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TITLE: Trunk Flexion Extension Excursion, Forces at the Feet and Gait Timing in Tactical Belt and Gear Vest Load Carriage

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Trunk Flexion/Extension Excursion, Forces at the Feet and Gait Timing in Tactical Belt and Gear Vest Load Carriage

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Abstract

Law enforcement agents often carry gear or equipment loads, which have a history of causing low back pain. Traditionally, police equipment is carried along a belt, which loads the pelvis and lower limbs. Over the shoulders, through a vest is an alternative method of load carriage for law enforcement agents. The aim of this study was to evaluate the differences in gear load carriage for law enforcement agents while walking. We hypothesize that there will be a difference in forces on the feet, timing of forces on the feet and trunk angle while distributing weight in a belt and a vest carriage strategies. **Methods:** Twenty-nine healthy participants were recruited to perform load carriage in three different conditions: a control trial (C) with no gear weight, a loaded nylon tactical gear belt (TB), and an anterior-loaded gear vest (ALV). The gear load carriage conditions had a total of 9.07 kg (20 lbs.) of weight. Moticon force sensors were placed in each shoe before participants walked on a treadmill for three minutes per condition. Data included gait timing and ground reaction forces that were measured using the Moticon force sensors. Trunk flexion/extension excursion was captured by a motion capture system. **Results:** Trunk flexion/extension excursion was significantly lower in the TB condition when compared to the C condition (p= 0.002). Double support time in the ALV condition was significantly longer when compared to the C condition (p= 0.023). Stance duration in the ALV condition was significantly longer when compared to the C and TB condition (p= 0.008 and 0.009, respectively). Mean ground reaction force was significantly greater in both the TB and ALV conditions, both with p= 0.00. **Conclusion:** There were differences found in mean trunk flexion/extension excursion, and gait timing when participants carried a gear load, demonstrating that participants walked in a more stable posture when they carried a load.

1. **Introduction**

Law enforcement agents often carry gear or equipment loads, which have a history of causing low back pain (Ershad et al.,2009, Filtness et al., 2014, Rodriguez et al., 2013). Lentz et al., (2020), reported that injuries to the low back contributed to the 19.6 % of law enforcement injuries reported from the Canadian police service. Factors that attribute to low back pain of agents could include how they carry equipment across their bodies and how the vehicle seat interacts with their equipment (Filtness et al., 2014, Gyi et al., 1998). Most loads are typically carried on the shoulders or around the pelvis (Coombes et al., 2005). Traditionally, law enforcement equipment is carried along a belt, which loads the pelvis and lower limbs (Filtness et al., 2014). Other forms of load carriage can be performed over the shoulders with a backpack or a vest (Liu et al., 2013, Merati et al., 2001, Schulze et al., 2013). When comparing the two load carriage appointments, the belt method resulted in significant discomfort when compared to the vest when participants sat in police issued vehicle seats (Filtness et al, 2014). Although past studies have examined standard issued police equipment, no previous study has examined the effects of how the equipment load affects gait patterns and ground reaction forces.

Other past studies have assessed the effects of asymmetrical load carriage while walking (Liu et al., 2013, Watson et al, 2008). Watson et al. (2008) found that walking with a symmetrical load, had a decreased oxygen consumption rate when compared to asymmetrical loading. Another past study, done by Liu et al., (2013), investigated short-term and long-term postural stability, using with an accelerometer, to determine the effects of symmetrical load carriage in a vest. They found a short-term effect in the anterior-posterior direction of stability, while a long-term effect was found in anterior-posterior, mediolateral and vertical stability. Liu et al., (2013) stated that load carriage placement affects trunk kinematics while walking.

Trunk angle has been used to characterize differences in walking trials (Silder et al., 2013). For example, past studies have evaluated symmetrical load carriage, but a limited number of have studies have assessed front-loaded gear carriage while walking. A past study, by Andersen et al., (2007), showed a significant effect of both walking speed and load height on trunk posture and trunk muscle activity levels in two different conditions: the barbell and bucket experiments. In the barbell experiment, the walking trials generated 43% more trunk muscle activity than the standing trials. Alamoudi et al., (2018), found that trunk flexion increased based off of load positioning, with the most trunk flexion found when load carriage was placed in the frontal compartment. Although load distribution affects trunk posture and trunk muscle activity, other past studies have shown that force distribution at the feet changes as load distribution changes.

