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# Ankle bracing's effects on lower extremity iEMG activity, force production, and jump height during a Vertical Jump Test: An exploratory study

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ABSTRACT

*Objective:* To determine if softshell (AE) and semi-rigid (T1) ankle braces affect lower extremity iEMG activity, force, and jump height during a Vertical Jump Test.
*Design:* Repeated measures, crossover.
*Setting:* Laboratory.
*Participants:* 42 healthy, active individuals.
*Outcome measures:* Vertical jump height, iEMG activity, peak vGRF.
*Results:* There was significant change across conditions in lateral gastrocnemius (LG) iEMG activity, $F(2,70) = 5.31$, $p = .007$, $\eta p2 = 0.132$, with T1 LG iEMG being significantly less (−2.08(99% CI, −3.98 to 0.18) %MVIC, $p = .004$) than no brace. Significant changes were seen in rectus femoris (RF) iEMG activity, $F(2,68) = 6.36$, $p = .003$, $\eta p2 = 0.158$, with T1 RF iEMG activity being significantly less than AE RF iEMG activity (−2.78(99% CI, −5.36 to −0.19) %MVIC, $p = .005$). There was a significant change in vertical jump height across conditions, $F(2,78) = 22.13$, $p < .0005$, $\eta p2 = 0.362$, with a significant decrease in the AE (−2.41(99% CI, −3.66 to −1.17) cm, $p < .0005$) and T1 conditions (−2.89(99% CI,−4.56 to −1.23) cm, $p < .0005$), compared to no brace.
*Conclusion:* Vertical jump height is significantly reduced when wearing ankle braces. Effects on lower extremity iEMG activity are dependent upon brace type.


## 1. Introduction

Ankle braces are often worn by athletes to help prevent and treat injuries to the ankle (Bahr, Lian, & Bahr, 1997; Kaminski et al., 2013). In high level sport, it is not uncommon for teams to have mandatory "bracing policies" that require all athletes to wear ankle braces, irrespective of their previous history of ankle injury (Pedowitz, Reddy, Parekh, Huffman, & Sennet, 2008). Although ankle braces are proven to be effective in reducing the risk of ankle injuries (Barelds, van den Broek, & Huisstede, 2018), their use in this fashion is not without controversy. Some clinicians have suggested that wearing ankle braces as a prophylactic measure may be detrimental to muscular strength and activation at the ankle (Cordova & Ingersoll, 2003). Furthermore, although the literature is inconclusive, significant decreases in vertical jump height have been identified when wearing ankle braces (Henderson, Sanzo, & Zerpa, 2016; Mann, Gruber, Murphy, & Docherty, 2018; Parsley, Chinn, Lee, Ingersoll, & Hertel, 2013; Smith, Claiborne, & Liberi, 2016). Despite observed decreases in vertical jump height, little is known about the potential changes that occur to lower extremity biomechanics in response to wearing ankle braces during vertical jumping. Specifically, the effect on muscular activation of the lower extremity and production of force during take-off; two factors important for achieving maximum vertical jump height (Aragón-Vargas & Gross, 1997) that may be affected by ankle bracing.

Vertical jump height is highly dependent on the ability to produce force (Aragón-Vargas & Gross, 1997). For optimal force production, this requires a coordinated sequence of biomechanical events involving sequential proximal-distal and/or simultaneous joint reversal and muscular contraction (Aragón-Vargas & Gross,

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1997; Pandy & Zajac, 1991). As the most distal major joint, the ankle and supporting musculature are responsible for producing, as well as transferring energy from proximal segments (Pandy & Zajac, 1991). Thus, forceful plantarflexion is an important component of the vertical jump (Prilutsky & Zatsiorsky, 1994). As the most common mechanism of injury to the ankle is excessive inversion of the foot while in plantarflexion (Martin, Davenport, Paulseth, Wukich, & Godges, 2013), softshell ankle braces are thought to prevent ankle injuries by restricting ankle plantarflexion and supination (Verhagen & Bay, 2010). This restriction of ankle range of motion (ROM) in the sagittal plane by ankle braces has previously been blamed for observed reductions in vertical jump height when wearing softshell ankle braces (Smith et al., 2016). Semi-rigid ankle braces, however, have also been shown to significantly reduce vertical jump height (Henderson et al., 2016), despite allowing for unrestricted sagittal plane motion (West, Ng, & Campbell, 2013). Therefore, vertical jump height may be reduced when wearing ankle braces by mechanical and physiological mechanisms other than restriction of ankle ROM.

