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Research article

TRAINING LOAD DEMANDS MEASURED BY SURFACE ELECTROMYOGRAPHY WEARABLE TECHNOLOGY WHEN PERFORMING LAW ENFORCEMENT-SPECIFIC BODY DRAGS

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Abstract. *The use of surface electromyography (sEMG) wearable technology to measure training load (TL) during law enforcement-specific tasks (e.g. a body drag) requires investigation. This study determined muscle activation differences represented as TL during a 9.75-m drag with 74.84 kg and 90.72 kg dummies. Eight men and three women were fitted with a compression short or legging embedded with sEMG wearable technology to measure the quadriceps (QUAD; vastus medialis+vastus lateralis), biceps femoris (BF), and gluteus maximus (GM). After fitting on day one, participants completed maximal voluntary isometric contractions for each muscle to normalize the sEMG signal and calculate TL units. On days two and three, participants performed a 9.75 m body drag using either the 74.84 kg or the 90.72 kg dummy while wearing the technology. Participants lifted the dummy off the floor to a standing position and dragged it as quickly as possible over 9.75 m. Paired samples t-tests calculated between-drag differences for: time; QUAD, BF, GM, and total TL; and QUAD-BF, GM-BF, anterior-posterior (QUAD-GM+BF) ratios. QUAD TL was 9% greater (p=0.035), and GM TL was 8% lower (p=0.043), in the 90.72 kg body drag compared to the 74.84 kg drag. There were no between-mass differences in time, BF TL, total TL, or the ratios. QUAD TL increased while GM TL decreased when participants dragged a 90.72 kg dummy. As drag time was not different between the masses, drag mechanics may have changed leading to increased QUAD TL. sEMG wearable technology could be a useful method to measure TL in law enforcement-specific dragging tasks.*

Key words: *Casualty Drag, Law Enforcement, Muscle Activation, Police, Tactical, Victim Drag*

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INTRODUCTION

Law enforcement can be a demanding profession and can place great deal of physical stress on those employed in this job. On-duty law enforcement officers (LEOs) may be required to push, pull, lift, carry, or drag objects or people at any time during their shift (Dawes et al., 2016). LEOs must also perform job-specific skills, including driving vehicles (Lockie, Dawes, Kornhauser, Holmes, & Orr, 2018c), discharging firearms (Kayihan, Ersöz, Özkan, & Koz, 2013; Orr, Pope, Stierli, & Hinton, 2017), defensive tactics (Mitrović et al., 2016; Orr et al., 2017; Dawes et al., 2018; Lockie et al., Cesario, Bloodgood, & Moreno, 2018a), vaulting obstacles, and pursuing and apprehending suspects (Dawes et al., 2017a; Schram, Hinton, Orr, Pope, & Norris, 2018a; Schram, Orr, Pope, Hinton, & Norris, 2018b). One of the more physically demanding critical job tasks is the body drag, where LEOs must rapidly drag an incapacitated civilian or colleague from a hazardous environment (Lockie et al., 2018b; Lockie, Balfany, Denamur, & Moreno, 2019b; Moreno et al., 2019). As successful completion of this task could determine the survival of all involved, the body drag is often incorporated into job-specific testing to ascertain physical readiness for policing. As an example, a 9.75 m body drag with a 74.84 kg dummy is a task in the Work Sample Test Battery for Californian law enforcement recruits, which they must successfully complete before they graduate academy (Peace Officer Standards and Training, 2012; Lockie et al., 2018b; Lockie, Balfany, Denamur, & Moreno, 2019b; Lockie, Orr, Moreno, Dawes, & Dulla, 2019e; Moreno et al., 2019).