One way to evaluate specific load carriage appointments is by examining the forces at the feet. Schulze et al., (2013), evaluated the forces at the feet while adding load to a solider to total traditional military equipment carriage. Researchers started with an unweighted control, and implemented piece-by-piece additions of standard issued military equipment, until standard equipment is being carried, weighing 31.13 kg in total. Schulze et al., (2013), found that as load carriage equipment increased in weight, the pressure contact area at the foot grew as necessary to help stabilize walking. However, the load carriage weight amounts are larger in this past study done by Schulze et al. (2013) then the typical 9.07 kg (20 lbs.) gear load for law enforcement.

Amount of activity for law enforcement agents can be sporadic, with long amounts of sedentary time accompanied by short durations of standing, along with the possibility of high intensity shorter duration bursts. Understanding how gear load can affect trunk posture and forces at the foot, could possibly help law enforcement agents reduce injury and prolong healthy careers. One way to alter health outcomes for law enforcement agents would be to change how their equipment is loaded on their body. The aim of this study is to evaluate the difference in gear load between the belt and vest strategy for law enforcement agents while walking. We hypothesize that there will be a difference in magnitude of forces on the foot, timing of forces on the foot and trunk flexion/extension angle while distributing equipment weight around the body in the belt and vest load strategies.

2. Methods

2.1 Participants

Twenty-nine (15 females and 14 males) healthy, participants were recruited as a convenience sample from California State University San Marcos. Subject characteristics are listed below in Table 1. We obtained written consent from all participants using forms and protocols approved by the California State University San Marcos Internal Review Board. Participant were instructed to wear athletic clothing and footwear in order to participant. Foot length was then measured for the foot sensors to determine the correct foot sensor size. Exclusion was assessed by a health history questionnaire, where each participant self-reported their ability to perform the study. Participants were excluded if they had a history of orthopedic surgery of the back, neck or shoulder within the past 5 years that would interfere with load carriage. Subjects were also excluded if they had a history of heart disease, neurological disorders, stroke or a traumatic brain injury that could interfere with exhaustion exercise.

Table 1: Subject Characteristics

Characteristics	Age (years)	Height (cm)	Weight (lbs)	Shoe Size (US)
Female (n=15)	26.47 ± 4.78	165.4 ± 7.54	161.25 ± 25.31	8.03 ± 0.896
Male (n=14)	25.21 ± 4.02	177/50 ± 5.65	178.98 ± 26.43	10.46 ± 0.692

2.2 Conditions

Load carriage was be performed in three different conditions: a control trial (C) with no gear weight, a nylon tactical gear belt (TB), and anterior-loaded vest (ALV, 5.11 TacTech Vest). The gear load carriage conditions had 20 lbs. (9.07 kg) of weight distributed throughout. The conditions were completed in a randomized order. The TB condition had the 20 lbs. weight distributed across the pelvis of the participant symmetrically around the belt. Equipment holders around the belt were filled with small weights to total 20 lbs. For the ALV condition, 75% of the weight was loaded in an anterior compartment of the vest (Rogue Weight Plates), with the remaining 25% loaded to the posterior compartment of the vest. The TB and ALV were properly fit to each participant according to size. Trials consisted of treadmill walking at 1.1 m/s (2.5 mph) for a duration of 3 minutes.

2.3 Foot Force Sensor

Moticon Force Sensors (Munich, Germany) of the correct size (five sizes available) were placed in the shoes of both feet of each participant to calculated the magnitude of forces and gait timing at the feet. Before trials were collected, each participant had to calibrated zero force on each foot force sensor. This was collected by participants standing on one foot at a time to calibrate zero force. The sampling rate for the Moticon sensors is 50 Hz. Magnitude of force and gait timing were measured for several complete gait cycles.

2.4 Motion Capture

Qualisys Motion Capture System (OQUS5+ Qualisys AB, Goteborg, Sweden) with 8 cameras was used to acquire trunk flexion angle while performing walking. 12 Reflective markers were placed on the thorax in each corresponding condition: on each shoulder (left and right acromial processes), cervical spine (C7), sternum, left and right ASIS, left and right PSIS and left and right greater trochanters. Rab et al. (2000), thorax model was used to complete trunk flexion analysis due to the blockage from the ALV condition. Reflective markers were not removed between conditions. Visual 3D software (C-Motion, Germantown, MD) was used to compute trunk angle from the recorded marker positions relative the vertical axis in the laboratory (Kauffman). Positive angles were indicated as anterior trunk flexion.