While contributing to both plantarflexion and knee flexion, the gastrocnemius muscle only contributes up to 25% of the force generated during a vertical jump (Pandy & Zajac, 1991). Thus, the larger musculature of the hip and knee joints play greater roles in vertical jump height. In their biomechanical analysis of the vertical jump when wearing the ASO® EVO® softshell style ankle brace, Smith et al. (2016) attributed observed decreases in vertical jump height to significant decreases in hip flexion and plantarflexion angles when wearing ankle braces, in addition to a significant reduction in soleus muscle integrated electromyographic activity (iEMG). Surface electromyographic (sEMG) activity, however, was not collected from proximal musculature. As hip flexion angle was altered, though, it is possible that sEMG activity of the hip flexor musculature may have also been affected. Furthermore, Macrum, Bell, Boling, Lewek, and Padua (2012) observed a significant reduction in rectus femoris (RF) sEMG activity when ankle plantarflexion was artificially reduced during the eccentric portion of a squat. Again, given that softshell ankle braces have been shown to significantly restrict ankle plantarflexion during dynamic tasks, this furthers the possibility that changes in the activation of proximal musculature may occur when wearing ankle braces.

Despite observed changes in hip flexion angle during a vertical jump take-off (Smith et al., 2016) and observed reductions in RF sEMG activity during the eccentric portion of a squat (Macrum et al., 2012), only one study has examined the effects of ankle braces on proximal lower extremity musculature during a vertical jump test. In a pilot study of 10 healthy, active individuals, Henderson, Sanzo, Zerpa, and Kivi (2019) observed no significant differences in vertical jump height or sEMG activity of the lower extremity when wearing softshell or semi-rigid ankle braces. There were, however, several tendencies in their data that would appear to warrant further investigation in a larger sample, including similar decreases when wearing semi-rigid and softshell ankle braces in RF and lateral gastrocnemius (LG) sEMG activity, as well as vertical jump height. As such, the primary purpose of the current study was to determine if softshell (ASO® EVO®; AE; Medical Specialties, Inc., Charlotte, NC; Fig. 1) and semi-rigid (Active Ankle T1™; T1; Active Ankle, Akron, OH; Fig. 1) ankle braces affect lower extremity iEMG activity, as well as vertical ground reaction force (vGRF) and vertical jump height during a Vertical Jump Test in healthy, active individuals. This exploratory study will build off the work of Henderson et al. (2019) to determine if ankle bracing affects proximal muscle activation, force production, and vertical jump performance. It was hypothesized that vertical jump height would be significantly decreased when wearing softshell ankle braces and semi-rigid ankle braces. Furthermore, compared to wearing no ankle braces, it was hypothesized that RF and LG iEMG activity, as well as vGRF would significantly decrease in the ankle brace conditions. Given the pervasiveness of ankle brace use in sport, the results of the current study could further the understanding of softshell and semi-rigid ankle bracing's impact on vertical jump height, and provide athletes, coaches, and healthcare providers with insight on their effects on lower extremity iEMG activity and vGRF.

## 2. Method

After ethical approval was granted by the institution's research ethics board, the current study aimed to recruit 42 healthy, active participants. Based on a priori analysis using previous pilot data (Henderson et al., 2019), this sample was determined to be sufficient to detect a medium to large effect size with 80% power at $\alpha = 0.05$ (two-tailed) for vertical jump height. Participant inclusion and exclusion criteria are presented in Table 1. All participants completed a Physical Activity Readiness Questionnaire (CSEP, 2013) and informed consent form prior to participating in the study.

### 2.1. Vertical jump test

The Canadian Society for Exercise Physiology (CSEP) procedures for vertical jump assessment were used in the current study (CSEP, 2013), with the addition of a Vertec™ device. The Vertec™ device has demonstrated good intrasession and intersession reliability for males (Intraclass correlation coefficient; ICC = 0.94; ICC = 0.90) and females (ICC = 0.87; ICC = 0.80) when measuring a countermovement vertical jump height (Nuzzo, Anning, & Scharfenberg, 2011). In short, participants aligned themselves with the Vertec™ device with the dominant extremity next to the device and their feet approximately shoulder width apart. When instructed to complete the jump, participants rapidly descended into a 45-degree semi-squatted position, with the arms acting as a counterweight. Participants visually came to a complete pause in the 45-degree semi-squatted position, before forcefully jumping and hitting the Vertec™ device with the dominant arm as high as they could.

