EVALUATION OF THE ANKLE ROLL GUARD'S EFFECTIVENESS TO IMPROVE ITS CLINICAL BENEFIT

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INTRODUCTION

The ankle is the most commonly injured structure in sports and recreation (Garrick, 1977). Ankle injuries usually occur from a sudden inversion of the ankle (i.e. sole of the foot directed inward greater than 30 degrees). To prevent these injuries, health practitioners and athletes use prophylactic products, such as an external brace or athletic tape. These prophylactic products add mechanical stability to the joint to prevent excessive inversion, and subsequent injury. Specifically, the objective of these prophylactic products is to restrict the range of ankle inversion, while not restricting other motions (such as, plantar- and dorsi-flexion) at the joint (Bot and Van Mechelen, 1999). Ankle prophylactic products are reportedly effective at reducing the frequency of joint injury (Alves et al., 1992; Jerosch et al., 1996; Shapiro et al., 1994). To reduce the frequency of joint injury, these products add the mechanical stability sufficient to significantly alter static and dynamic ankle position (Vaes et al., 1998), reduce maximum ankle inversion angle and velocity (Anderson et al., 1995; Bruns et al., 1996; Eils and Rosenbaum, 2003), and increase the time to reach peak ankle inversion when compared to unbraced (control) ankles (Anderson et al., 1995). However, the ability to add mechanical stability, and prevent initial ankle injury or re-injury is reportedly dependent on the design of the specific prophylactic device worn.

Nearly 50 percent of all athletes who suffer an initial ankle injury go on to develop chronic ankle instability from repeated re-injury of the joint (Braun, 1999). Existing prophylactic products reportedly add mechanical stability to the ankle, but may not prevent re-injury. In fact, the use of an ankle prophylactic product may actually increase the likelihood of re-injury. Existing ankle prophylactics are reported to restrict other joint motions (plantar- and dorsi-flexion), while limiting the ankle inversion that leads to joint injury (McCaw and Cerullo, 1999). Consequently, existing ankle prophylactic devices may impair the functional capacity of the joint, leading to increased re-injury and chronic instability. Considering chronic ankle instability costs 2 billion dollars annually to treat (Soboroff et al., 1984) and also results in diminished health-related quality of life, often leading to osteoarthritis and joint replacement later in life (Arnold et al., 2011; Valderrabano et al., 2006), it is imperative to develop ankle prophylactic devices that prevent repeated re-injury of the joint and development of this instability.

The etiology of chronic ankle instability is a multifactorial issue that stems from a combination of mechanical and functional instabilities of the joint (Gutierrez et al., 2009). Existing prophylactic products reportedly may not provide mechanical stability to the ankle without impairing the functional capacity of the ankle, as evidenced by a reduction in whole-body performance. Specifically, ankle prophylactic products are purported to produce a significant decrease in whole-body functional performance, including: impaired balance (Bennell and Goldie, 1994), reduced maximum vertical jump height (Metcalfe et al., 1997; Paris, 1992) and increased time to perform an agility test (Metcalfe et al., 1997; Rosenbaum et al., 2005). Although, the reduction of whole-body performance when wearing an ankle prophylactic product is not consistent across all studies (Gross et al., 1994; Gross et al., 1997; Hardy et al., 2008), the functional ability of the "wearer" may depend on the specific ankle prophylactic worn. Ankle prophylactic products that significantly constrain the other motions of the ankle joint (i.e., plantar- and dorsi-flexion) may contribute to decrement in functional capacity of the joint, and whole-body performance for the

individual. Wearing an ankle prophylactic that restricts other ankle motions, subsequently changes the activation of the underlying muscles potentially limiting the joint (Barlow et al., 2015). This limitation may subsequently prevent the restoration of proprioceptive, neuromuscular, and sensorimotor capabilities necessary for healthy joint function with the use of existing prophylactic products on an injured ankle. Therefore, existing prophylactic device designs may contribute to a high rate of re-injury and lead to the development of chronic ankle instability in users as time passes.

The ideal ankle prophylactic product would not restrict the typical anatomical joint motions, but rather only prevent excessive joint motion at the anatomical limit - positions where ligament damage, and subsequent injury begins (Garrick and Requa, 1973). This design would: (a) prevent excessive ankle inversion that leads to initial and re-injury of the joint, while (b) not impairing joint and whole-body functional performance, potentially leading to a reducing the development of chronic ankle instability. With that in mind, an innovative prophylactic product – Ankle Roll Guard – was recently patented (Figure 1). The Ankle Roll Guard is a new orthopedic product designed to alleviate the problems associated with existing prophylactic devices. To alleviate the prevailing issues of existing ankle prophylactic products, the Ankle Roll Guard seeks to provide mechanical stability to the joint by using a lightweight buttress on the lateral aspect of the shoe to prevent inversion of the ankle. This novel design results in a device that allows the user to maintain normal ankle motion (i.e., typical anatomical joint motions) and functional capacity of the joint. Yet, still adds the mechanical stability necessary to prevent injury of the ankle. The Ankle Roll Guard, LLC, however, currently lacks verifiable and independent scientific data on the effectiveness of their prophylactic product. There is a critical need to quantify the Ankle Roll Guard effectiveness, and compare its effectiveness with existing prophylactic products. With that in mind, this effort sought to quantify and compare the Ankle Roll Guard's effectiveness with existing prophylactic products during a sudden ankle inversion event and performance of functional tasks.