2.5 Data Analysis

Trunk flexion, along with gait timing and ground reaction force were compared among gear conditions. Measurements of left and right foot were compared for force magnitude and gait timing. The middle minute of each three-minute trial of data was analyzed. Mean and standard deviations were computed for force magnitude and gait timing measures. Gait timing measurements included mean gait cycle time, mean cadence, double support time, step duration and stance duration. Trunk flexion/extension excursion was calculated by finding the difference between the minimum and maximum trunk angle and was computed to compare means and standard deviations across each condition. Microsoft Excel (Microsoft, Redmon, WA.) and SPSS (IBM, Armonk, NY.) for statistical analysis. Repeated measures ANOVA was used with a Bonferroni's post-hoc test to compare among conditions. Significance level was set at $p<0.05$.

3. Results

3.1 Trunk Flexion/Extension

The mean trunk flexion while walking was greatest for the C condition, with an average of 0.98 ± 3.04 degrees of anterior trunk flexion. Trunk flexion was lower in both weighted conditions, with an average for the TB and the ALV, respectively, -0.37 ± 2.98 and 0.55 ± 3.54 degrees of anterior trunk flexion. When comparing each weighted condition to the C condition, only the TB condition ($p=0.002$) was significantly different (ALV $p=0.507$). There was no significant difference found between the TB and ALV condition when comparing mean trunk flexion. The mean trunk flexion excursion while walking was greatest for the C condition, with an average of 7.94 ± 1.74 degrees of anterior trunk flexion (Figure 1). Mean trunk flexion excursion for the ALV condition was 7.17 ± 2.03 degrees of anterior trunk flexion, which was not significantly difference compared to either the C or TB condition ($p = 0.109$ and 1.00). The TB condition had a mean trunk flexion/extension excursion of 7.31 ± 1.61 degrees and was significantly different when compared to the C condition ($p=0.034$).

3.2 Gait Timing

Mean gait cycle time in seconds for the ALV condition, with a mean of 1.13 ± 0.06 s. The TB had an average of 1.14 ± 0.05 s, with the C condition having a mean of 1.14 ± 0.06 s. No significant differences were found in mean gait cycle when comparing the C condition to the weighted conditions ($p = 0.886$ and 0.332 for the TB and ALV conditions, respectively). Mean gait cadence was greatest in the ALV condition, with a mean of 53.9 ± 3.5 steps per minute. The TB had a mean gait cadence of 53.2 ± 2.73 steps per minute, followed by the C condition having the lowest mean gait cadence with 52.99 ± 2.70 steps per minute. When compared the C condition, neither the TB condition nor the ALV condition were significantly different (p-value= .0972 and 0.053, respectively). Double support time was greatest in the ALV condition, with an average of 0.35 ± 0.08 s, followed by the TB condition (0.34 ± 0.06 s) then the C condition (0.32± 0.08 s, Figure 2). Double support in the ALV condition was significantly different when compared to the C condition, with a $p = 0.023$. There was no significant difference when comparing the TB condition to the either the C or the ALV condition ($p = 0.367$ and 0.628, respectively). Step duration for the left foot and right foot for the C condition was 0.558 ± 0.006 s and 0.572 ± 0.007 s. When comparing the means for the left and right foot of the ALV condition (0.553 ± 0.007 s and 0.563 ± 0.007 s) to the C condition, both feet were significantly different (p= 0.002). The TB conditions with a mean step duration on the left and right foot had a mean of 0.560 ± 0.006 s and 0.567 ± 0.006 s (Figure 3), and both feet were significantly different compared to the C condition (p= 0.002). Step duration in the TB condition was also significantly different when compared to the ALV condition for both left and right foot (p= 0.003 and 0.002, respectively). Stance duration had the lowest value was in the C condition, with an average of 0.717 ± 0.009 s for the left foot and 0.740 ± 0.013 s for the right foot. Stance duration in the TB condition had an average of 0.738 ± 0.011 s for the left foot and 0.734 ± 0.009 s for the right foot (Figure 4), and was significantly different when compared to the C condition (p= 0.005 and 0.009, respectively). Stance duration was greatest in the ALV condition, with an average of 0.739 ± 0.013 s for the left foot and 0.747 ± 0.012 s for the right foot. The ALV condition was significantly different for both the left and right foot when compared to C condition (p= 0.008). When comparing stance duration in the TB condition to the ALV condition, there was a significant difference found in both left and right feet (p= 0.010 and 0.009, respectively).