### 2.2. Surface electromyography and force platform

sEMG and vGRF data were collected during the Vertical Jump Test via a 16 channel Delsys (Salford, UK) Trigno™ Wireless EMG system, Delsys Trigno™ IM sensors, and an Advanced Medical Technology Incorporated (AMTI) force platform (Watertown, MA). sEMG has demonstrated high reliability (ICCs greater than 0.80) when measuring quadriceps and hamstring EMG activity during dynamic tasks (Fauth, Petushek, Feldmann, Hsu, & Garceau, 2010), while the AMTI force platform has demonstrated excellent reliability when assessing vertical jumping (Cordova & Armstrong, 1996). All sEMG and force platform data were collected simultaneously in LabChart® (ADInstruments, Colorado Springs, USA) software via a PowerLab (ADInstruments, Colorado Springs, USA) 16/30 data acquisition unit. Raw sEMG data were collected from the LG, peroneus longus (PL), biceps femoris (BF), RF, and gluteus medius (GM) muscles. All sEMG and vGRF data were sampled at 1000 Hz. sEMG data was amplified (1000 gain), bandpass filtered (10–500 Hz), and subsequently lowpass filtered (10 Hz) and full wave rectified to create a linear envelope. vGRF were measured in Volts (V). These values were then converted to Newtons (N); an external load cell was regularly used to calibrate the force platform and determine the appropriate V to N ratio in LabChart®.


**Fig. 1.** (A) ASO® EVO® softshell ankle brace; (B) Active Ankle T1™ semi-rigid ankle brace.

**Table 1**
Participant inclusion and exclusion criteria.

| Inclusion | Exclusion |
|---|---|
| 1.18–30 years old | 1. Were diagnosed or self-reported ankle injury over the last 6 months (e.g., sprain, fracture, tendonitis) |
| 2. Participated in at least 150 min of moderate to vigorous aerobic activity each week | 2. Were currently suffering from an acute and/or chronic lower extremity or lumbar spine injury (i.e., strain or sprain) that precluded them from participating in jumping activities |
| 3. Had previous experience with “jumping” and/or “cutting” sports (i.e., basketball, volleyball, soccer) | 3. Had undergone any lower extremity or lumbar spine surgical procedure in the last six months |
| | 4. Were allergic or sensitive to adhesive tape, or any of the material present in the AE and T1 ankle braces (i.e., Velcro or plastic) |

### 2.3. Protocol

Data were collected during one, 60 min session. Participants were assigned to one of six experimental orders, involving a total of three conditions (no brace, AE, and T1; see Table 2). Participants completed a 5 min warm-up on a cycle ergometer at an intensity of 10–12 on the Borg Rate of Perceived Exertion Scale. Following the warm-up, an IM wireless electrode was applied to the PL, LG, BR, RF, and GM muscles of the participants’ dominant lower extremity (SENIAM, 2016), defined as the foot the participant would kick a ball with. Preparation of the skin and application of the electrodes were based on the DELSYS™ guidelines (Delsys Inc., 2012). After the application of each electrode, participants performed a maximum voluntary isometric contraction (MVIC) for each muscle, where sEMG data were collected for 3 s from the start of the contraction.

After the application of electrodes and performance of MVICs, participants applied ankle braces if needed (based on the assigned intervention order). Ankle braces were sized and applied by the participants based on the manufacturer's guidelines. The application of all braces was supervised by the researchers to ensure braces were applied properly. Participants were allowed to adjust the ankle braces during the testing session, if required, to maintain the manufacturer's described fit. Ankle braces were applied without modifying participants' normal training shoes.