However, it is questionable whether the 74.84 kg dummy is representative of the current USA population. Recent data has shown that the average adult female in the USA weighs approximately 76-77 kg, while the average adult male weighs almost 90 kg (Fryar, Gu, Ogden, & Flegal, 2016). Further issues arise if an LEO has to drag one of their colleagues. Previous research on incumbent LEOs has reported mean body masses of 68-77 kg for women and approximately 92 kg for men (Dawes et al., 2017b; Lockie, Dawes, Kornhauser, & Holmes, 2019c). LEOs may also be carrying approximately 8-22 kg of equipment while on duty (Joseph, Wiley, Orr, Schram, & Dawes, 2018). These data seem to indicate that the dummy mass should be increased from 74.84 kg to a load commensurate with either the general population (~90 kg) (Fryar et al., 2016) or fellow LEOs with their duty load (~100 kg) (Baran, Dulla, Orr, Dawes, & Pope, 2018) to better prepare recruits for this task. Before that can be considered, it would be of interest to know the demands associated with dragging individuals of different masses during a law enforcement-specific body drag.

Tactical populations, predominantly the military, have started using technology more associated with elite sport (Friedl, 2018). The integration between these processes has been done to ensure trainees experience the appropriate load to attain the desired training adaptations, and to reduce injuries (Jones, Hauschild, & Canham-Chervak, 2018). The challenge for law enforcement populations is finding technology that can be used when in physical training attire or uniform that can directly measure specific tasks when performed in the field. One example of emerging technology that could have practical application in policing is surface electromyography (sEMG) wearable technology. This system evaluates the activation of muscles during physical activity, and can use these measurements as an indicator of training load (TL) (Lynn, Watkins, Wong, Balfany, & Feeney, 2018). The measurement of TL via wearable technology provides a measure of the resultant stress placed on the body by the performed activity (Jones, Griffiths, & Mellalieu, 2017). This would appear to have value for law enforcement, as sEMG wearable technology can be worn under training attire or uniforms, and could be used to ascertain the TL via muscle activation during tasks such as the body drag.

Thus, the purpose of this research note was to determine if the TL and muscle activation patterns required to drag a 74.84 kg or 90.72 kg dummy changed during a 9.75 m drag in recreationally-trained males and females. Wearable technology with built-in sEMG sensors measured muscle activation during the drags. It was hypothesized that the 90.72 kg body drag would be performed slower than the 74.84 kg drag. In accordance with this, it was further hypothesized that a greater TL would be recorded during the 90.72 kg body compared to the 74.84 kg drag. This study provided an initial analysis of the potential use of this equipment to measure the stress incurred by a specific law enforcement task, within the context of population demographic changes (Fryar et al., 2016) and the mass of LEOs (Dawes et al., 2017b; Lockie et al., 2019c). This study will provide useful information which could have health and exercise implications for law enforcement populations.

METHODS

Participants

A convenience sample of 11 physically active participants, including eight males (age=25.50±5.66 years; height=1.78±0.06 m; body mass=82.86±6.15 kg) and three females (age=24.33±2.52 years; height=1.71±0.04 m; body mass=73.87±9.51 kg) completed this study. Participants were recruited from the student population at the university via information sessions and word-of-mouth on campus. Civilians were used as surrogates for a tactical population (Williams-Bell, Villar, Sharratt, & Hughson, 2009; Mala et al., 2015; Nindl et al., 2017; Stevenson, Siddall, Turner, & Bilzon, 2017; Lockie et al., 2019b), and were age-matched to law enforcement recruits (Boyce, Jones, Schendt, Lloyd, & Boone, 2009; Crawley, Sherman, Crawley, & Cosio-Lima, 2016). Additionally, the physical qualities important for a tactical task such as the body drag should be similar whether they are performed by a tactical operator or civilian (Stevenson et al., 2017; Lockie et al., 2019b). Previous research has demonstrated minimal learning effects with a military-style body drag (Foulis et al., 2017). This should mean that even for participants who were not law enforcement recruits or officers, they should perform the body drag with consistency across trials. No participants have previously been involved with law enforcement 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 (Garber et al., 2011), and were required to be free from any musculoskeletal disorders that could influence study participation. The institutional review board approved the study (HSR-18-19-109), all participants received an explanation of the procedures, and written informed consent was obtained. The study still conformed to the recommendations of the Declaration of Helsinki (World Medical Association, 1997).