3.3 Ground Reaction Force

There were significant differences found in two categories of ground reaction force, GRF mean and GRF max. Both weighted conditions (TB and ALV) for GRF mean were significantly greater from the control, both with p= 0.00 (Figure 5). There was no significant difference found between the left and right foot when examining GRF mean in all three conditions (p= 0.27). The percent change from the control was 9.7% for the left foot and 8.8% for the right foot in the TB condition, while the percent change in the ALV condition was 8.3% for the left foot and 9.2% for the right foot. GRF max was increased significantly when comparing the TB and ALV condition to the C condition with p-values of 0.00 and 0.00, respectively.

4. Discussion

The results of this study demonstrated that adding a gear load resulted in differences in walking patterns compared to when the subject walked with no load. Specifically, double support time and stance duration increased when comparing weighted conditions to the control trial. Also, ground reaction force increased as expected when weight was added. Although adding weight changed timing and force at the feet, the position of the weight can also have effects on the body while walking. By changing the positioning of the load, the trunk flexion/extension excursion changed when the load was applied, specifically for the belt compared to the control. We hypothesized that a difference would be observed in gait timing, force on the foot and trunk flexion while a gear load was assessed. Our hypothesis was supported by the findings in this study by changes observed in the double support and stance duration compared to the control trial.

Our hypothesis was also supported by changes in ground reaction forces observed when adding a gear load to walking participants

This study's findings were similar to previous research that showed trunk angle changed when carrying a gear load (Alamoudi et al., 2018). Two main differences between past research and the current study are how the gear load was appointed, along with the amount of gear load weight. Past research had the participants carrying the load by hand, while the current study appointed gear by wearing the load in the TB or ALV condition. Another difference from past research is that the amount of load weight was different from the current study. The past study had two different weights (10 and 30 lbs.), carried in four separate carriage positions, frontal, lateral, bilateral and posterior (Alamoudi et al., 2018). The participants in the current study carried 20 lbs. of gear load. Alamoudi et al., (2018) also examined the amount of trunk flexion/extension with load carriage. The past research stated that the anterior load created an unstable position, resulting in compensation compared to unloaded walking, with an increase in trunk flexion. The difference with the current study is a more balanced load, with 75% of the 20 lbs. load anteriorly on each subject, which resulted in less trunk flexion/extension excursion when compared to the anterior load hand weight load applied in past research (Alamoudi et al., 2018). The results from this study found that people changed upright trunk angle in order to increase stability or to walk ergonomically efficient with a gear load.

Gait timing results were consistent with previous research on double support time, which was shown to change due to load carriage. Alamoudi et al. (2018), reported that double support time increased due to a load being applied while walking, but only in the heavier load. Their findings are supported by the current study, which found that double support time increased significantly while walking with load, although the load applied differed from past research. Another study collected in firefighters examined how load carriage over one shoulder changed timing at the feet, and found that gear load carried asymmetrically caused an increase in double support time (Park et al., 2018). Although Alamoudi et al. (2018) stated that gait parameters became unstable, specifically in the anterior load, a more balanced appointment of the gear load in the current study limits instability. With decreased trunk flexion/extension excursion, stance phase and double support time exhibited adaptations while walking loaded with gear.

In this study, the same gear load weight was added to each participant in both the TB and ALV condition. Results of this research demonstrate that the ground reaction force didn’t increase by the total load added to the participants. Similarly, Silder et al., (2013) found that with a 10% increase in load, ground reaction force increased by only 6% which agrees with the current findings. Therefore, our findings for ground reaction force are in agreement with past research, as ground reaction force didn’t increase by the 88.98 N of gear load.

This research did have limitations. Moticon force sensors were used, which have been shown to have a 13-30% difference between a calibrated force platform (Stöggl et al., 2017). The current study made comparisons between each of the three conditions, and reported the percent change from control, per participant to emphasize comparison rather than force recorded. Another limitation is the variation of shoes worn by each participant. The only guidelines given were to wear comfortable athletic shoes. Moticon force sensors fit in all shoes without causing discomfort and therefore should have provided accurate data for all participants.

In conclusion, changes in the gait timing, forces at the feet, and trunk flexion/extension excursion were observed with the addition of a 9.07 kg gear load carried on either a tactical belt or an anterior-weighted gear vest while walking. Positioning and weight of the load contributed to adaptations in gait parameters. Participants changed their trunk posture and gait timing to a more ergonomically efficient gait with additional load.