**Table 2**
Intervention sequences.

| Order | Sequence |
|---|---|
| 1 | no brace, AE, T1 |
| 2 | no brace, T1, AE |
| 3 | AE, no brace, T1 |
| 4 | AE, T1, no brace |
| 5 | T1, no brace, AE |
| 6 | T1, AE, no brace |

Following the application of any ankle braces, participants were introduced to the Vertical Jump Test via verbal and visual coaching. The Vertical Jump Test was performed with only the participants' dominant foot in contact with the force platform. If necessary, the position of the Vertec™ device was adjusted so that it was an appropriate distance from the participants. A diagram (CSEP, 2013), as well as a visual demonstration of the Vertical Jump Test was provided by the researcher. A maximum of five submaximal attempts were allowed for participants to become comfortable with the test, ensure equipment was in working order, and allow the researchers to provide internal and external feedback regarding the participant's form. Once participants were familiar with the test, they performed the first of three recorded trials. To begin the test, the researchers began collecting sEMG and vGRF data and notified the participant; when the participant was ready, they performed a maximal effort jump. The participant then performed the test for two more recorded trials, spaced approximately 1 min apart.

After completing the Vertical Jump Test under the first condition, a 5 min rest period was provided to participants. The purpose of this rest period was to allow participants to transition to the next component of the testing protocol and allow for physical recovery. If the application of ankle braces was required, participants did so during this time. Once the participants transitioned to the next condition, testing procedures mirrored that of the first condition, as described in detail previously. After the completion of the second set of trials, another 5 min rest period took place, allowing the participants to transition to the last condition. Testing procedures followed the same procedures outlined for the previous two conditions. The testing session concluded with a 5 min cooldown on a cycle ergometer.

### 2.4. Statistical analysis

To normalize vertical jump height, flat-footed standing reach height was subtracted from the participant's highest measured jump. The participant's highest jump was then used for jump height, sEMG, and vGRF analysis (Smith et al., 2016).

All sEMG and vGRF data were processed for the take-off phase with LabChart® software. The take-off phase for the vertical jump test was determined by examining vGRF data; the take-off phase was considered to be the time at which participant's centre of mass reached peak downward acceleration, to the point at which system weight equalled 0 N (Linthorne, 2001). iEMGwas then calculated as a measure of muscle activity (Kamen & Gabriel, 2010) for the PL, LG, BF, RF, and GM muscles during the take-off phase, as well as peak vGRF. iEMG data for each muscle during the Vertical Jump Test was then expressed as a percentage of the participant's 3 s integrated MVIC, and peak vGRF was expressed as percentage of bodyweight. These values were then used for statistical analysis.

The current study was a crossover, repeated measures study design with 1 within subjects factor (brace type) consisting of 3 levels (no brace control, AE ankle brace, T1 ankle brace). As such, a one-way analysis of variance (ANOVA) for repeated measures was conducted to determine the effect of brace type on 7 dependant variables: peak vertical jump height, iEMG of the PL, LG, BF, RF, and GM muscles, and peak vGRF. Due to multiple comparisons and to minimize the risk of type I error, a Bonferroni correction ($p < .05/7$) was applied a priori, resulting in an $\alpha$ level of .007 for all variables. If significant differences were present, a Bonferroni post hoc test was conducted to determine any pairwise differences. Prior to inferential analysis, all outliers were determined by boxplot inspection and were removed if they were found to significantly affect the results. All data was visually inspected and removed if considered to be the result of participant or equipment error (i.e., signals beyond physiological norms, as the result of electrode detachment or participant hitting the electrode). One participant was removed from the analysis due to the braces not fitting properly into their normal training shoe. Statistical analysis was conducted in SPSS Statistics (Version 25; IBM, Armonk, New York).

## 3. Results

### 3.1. Participants

42 healthy, active individuals were recruited into the study. Demographic information is presented in Table 3.

### 3.2. iEMG activity

Means and standard deviations are presented in Fig. 2. Number of participants analysed for each variable are presented as (n = ). There was no statistically significant change in PL iEMG activity (n = 32) across conditions, $F(2,62) = 1.68$, $p = .194$. There was a statistically significant change across conditions in LG iEMG activity (n = 36), $F(2,70) = 5.31$, $p = .007$, $\eta p^2 = 0.132$. Post hoc analysis revealed a significant decrease in LG iEMG activity in the T1 condition (−2.08 (99% CI, −3.98 to 0.18) %MVC, $p = .004$), compared to the no brace condition. There was no statistically significant change in BF iEMG activity (n = 34), $F(2,66) = 0.17$, $p = .845$. There was a statistically significant change across conditions in RF iEMG activity (n = 35), $F(2,68) = 6.36$, $p = .003$, $\eta p^2 = 0.158$. Post hoc analysis revealed a significant decrease in RF iEMG activity in the T1 condition, compared to the AE condition (−2.78 (99% CI −5.36 to −0.19) %MVC, $p = .005$). There was no statistically significant change in GM iEMG activity (n = 35), $F(2,47.29) = 1.22$, $p = .291$; see Fig. 2.