Procedures

Participants completed three testing sessions separated by 48-72 hours. On day one, participants had their age, height, and body mass recorded. Height was measured barefoot using a portable stadiometer (Detecto, Webb City, MO, USA), while body mass was recorded by electronic digital scales (Ohaus, Parsippany, NJ, USA). Waist and hip circumference were measured to determine the garment size, before participants were fitted with the sEMG wearable technology (Athos, Redwood City, California). Males wore compression shorts, females wore leggings, and each were embedded with sEMG sensors that measured the vastus medialis (VM), 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 this aligned with recommended product usage (Lynn et al., 2018). Participants then completed a standard dynamic warm-up, which was also used on days two and three. Participants cycled for 5 minutes at a self-selected intensity on a bicycle ergometer (Assault Fitness, Carlsbad, California), before completing approximately 10 minutes of full-body dynamic stretching. Participants refrained from intensive lower-body exercise and maintained a standardized dietary intake in the 24-hour period prior to each testing session, and were permitted to consume water as necessary throughout each testing session.

After the warm-up on day one, participants completed maximum voluntary isometric contraction (MVIC) assessment via manual muscle testing for each leg which was used to normalize the sEMG data (Burden, 2010; Aquino & Roper, 2018). This followed manufacturer guidelines to use an MVIC recorded on a different testing day to ensure practicality of use for the technology. Internal testing showed that this normalization procedure for all muscles displayed similar results to MVICs performed on an isokinetic dynamometer ($r>0.8$, $p<0.001$) (Balfany, Chan, Lockie, & Lynn, 2019). 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 the participant as they 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. The participant performed three repetitions of each MVIC trial for 5 seconds each, with 60 seconds rest between trials (Balfany et al., 2019). Familiarization to the body drag was also completed on day 1, such that participants achieved the required body drag techniques for the subsequent testing sessions. Participants completed several practice drags as required with both dummies.

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 app 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)]. These muscle ratios were specific to the app, and were included for exploratory analysis in this research note.

Body Drag

Body drag testing was conducted in days two and three, and followed protocols used in California for law enforcement recruits (Lockie et al., 2019b; Lockie et al., 2018b; Lockie et al., 2019e; Moreno et al., 2019; Peace Officer Standards and Training, 2012). The mass dragged each day (either the 74.84 kg or 90.72 kg dummy) was counterbalanced amongst the sample. All trials were performed on a wooden floor, with tape marking the start and finish lines for the 9.75-m dragging distance. The dummies (Dummies Unlimited, Pomona, California) were positioned face side up, with the head orientated towards the finish line, and the feet 0.3 m behind the starting line. As shown in Figure 1, participants picked the dummy up by wrapping their arms underneath the arms of the dummy and lifting it to a standing position (Peace Officer Standards and Training, 2012; Lockie et al., 2018b; Lockie et al., 2019b; Lockie et al., 2019e; Moreno et al., 2019). Once standing, the participant informed the researcher they were ready, and timing was initiated when the feet of the dummy passed the start line via stopwatch by a researcher trained in the use of stopwatch procedures (Peace Officer Standards and Training , 2012; Lockie et al., 2019b; Lockie et al., 2018b; Moreno et al., 2019). Testers trained in the use of stopwatch timing procedures for athletic performance tests can record reliable data (Hetzler, Stickley, Lundquist, & Kimura, 2008). Participants dragged the dummy as quickly as possible by walking backwards over the required distance. Timing stopped when the dummy's feet crossed the finish line, and was recorded to the nearest 0.1 second. Two trials were completed for the drags with each mass, with three minutes rest between trials. The wearable technology recorded data for the duration of all body drags.