5. References

Alamoudi, M., Travascio, F., Onar-Thomas, A., Eltoukhy, M., & Asfour, S. (2018). The effects of different carrying methods on locomotion stability, gait spatio-temporal parameters and spinal stresses. *International Journal of Industrial Ergonomics, 67*, 81–88. doi: 10.1016/j.ergon.2018.04.012

Anderson, A. M., Meador, K. A., Mcclure, L. R., Makrozahopoulos, D., Brooks, D. J., & Mirka, G. A. (2007). A biomechanical analysis of anterior load carriage. *Ergonomics,50*(12), 2104-2117. doi:10.1080/00140130701450195

Cho, T., Jeon, W., Lee, J., Seok, J., & Cho, J. (2014). Factors Affecting the Musculoskeletal Symptoms of Korean Police Officers. *Journal of Physical Therapy Science,26*(6), 925-930. doi:10.1589/jpts.26.925

Coombes, J. S., & Kingswell, C. (2005). Biomechanical and physiological comparison of conventional webbing and the M83 assault vest. *Applied Ergonomics,36*(1), 49-53. doi:10.1016/j.apergo.2004.09.004

Ershad, N., Kahrizi, S., Abadi, M. F., & Zadeh, S. F. (2009). Evaluation of trunk muscle activity in chronic low back pain patients and healthy individuals during holding loads. *Journal of Back and Musculoskeletal Rehabilitation,22*(3), 165-172. doi:10.3233/bmr-2009-0230

Ferraris, C., Nerino, R., Chimienti, A., Pettiti, G., Cau, N., Cimolin, V., Mauro, A. (2019). Feasibility of Home-Based Automated Assessment of Postural Instability and Lower Limb Impairments in Parkinson's Disease. *Sensors,19*(5), 1129. doi:10.3390/s19051129

Filtness, A., Mitsopoulos-Rubens, E., & Rudin-Brown, C. (2014). Police officer in-vehicle discomfort: Appointments carriage method and vehicle seat features. *Applied Ergonomics,45*(4), 1247-1256. doi:10.1016/j.apergo.2014.03.002

Gyi, D. E., & Porter, J. M. (1998). Musculoskeletal problems and driving in police officers. *Occupational Medicine*,*48*(3), 153-160. doi:10.1093/occmed/48.3.153

Kaufman, K.R., Wyatt, M.P., Sessoms P.H., Grabiner, M.D. (2014). Task-specific fall prevention training is effective for warfighters with transtibial amputations. *Clinical Orthopaedics and Related Research*,472:3076-3084.

Larsen, B., Aisbett, B., & Silk, A. (2016). The Injury Profile of an Australian Specialist Policing Unit. *International Journal of Environmental Research and Public Health*,*13*(4), 370. doi:10.3390/ijerph13040370

Lentz, L., Voaklander, D., Gross, D., Guptill, C., & Senthilselvan, A. (2020). A description of musculoskeletal injuries in a Canadian police service. *International Journal of Occupational Medicine and Environmental Health*, *33*(1), 59–66. doi: 10.13075/ijomeh.1896.01454

Liu, J., & Lockhart, T. E. (2013). Local Dynamic Stability Associated with Load Carrying. *Safety and Health at Work*,*4*(1), 46-51. doi:10.5491/shaw.2013.4.1.46

Lyons, K., Radburn, C., Orr, R., & Pope, R. (2017). A Profile of Injuries Sustained by Law Enforcement Officers: A Critical Review. *International Journal of Environmental Research and Public Health*,*14*(2), 142. doi:10.3390/ijerph14020142

Qu, X., & Yeo, J. C. (2011). Effects of load carriage and fatigue on gait characteristics. *Journal of Biomechanics*,*44*(7), 1259-1263. doi:10.1016/j.jbiomech.2011.02.016

Park, K., Sy, J. F., Horn, G. P., Kesler, R. M., Petrucci, M. N., Rosengren, K. S., & Hsiao-Wecksler, E. T. (2018). Assessing gait changes in firefighters after firefighting activities and while carrying asymmetric loads. *Applied Ergonomics*, *70*, 44–50. doi: 10.1016/j.apergo.2018.01.016