**Table 3**
Participant demographics.

| Variable | Total |
|---|---|
| Sex | 23 male, 19 female |
| Height (cm) | 174.47 ± 8.06 |
| Mass (kg) | 77.8 ± 13.31 |
| Age (years) | 22.16 ± 1.88 |
| Dominant Foot | 37 right, 5 left |

### 3.3. Vertical ground reaction force

Means and standard deviations are presented in Fig. 3. There was no statistically significant change in peak vGRF (n = 39), $F(2, 76) = 0.08$, $p = .920$; see Fig. 3.

### 3.4. Vertical jump height

Means and standard deviations are presented in Fig. 4. There was a statistically significant change in peak vertical jump height (n = 40) across conditions, $F(2,78) = 22.130$, $p < .0005$, $\eta p^2 = 0.362$. Post hoc analysis revealed a significant decrease in peak vertical jump height in the AE condition (−2.41 (99% CI, −3.66 to −1.17) cm, $p < .0005$) and T1 condition (−2.89 (99% CI, −4.56 to −1.23) cm, $p < .0005$), compared to the no brace conditions ;see Fig. 4.

## 4. Discussion

The aim of the current study was to determine if softshell (AE) and semi-rigid (T1) ankle braces affected lower extremity iEMG activity, peak vGRF, and peak vertical jump height during a Vertical Jump Test in healthy, active individuals. There was a statistically significant decrease in peak vertical jump height of 2.41 cm when wearing the AE softshell and 2.89 cm when wearing the T1 semi-rigid ankle braces, relative to wearing no ankle braces. Additionally, there was a significant decrease in LG iEMG activity of 2.08 % MVC when wearing the T1 ankle braces, relative to no ankle braces. A significant decrease in RF iEMG activity of 2.28 %MVC was also present when wearing the T1 ankle braces, compared to the AE ankle braces.

Although previous studies found no effect of ankle braces on vertical jump height, more recent research has identified significant decreases in vertical jump height when wearing softshell and semi-rigid ankle braces, with decreases ranging from 1.4 cm (Parsley et al., 2013) when wearing softshell ankle braces to 2.35 cm when wearing semi-rigid ankle braces (Henderson et al., 2016). One potential reason for the large variability in study results are differences in both the methodology and model of braces used. The current study, however, utilized the same Vertical Jump Test and ankle brace models as Henderson et al. (2016) and reproduced the methodology of Henderson et al. (2019). Henderson et al. (2016) observed a decrease of 1.47 cm when wearing AE ankle braces, and, in line with the current study, a significant decrease of 2.35 cm when wearing T1 ankle braces. While not significant, Henderson et al. (2019) also observed a similar tendency for vertical jump height to decrease across the AE and T1 conditions. Although the magnitude of change was not the same in these studies, the sample size was much lower (n = 10 and n = 14, respectively) than the