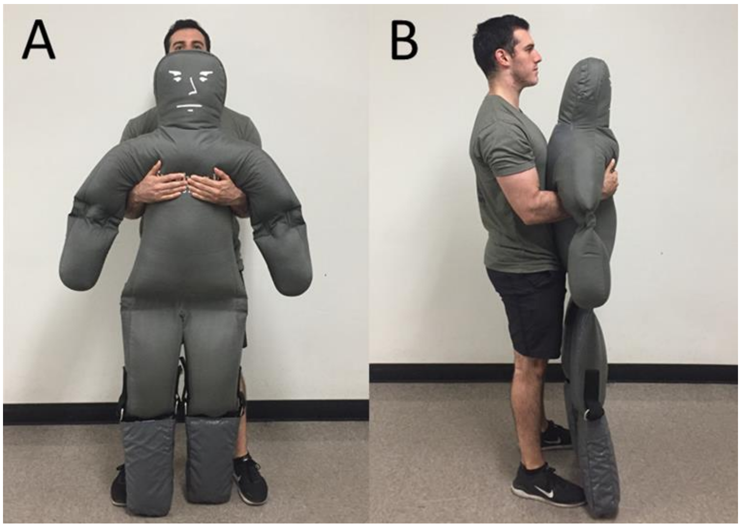

Fig. 1 Starting position for the body drag

Statistical Analysis

All statistics were computed using the Statistics Package for Social Sciences Version 25.0 (IBM, Armonk, United States of America). Descriptive statistics (mean±SD) profiled all variables, and data was combined between the sexes. Previous law enforcement specific-research has combined data for the sexes (Cesario et al., 2018; Lockie et al., 2018d; Lockie et al., 2018e; Lockie et al., 2019c; Lockie et al., 2019d; Lockie et al., 2020; Bloodgood et al., in press). This approach was taken in this study as well because the focus was on the absolute effects of the dummy masses on TL regardless of sex. Paired samples t-tests compared drag time, QUAD, BF, GM, and total TL, and muscle ratios between the two masses. Significance was set a priori at $p<0.05$.

RESULTS

Table 1 displays the data recorded from each drag. No significant differences were found between the 74.84 kg body drag time versus the 90.72 kg drag time. In the 90.72 kg body drag, QUAD TL was significantly greater (9%), and GM TL was significantly lower (8%) compared to the 74.84 kg body drag. There were no significant differences between the masses in BF TL, total TL, or the between-muscle ratios.

Table 1 Descriptive data (mean±SD) for time, QUAD (VM+VL) TL, BF TL, GM TL, and total TL, and muscle ratios (QUAD:BF, GM:BF, and A:P) for the 74.84 kg and 90.72 kg body drags

Variables	74.84 kg Body Drag	90.72 kg Body Drag	*p*-value
Time (s)	6.57 ± 2.50	6.75 ± 2.56	0.340
QUAD TL (AU)	12.22 ± 6.35	13.26 ± 7.20*	0.035
BF TL (AU)	9.22 ± 4.23	9.69 ± 4.63	0.629
GM TL (AU)	5.96 ± 4.31	5.46 ± 4.09*	0.043
TOTAL TL (AU)	27.41 ± 12.13	28.43 ± 13.42	0.482
QUAD:BF	0.86 ± 3.45	0.89 ± 0.31	0.653
GM:BF	0.65 ± 0.33	0.57 ± 0.25	0.168
A:P	0.90 ± 0.45	0.97 ± 0.41	0.216

* Significantly (<0.05) different from the 74.84 kg body drag.

DISCUSSION

This study determined whether the TL and muscle ratios required to drag a 74.84 kg or 90.72 kg dummy during a 9.75 m drag were different in trained males and females. Although a law enforcement-specific task was analyzed with civilians, this approach has been adopted in other tactical research (Williams-Bell et al., 2009; Mala et al., 2015; Stevenson et al., 2017; Nindl et al., 2017; Lockie et al., 2019b). The analysis of the TL derived from the body drag performed with 74.84 kg or 90.72 kg dummies was important, as the current dummy mass for Californian law enforcement recruits is below that of the general population (Fryar et al., 2016) and many LEOs (Dawes et al., 2017b; Lockie et al., 2019c). Firstly, there were no differences in the drag time for each mass. The testing conditions could have influenced these results, as the lifting component was not included in the time (Peace Officer Standards and Training, 2012; Lockie et al., 2018b; Lockie et al., 2019b; Moreno et al., 2019). Including the lifting time in the body drag increases the total time recorded, which is exacerbated even more when a participant has to drag a heavier mass (Lockie et al., 2019b). Furthermore, participants had to be strong enough to lift the dummy mass from the ground. This could reduce the friction encountered as less of the dummy is in contact with the ground, allowing for similar times between the masses.