Peoples, G. E., Lee, D. S., Notley, S. R., & Taylor, N. A. (2016). The effects of thoracic load carriage on maximal ambulatory work tolerance and acceptable work durations. *European Journal of Applied Physiology*,*116*(3), 635-646. doi:10.1007/s00421-015-3323-5

Reichard, A. A., & Jackson, L. L. (2009). Occupational injuries among emergency responders. *American Journal of Industrial Medicine*. doi:10.1002/ajim.20772

Rhee, H. Y., Cho, J. H., Seok, J. M., Cho, T. S., Jeon, W. J., Lee, J. G., & Kim, S. K. (2013). Prevalence of Musculoskeletal Disorders Among Korean Police Personnel. *Archives of Environmental & Occupational Health*,*70*(4), 177-188. doi:10.1080/19338244.2013.807762

Rodríguez-Soto, A. E., Jaworski, R., Jensen, A., Niederberger, B., Hargens, A. R., Frank, L. R., Ward, S. R. (2013). Effect of Load Carriage on Lumbar Spine Kinematics. *Spine*,*38*(13). doi:10.1097/brs.0b013e3182913e9f

Schulze, C., Lindner, T., Woitge, S., Finze, S., Mittelmeier, W., & Bader, R. (2013). Effects of Wearing Different Personal Equipment on Force Distribution at the Plantar Surface of the Foot. *The Scientific World Journal*,*2013*, 1-8. doi:10.1155/2013/827671

Silder, A., Delp, S. L., & Besier, T. (2013). Men and women adopt similar walking mechanics and muscle activation patterns during load carriage. *Journal of Biomechanics*, *46*(14), 2522–2528. doi: 10.1016/j.jbiomech.2013.06.020

Stöggl, T., & Martiner, A. (2016). Validation of Moticon's OpenGo sensor insoles during gait, jumps, balance and cross-country skiing specific imitation movements. *Journal of Sports Sciences*, *35*(2), 196–206. doi: 10.1080/02640414.2016.1161205

Sullivan, C. S., & Shimizu, K. T. (1988). Epidemiological Studies of Work-Related Injuries Among Law Enforcement Personnel. *Occupational Medicine*,*38*(1-2), 33-40. doi:10.1093/occmed/38.1-2.33

Watson, J., Payne, R., Chamberlain, A., Jones, R., & Sellers, W. (2008). The energetic costs of load-carrying and the evolution of bipedalism. *Journal of Human Evolution*,*54*(5), 675-683. doi:10.1016/j.jhevol.2007.10.004

6. Figures

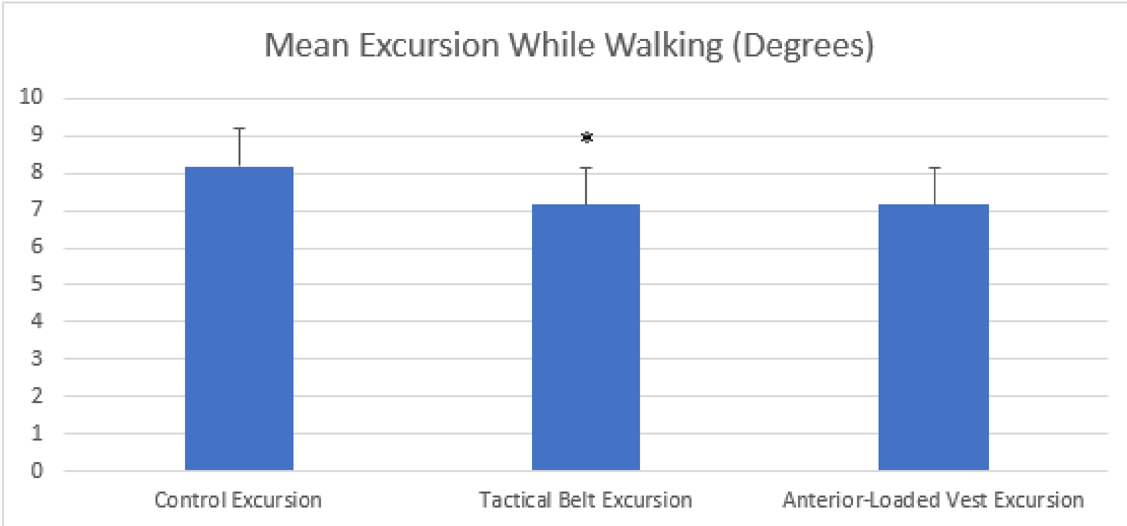

Figure 1: Mean flexion/extension excursion in the sagittal plane while walking. The control condition had the greatest average when compared to both the TB and ALV conditions, but was significantly different to only the TB condition, p=0.002; when control compared to ALV p= 0.507. *denotes significantly different from the control.