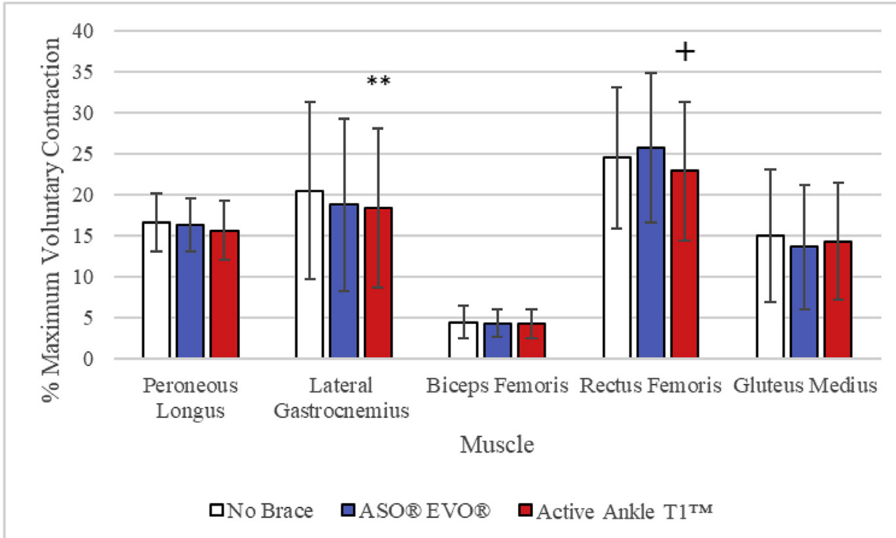


**Fig. 2.** iEMG activity across conditions. ** Significant difference compared to no brace condition ($p < .007$). + Significant difference compared to ASO® EVO® brace condition ($p < .007$).

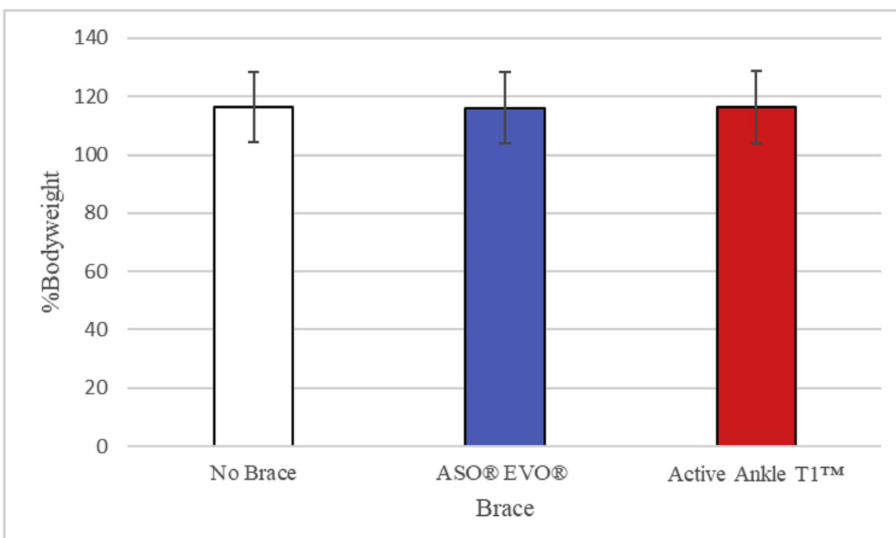


**Fig. 3.** Mean peak vertical ground reaction force across conditions.

current study (n = 40). As such, with respect to vertical jump height, the current methodology appears to consistently result in decreases in vertical jump height when wearing AE and T1 ankle braces, with T1 ankle braces producing greater decreases than the AE ankle braces, relative to no braces.

Regarding lower extremity iEMG activity, the lack of a significant decrease in LG iEMG activity when wearing the AE ankle braces was unexpected and did not support the initial hypothesis, although the results were in line with previous research. Smith et al. (2016) observed a decrease in iEMG activity of the plantarflexor musculature when wearing the AE ankle braces during a vertical jump. Specifically, a nonsignificant decrease in gastrocnemius muscle iEMG activity and a significant decrease in soleus muscle iEMG activity. As the AE ankle braces were observed to significantly restrict plantarflexion ROM, this was hypothesized by Smith, Claiborne, and Liberi (2014) to result in decreased iEMG activity due to reduced lengthening and of the plantarflexor musculature. Due to the LG being a biarticulated muscle, contributing to both plantarflexion and knee flexion (Tortora & Nielson, 2010), a restriction of only plantarflexion may not have been enough to elicit a detectable change in muscle length or activity in the current study.