QUAD TL was greater in the 90.72 kg body drag compared to the 74.84 kg body drag, while GM TL was lower. 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. As the body drag time measured in this study was not different between the masses, it could be assumed the drag mechanics changed, leading to increased demands on the QUAD (and reduced demands on the GM). The body drag, especially how it was performed in this study (Peace Officer Standards and Training, 2012; Lockie et al., 2018b; Lockie et al., 2019b; Lockie et al., 2019e; Moreno et al., 2019), has some similarities to a deadlift. In an analysis of lower-body strength exercises, Schellenberg, Taylor, & Lorenzetti (2017) found that the quadriceps were most active in the deadlift. The need to physically stand with the dummy by extending the legs could have increased the QUAD TL. This is useful information when considering the use of wearable technology in law enforcement, the stress associated with lifting external loads, and the relevance of lifting tasks for LEOs (Anderson, Plecas, & Segger, 2001). Specific to law enforcement recruits and officers, the adoption of training exercises that stress the QUAD could be useful in training to enhance their ability to complete dragging tasks. Some examples include deadlifts with a conventional or hexagonal bar (Camara et al., 2016) and sled drags (Jenkins & Palmer, 2012). The ability for the QUAD to tolerate load during a dragging task especially important to develop, given the heavier citizens (Fryar et al., 2016) or colleagues (Dawes et al., 2017b; Lockie et al., 2019c) LEOs may encounter during their shift.

These data are important when considering the implications of measuring TL. In athletes, TL is essential for understanding the individual's response to training (Halson, 2014). A unique aspect to this study was the use of sEMG wearable technology to measure the demands of the body drag with different masses. The TL derived from muscle activation provides a new internal load metric (Chan, 2017). Further to this, the sEMG wearable technology appeared to provide a useful measure of the stress imposed by the body drag, as QUAD TL increased with the heavier mass. Previous research has used this technology to measure push-ups and body weight squats (Aquino & Roper, 2018) and isokinetic knee flexion and extension (Lynn et al., 2018). This is the first study to measure a law enforcement-specific task such as the body drag. These data have further use when considering how law enforcement physical training is often conducted at the academy. If TL monitoring via equipment such as sEMG wearable technology is utilized, it can allow for monitoring of the variations that occur between individuals. This is prescient when considering the 'one-size-fits-all' model of physical training commonly completed by law enforcement recruits (Orr, Ford, & Stierli, 2016; Moreno, Cesario, Bloodgood, & Lockie, 2018; Cesario, Moreno, Bloodgood, & Lockie, 2019; Lockie et al., 2019a). This would result in great variations between the TL experienced by individuals. Although further research is needed to further validate this equipment, sEMG wearable technology could be a useful tool in measuring the TL associated with typical law enforcement tasks during training, and potentially when on-duty.

There were no differences between the two drags in BF TL, total TL, and the between-muscle ratios. There was a non-significant, 14% decrease in the GM:BF ratio in the 90.72 kg body drag, which may have been a function of the reduced GM TL. Regarding the total TL, as QUAD TL increased, GM TL decreased in the 90.72 kg body drag versus the 74.84 kg drag, providing some indication as to why total TL was not different between the masses. Furthermore and as noted, there were no between-mass differences in drag time. A longer drag should result in a greater total TL due to the increase in task completion time. Nonetheless, this concept requires further analysis in LEOs. If an LEO is slower in job-specific tasks, not only is this less effective, but could also result in a greater TL being experienced. This could increase the likelihood of fatigue (Halson, 2014), which could hamper further job task performance.

