocity for all participants combined, males, and females, and to body mass for all participants combined. Specific to the QUAD, an increase in TL could be the result of an increase in task completion time or an increase in stress placed on the muscles as a result of the external load. The movement patterns required in the backwards casualty drag could place greater demands on the QUAD relative to the BF and GM. In an analysis of different lower-body strength exercises (deadlifts, good mornings, and split-squats), Schellenberg et al. (50) utilized computational modelling to illustrate differences in the loading experienced by different muscles. Schellenberg et al. (50) found that the quadriceps experienced the greatest loading in the deadlift, primarily due to the range of motion at the hip and knee. The body position required for the backwards casualty drag, where the individual needs to flex and the hips and knees to grasp the vest handles before commencing the drag, has some similarities to the deadlift. Furthermore, the individual is required to remain in a position with flexed hips and knees for the duration of the drag, potentially placing more stress on the QUAD. It is important to note that greater BF and GM TL related to a slower casualty drag velocity when considering all participants combined, suggesting all of these muscles could experience greater TL the longer the task is performed. Additionally, the muscle ratios (QUAD:BF, GM:BF, and A:P) were not significantly different between males and females or the heavier and lighter groups, nor did they correlate with casualty drag velocity or body mass. Nevertheless, the sEMG wearable technology can provide some indication of the TL experienced in lower-body muscles, particularly in the QUAD for the casualty drag. This is useful information when considering the use of wearable technology in basic training to measure the stress associated with moving heavy external loads, and selection of appropriate exercises to develop the ability to tolerate this stress. Some examples of exercises that could target the muscles experiencing the greatest TL in the drag include deadlifts with a conventional or hexagonal bar (8) and sled drags (29).

There are study limitations that should be noted. This study did not use soldiers or other military personnel, although as stated, the use of civilians to analyze tactical tasks has been adopted in other studies (36, 42, 46, 54, 57). This is because the physical qualities important for a tactical task should be similar whether they are performed by a tactical operator or civilian (36, 54). Participants did not wear any combat gear while performing the casualty drag, which has been used with soldiers (9, 15). It would be expected that TL would increase if combat gear is also worn during a casualty drag, considering that load carriage increases the physiological demands of military task performance (33, 34). As such, the differences between groups found in this research may be amplified when combat loaded is added to the participant. The participants in this study were heavier than active-duty soldiers when both sexes were combined (82.49 ± 20.92 kg vs. ~78 kg) (9), and when the sexes were considered separately relative to male (88.93 ± 21.59 kg vs. ~70-80 kg) and female (67.86 ± 8.58 kg vs. ~59-62 kg) recruits (53, 59). The current results should be considered within that context. Smaller individuals who are effective performing the casualty drag may have made biomechanical adaptations to their dragging technique which could not be detailed in this study. Future studies should investigate whether strength training, technical training, or a combination of the two can improve the ability to perform the casualty drag. The sEMG wearable technology only measured select muscles of the lower-body, even though the casualty drag is a full-body activity. Future research should incorporate sEMG wearable technology that also measures the TL of upper-body muscles. In addition to this, long-term studies are required to confirm the viability of sEMG wearable technology to measure TL in military populations. The sample size was relatively small (n = 36), especially for females (n = 11). Larger sample sizes should be used in forthcoming studies analyzing TL demands during military tasks such as the casualty drag. Body mass was used as an anthropometrical metric, which did not take into account lean body mass or fat mass. Given that greater lean body mass and less fat mass can be beneficial in military populations (13, 21), this should be investigated specific to the casualty drag and sEMG wearable technology. Nonetheless, this study still provided an initial analysis of the TL demands and muscle ratios for an essential task for tactical populations.

In conclusion, female civilians tended to experience a greater TL (total, QUAD, BF, and GM) compared to male civilians during the backwards casualty drag. When the sample was split into heavier and lighter groups, the lighter individuals also experienced greater TL as measured by sEMG wearable technology compared to heavier individuals. Performing a casualty drag slower will increase the TL demands, predominantly via greater QUAD stress. In practice, experiencing greater total and QUAD TL during dragging tasks could impact other activities where QUAD activity is required, such as moving to cover. In accordance with this, training staff should ensure strength and conditioning forms part of task preparation training and maintenance, especially for those who may experience higher TL, generally female and lighter soldiers. As lighter individuals may always be at a physically disadvantage due to their body mass, strength training should be a particular focus for these individuals to maximize their potential in tasks such as a casualty drag. Lastly, there is potential for the use of sEMG wearable technology to measure TL during basic training for military populations.

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