METHODOLOGY

Participants:

Twenty recreationally active people participated in this study (Table 1). Participants were required to be 5 or higher on the Tegner Scale. Any potential participant that reported current pain or recent injury to the back or lower extremity (previous six months), history of back or lower extremity (hip, knee or ankle) injury or surgery, and/or any known neurological disorder was excluded. Prior to testing, research approval was obtained from the local institutional review board and all participants provided written informed consent.

Table 1: Subject Demographics (n = 24).

Age	21.0 ± 2.4 years
Height (m)	1.7 ± 0.8 m
Weight (kg)	72.0 ± 11.4 kg
Tegner	6.5 ± 1.1

Testing Procedures:

Each participant completed two separate test sessions. Each test session was performed at the Center for Orthopaedic and Biomechanics Research (COBR) at Boise State University. During each test session, participants completed the study tasks with two different conditions. The conditions included four different ankle prophylactic devices: Ankle Roll Guard (ARG), Medspec ASO Ankle Stabilizer (Brace), Closed Basket Weave Athletic Tape (Tape), and no prophylactic device (Control) (Figure 1). To avoid bias and confounding the data, the sequence of testing each condition was randomly assigned to each participant prior to beginning the study from a 4 x 4 Latin square.

With each condition, participants completed a sudden inversion event and a battery of functional tasks. The functional tasks included: over-ground running, single-leg cutting, vertical jump, drop landing, and single-leg balance. For this white paper, only the sudden inversion and vertical jump have been analyzed and therefore, we have only provided a description of those tasks in this report. The order the tasks executed during each biomechanical testing session was randomized using a 5 x 5 Latin square prior to beginning the study.

Figure 1: The four ankle prophylactic devices included: Ankle Roll Guard (ARG) (A), Medspec ASO Ankle Stabilizer (Brace) (B), Closed Basket Weave Athletic Tape (Tape) (C), and no prophylactic device (Control) (not pictured).

For the sudden inversion event, participants were required to stand on a wooden platform, similar to Hopkins et al. (2007). On the wooden platform participants stood with feet shoulder width apart, arms to the side, and looking straight ahead (Figure 2). The wooden platform contains side-by-side trap doors that rotate inward to 30 degrees when released, allowing the ankle to invert from a neutral standing position (Hopkins et al., 2009; Hopkins et al., 2007). Randomly, a research assistant removed the mechanical support of one trap door, allowing the door to fall producing a sudden ankle inversion. Adhesive, non-slip strips on each trap door marked appropriate foot placement and prevented the foot from slipping when the trap door falls. Each participant performed five successful trials of the sudden inversion event with each leg, but only dominant limb (braced ankle) has been included in this analysis.