Unlike the AE ankle braces, the T1 ankle braces produced a significant decrease in LG iEMG activity. Given that softshell ankle braces have been shown to restrict plantarflexion more than semi-rigid ankle braces during dynamic tasks (Cordova, Takahashi, Kress, Brucker, & Finch, 2010; Tamura et al., 2017), the significant decrease in LG iEMG activity when wearing the T1 ankle brace cannot be explained by reduced plantarflexion ROM. Alternatively, the differences in LG iEMG activity may be influenced by the design differences of the braces, specifically the hinge and heel pad of the T1. The heel and sole of the foot are highly sensitive to cutaneous and tactile stimulation, due to the presence of Meissner's corpuscles, Pacinian corpuscles, Merkel disk receptors, and Ruffini endings

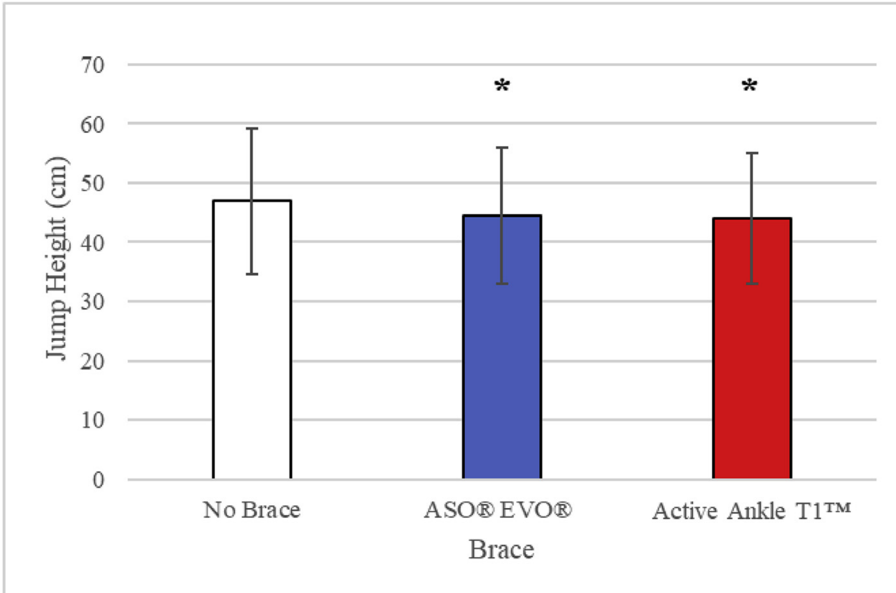


**Fig. 4.** Mean peak vertical jump height across conditions. * Significant difference compared to no brace condition ($p < .007$).

(Zehr et al., 2014). Increased tactile stimulation has been noted to result in facilitation of the tibialis anterior muscle (TA; Zehr et al., 2014), which is the antagonistic muscle to the LG (Tortora & Nielson, 2010). If the heel pad on the T1 ankle braces increased cutaneous feedback, the resulting TA facilitation would potentially result in the antagonistic LG muscle being inhibited, potentially explaining the reduction in LG iEMG activity. As TA sEMG data was not collected in the current study, however, it is unknown if this facilitation/inhibition relationship was present.

In combination with a reduction in plantarflexion ROM and plantarflexor iEMG activity, Smith et al. (2016) suggested that changes in hip kinematics also contributed to decreased vertical jump height when wearing AE ankle braces, although they did not collect sEMG data of the proximal leg musculature, specifically of the knee and hip. While kinematic data was not collected in the current study, there was a significant difference in RF iEMG activity between the AE and T1 ankle braces, with the AE ankle brace producing more RF iEMG activity and the T1 ankle brace producing less iEMG activity when compared to the no brace condition, respectively. As the RF muscle contributes to hip flexion and knee extension, this may indicate changes in the kinematics of the hip and knee. In turn, as forceful hip extension and knee flexion are important to achieve maximum vertical jump height (Aragón-Vargas & Gross, 1997), the altered RF iEMG activity may be contributing to the decrease in vertical jump height observed in the current study when wearing ankle braces.