There are some study limitations that should be noted. This study did not use law enforcement recruits or officers, although as stated, the use of civilians to analyze tactical tasks has been adopted in other studies (Williams-Bell et al., 2009; Mala et al., 2015; Nindl et al., 2017; Stevenson et al., 2017; Lockie et al., 2019b). This is because the physical qualities important for a tactical task such as a body drag should be similar whether they are performed by a tactical operator or civilian (Stevenson et al., 2017; Lockie et al., 2019b). The sEMG wearable technology used in this research only measured muscles in the lower-body, even though the body drag is a full-body activity. Future studies should incorporate sEMG wearable technology that also measures upper-body muscle TL. In addition to this, long-term studies are required to confirm the viability of sEMG wearable technology to measure TL in law enforcement populations. The sEMG wearable technology needs to be validated against other equipment that also measures TL (e.g. global positioning system technology, heart rate, rating of perceived exertion) to confirm its viability. The sample size was small (N=11), for both males (n=8) and females (n=3). Larger sample sizes should be used in forthcoming studies analyzing TL demands during law enforcement-specific tasks such as the body drag.

CONCLUSIONS

Although more research is required, this study provided some initial data that suggested sEMG wearable technology could be a useful tool to measure TL in law enforcement-specific tasks such as 74.84 kg and 90.72 kg body drags. Moreover, the data indicated that QUAD TL increased and GM TL decreased in participants when they dragged a 90.72 kg dummy versus a 74.84 kg dummy, suggesting changes to the mechanics associated with lifting the heavier mass. The measurement of data such as this could influence the training of dragging tasks for law enforcement recruits. That is, law enforcement recruits and officers should incorporate exercises that develop the ability of the QUAD to tolerate load during dragging tasks. Lastly, there is potential for the use of sEMG wearable technology to measure TL during law enforcement training for recruits, and potentially when on shift for LEOs.

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TRENAŽNA OPTREĆENJA MERENA NOSIVOM POVRŠINSKOM ELEKTROMIOGRAFIJOM PRILIKOM IZVOĐENJA SPECIFIČNOG POVLAČENJA TELA OD STRANE PRIPADNIKA POLICIJE

Upotreba tehnologije površinske elektromiografije (sEMG) za merenje trenažnih opterećenja (TO) tokom specifičnih policijskih zadataka (npr. povlačenje tela) zahteva istraživanje. Ovim istraživanjem utvrđene su razlike u aktivaciji mišića predstavljene kao TO tokom povlačenja u rastojanju od 9.75 m sa lutkama mase 74.84 kg i 90.72 kg. Osam muškaraca i tri žene opremljeni su prslucima sa ugrađenom sEMG nosivom tehnologijom radi merenja aktivnosti kvadricepsa (QUAD; vastus medialis+vastus lateralis), biceps femoris (BF) i gluteus maximus (GM). Nakon prilagođavanja tokom prvog dana, učesnici su izveli maksimalne izometrijske kontrakcije svakog od navedenih mišića zbog normalizacije sEMG signala i izračunavanja TL jedinice. Tokom drugog i trećeg dana, učesnici su izveli povlačenje tela u rastojanju od 9.75 m koristeći lutke mase 74.84 kg i 90,72 kg i nosivu sEMG tehnologiju. Učesnici su lutku podigli sa poda u uspravni položaj i povukli je što je brže moguće u rastojanju od 9.75 m. T-testom za uparene uzorke izračunate su razlike u povlačenju za: vreme; QUAD, BF, GM i ukupan TL; i odnose QUAD-BF, GM-BF, prednji-zadnji (QUAD-GM+BF). QUAD TL je bio 9% veći (p=0.035), a GM TL 8% niži (p=0.043), prilikom povlačenja lutke mase 90.72 kg u odnosu na povlačenje lutke mase 74,84 kg. Nije bilo razlika između mase u vremenu, BF TL, ukupnog TL ili navedenih odnosa. QUAD TL je porastao, dok se GM TL umanjio kada su učesnici povlačili lutku od 90.72 kg. Kako se vreme vuče između masa nije razlikovalo, možda se promenila mehanika vuče što je dovelo do povećanja QUAD TL. Tehnologija nošenja sEMG-a mogla bi da bude od korisna metoda za merenje TL-a u zadacima vuče tela.

Ključne reči: *vuča povređenih, sprovođenje zakona, aktivacija mišića, policijske snage, taktika, vuča žrtava*