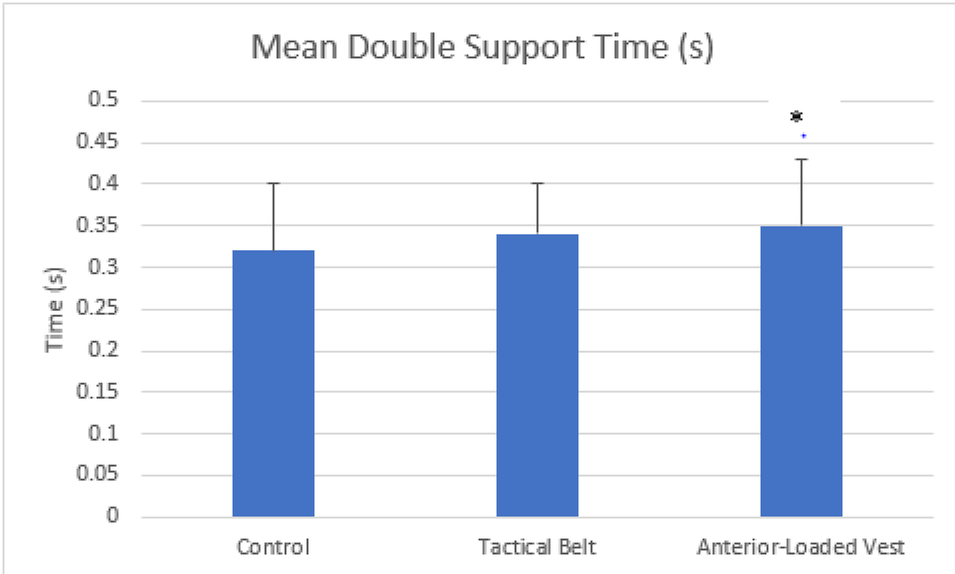

Figure 2: As load was applied to each participant, mean double support time increased compared to the C condition. The ALV was significantly longer when compared to the C condition, p=0.023. *denotes significantly different from the control.

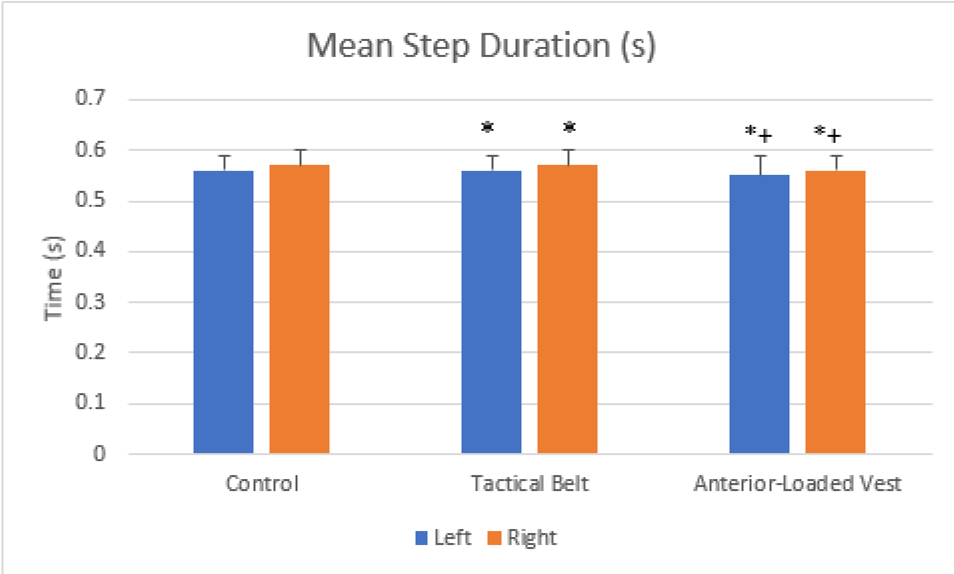

Figure 3: Step duration decreased as weight was applied to the participants with the C condition having the greatest means for both the left and right foot, followed by the TB condition then the ALV condition. The ALV condition was significantly shorter when compared to both the C condition (p= 0.002 for both feet) and the TB condition (p= 0.003 for the left foot and 0.002 for the right foot). *denotes significantly different from the control. +denotes significantly different from the TB.