While it is logical to suggest that the decrease in RF iEMG activity when wearing the T1 ankle braces may result in decreased peak vertical jump height, the similar decrease in peak vertical jump height and relative increase in RF iEMG activity when wearing the AE ankle braces does not support this rationale. Furthermore, the lack of a significant decrease in RF iEMG activity when wearing the AE ankle braces did not support the hypothesis that RF iEMG activity would decrease as a result of reduced plantarflexion ROM. Assuming that the AE ankle braces restrict plantarflexion ROM, while the T1 ankle braces allow for unrestricted plantarflexion, this again would suggest that there is a mechanism other than ROM restriction at the ankle causing changes in RF iEMG activity. Ankle bracing has been hypothesized to improve proprioception at the ankle, by increasing afferent feedback (Olmsted, Vela, Denegar, & Hertel, 2004) via increased stimulation to the cutaneous receptors (Feuerbach, Grabiner, Koh, & Weiker, 1994). As vertical jumping relies on both reflex and preprogramed mechanisms, the former being dependent on afferent feedback (Taube , Leukel, & Gollhofer , 2012), alteration in afferent feedback by ankle braces may affect vertical jump biomechanics, specifically timing and co-ordination of muscular activation. Given the importance of sequential proximal-distal and/or simultaneous joint reversal and muscular contraction (Aragón-Vargas & Gross, 1997; Pandy & Zajac, 1991), this may suggest that timing of muscular activation is being affected in both brace conditions. As the current study did not examine onset of muscular activation, however, this rationale is speculative.

As vertical jump height decreased across brace conditions, the lack of a decrease in peak vGRF was unexpected. As force production is an important component of a vertical jump (Aragón-Vargas and Gross), it was hypothesized that vGRF would decrease alongside vertical jump height. Based on the results of the current study, however, this was not the case. This may be due to a limitation of the study, in that iEMG activity and kinetic data was only collected for the dominant extremity. Therefore, it is possible that force may have been reduced in the non-dominant extremity, which resulted in a decrease in vertical jump height when wearing ankle braces. Furthermore, the Vertec™ device is only capable of measuring vertical jump height in 1.27 cm increments. As such, it is possible the participants true jump height may be up to 1.26 cm higher, or lower, than what was recorded by the Vertec™ device.

Additional limitations of the current study include the choice of protocol for the Vertical Jump Test. Although an established protocol, due to the pause component of the test, the external validity of the test is likely limited in an athletic setting. The incorporation of the pause removed the contribution of the stretch shortening cycle, which, in an athletic setting, athletes try to maximize (Hamill et al., 2015). As such, the ecological validity of the study may be reduced using the current protocol. Furthermore, the type of shoe was not controlled between participants; however, participants wore the same shoe for each testing sessions. Previous literature has indicated that sEMG activity of the soleus muscle during vertical jumping can be affected by shoe type, due to varying levels of ROM restriction and stiffness provided by minimalist and crosstraining footwear (Harry et al., 2015). As such, it is possible that the participants' footwear, in combination with the ankle braces, may affect ROM and thus vertical jump height and lower extremity iEMG activity.

### 4.1. Clinical implications

Currently, the National Athletic Trainers Association only recommends that players returning to play from an ankle sprain do so with the support of an external ankle support (Kaminski et al., 2013). Furthermore, a recent consensus statement from the British Journal of Sports Medicine on ankle sprain prevention, treatment, and diagnosis emphasized that, based on the current evidence, the use of external ankle support should be based on personal preference (Vuurberg et al., 2018). Based on this recommendation, the current study presents potential negative effects of ankle braces on vertical jump height. The results of the current study, however, suggest that the effects of ankle braces on iEMG activity and biomechanics are complex. Therefore, athletes, coaches, and healthcare providers should consider the use of ankle braces as a prophylactic measure in the context of the overall body of literature, personal preference, and clinical or coaching expertise.

## 5. Conclusion

The results of the current study support previous research indicating that vertical jump height is significantly reduced when wearing softshell and semi-rigid ankle braces in a laboratory setting. Furthermore, this study is the first to suggest that iEMG activity of proximal and distal leg musculature may be significantly affected, depending on the ankle brace type, during vertical jumping. Further, more comprehensive research incorporating kinematic, kinetic, and EMG measures is needed to determine the extent to which potential biomechanical and neuromuscular changes when wearing ankle braces contribute to reductions in vertical jump height. Additionally, further research should utilize more externally valid measures to assess the impact on sport performance. In the meantime, athletes, coaches, and healthcare providers should continue to use and prescribe ankle braces when warranted but should be aware of the potential impact on vertical jump height and lower extremity muscular activation.

## Declaration of interest

The authors declare no conflict of interest.

## Ethical approval

The current study was approved by the Lakehead University Research Ethics Board. All participants gave informed consent prior to participating in the current study.


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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ptsp.2019.04.002.

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