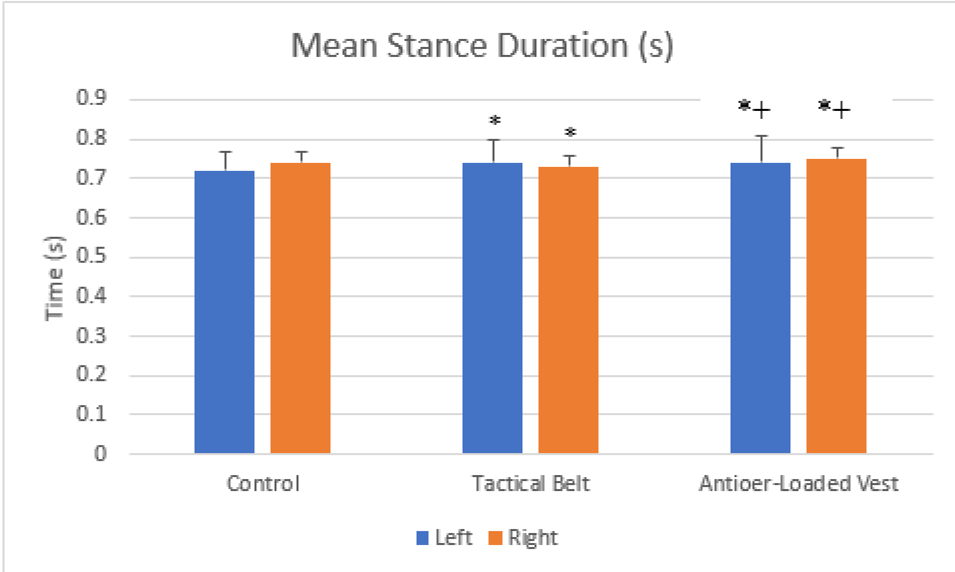

Figure 4: The ALV condition was significantly longer for both the left and right foot when compared to C condition (p= 0.008). When comparing stance duration in the TB condition to the ALV condition, there was a significant longer found in both left and right feet (p= 0.010 and 0.009, respectively). *denotes significantly different from the control. +denotes significantly different from the ALV.

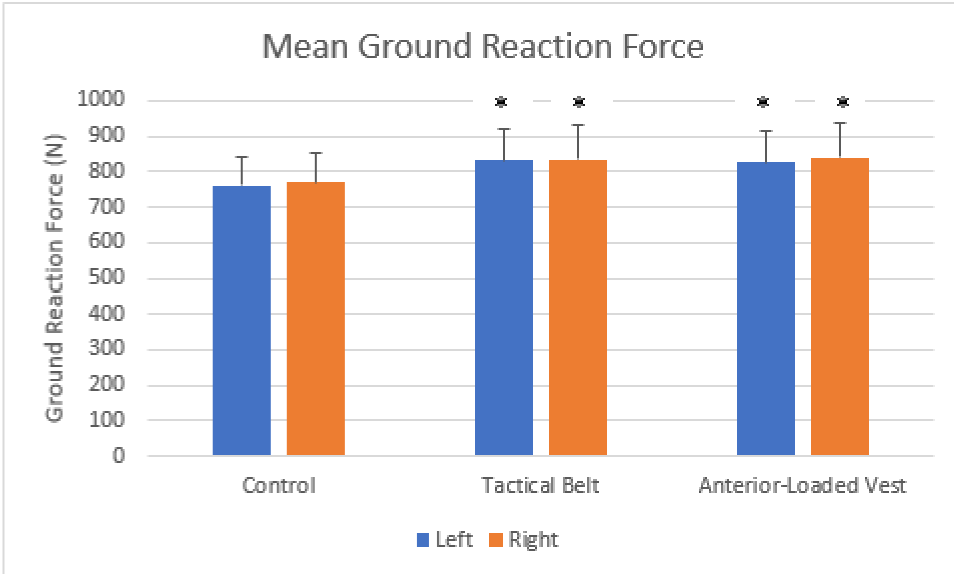

Figure 5: Mean ground reaction while walking with load. Both weighted conditions (TB and ALV) for GRF mean was significantly greater from the control, both with p=0.000. *denotes significantly different from the control.