A. B.

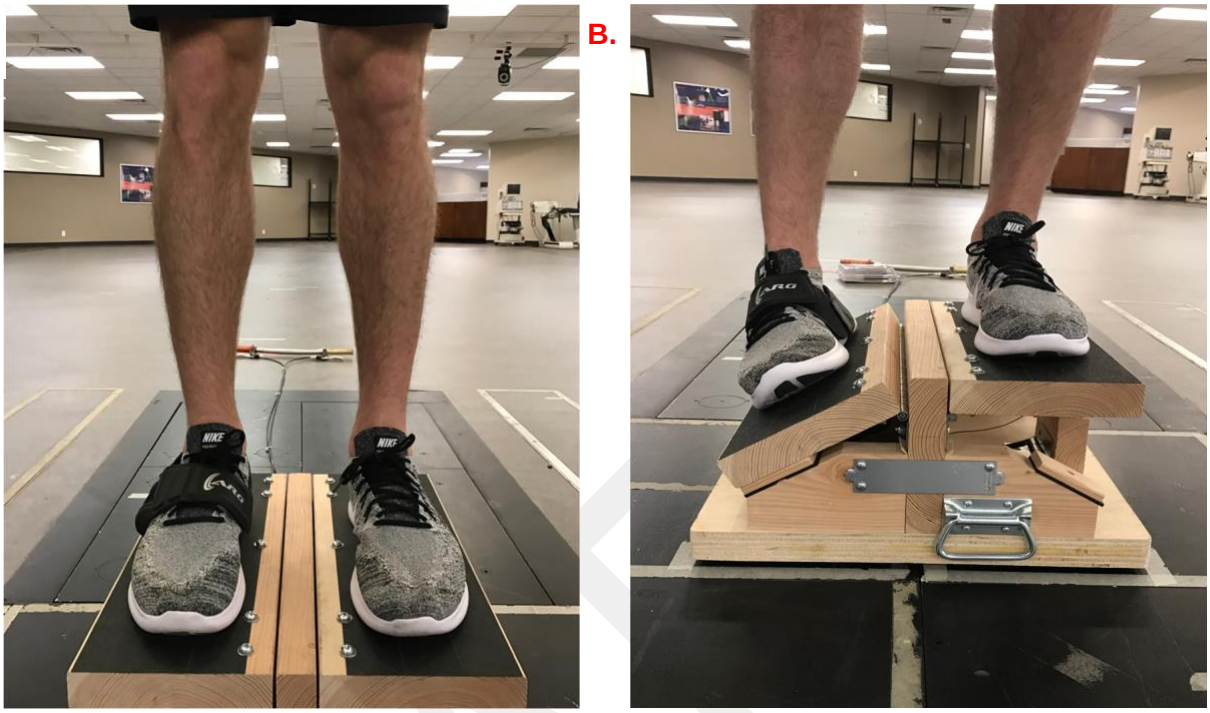

Figure 2: For the sudden inversion event, participants stood with feet shoulder width apart on a wooden platform that contained trap doors under each foot (A). Then, a researcher randomly dropped one of the trap doors, causing the ankle to invert 30° (B).

For the vertical jump, each participant performed three maximal countermovement jumps. Each jump required the participant start in athletic position, with feet shoulder width apart on side-by-side force platforms, and bend down into a squatting position before performing a maximal effort vertical jump. Vertical jump height (m) was determined by the time in air, which was defined as period between take-off and landing of the vertical jump:

Height (m) = 1⁄2g(t⁄2)^2; where g = 9.81 m/s^2, t = time in air (s)

Biomechanical Analysis:

During each task, participants had dominant limb lower limb 3D biomechanical data recorded. To record biomechanical data, a force platform (OR-6, AMTI, Watertown, MA, USA) quantified ground reaction force (GRF) data at 2400 Hz, while eight high-speed (240 fps) optical cameras (Vicon, Oxford, UK) captured 3D marker trajectories.

Dominant limb biomechanical data were quantified from the 3D trajectories of 32 retro-reflective skin markers (Table 2). Each marker was secured to a specific landmark with double-sided and elastic tape by a single experimenter (WDI). After securing each marker, participants stood in anatomical position to create a kinematic model with Visual 3D v5.00 (C-Motion, Rockville, MD). The kinematic model had 24 degrees of freedom (DoF) and included seven skeletal segments (bilateral foot, shank and thigh, and pelvis segments). For each segment of the kinematic model, the orthogonal axes of rotation were specified using a joint coordinate system and arranged so that the x-axis was the medial-lateral axis, y-axis was the anterior-posterior axis

and z-axis was the vertical axis. The orthogonal axes of each segment were used to calculate 3D joint angles. For the kinematic model, the pelvis segment had six (three translational and three rotational) DoF and was defined with respect to the global coordinate system. The hip had a functional joint center was calculated according to Schwartz and Rozumalski (2005) and assigned a local coordinate system with 3 DoF. The knee and ankle had three DoF with joint centers and local coordinate systems defined according to Grood and Suntay (1983) and Wu (2002), respectively.

Table 2: Placement of retro-reflective marker (~ 14 mm) for the kinematic model.

Segment	Markers
Pelvis:	**posterior superior iliac spine**, **anterior superior iliac spine**, superior iliac crest
Thigh:	greater trochanter, **medial and lateral femoral epicondyles**, anterior thigh
Shank:	tibia tuberosity, lateral fibula, distal tibia, **medial and lateral malleoli**,
Foot:	**calcaneus**, middle cuneiform, **first and fifth metatarsal heads**

Bold: denotes markers used for calibration.

For each task, the GRF data and marker trajectories recorded during each trial were low pass filtered with a fourth-order Butterworth filter at a cut-off frequency of 12 Hz. The filtered 3D marker trajectories were then processed to solve joint rotations at each time frame in Visual 3D. Each joint rotation was expressed relative to each participant's anatomical position. During the sudden inversion, the ankle kinematics were time-normalized to 100% of the sudden inversion event and re-sampled at 1% increments (N = 101).

Using a conventional inverse dynamics approach and segmental inertial properties defined in accordance with Dempster (1959), the filtered kinematic and GRF data were processed to obtain intersegmental moments at the hip, knee and ankle (Winter, 2005). For the vertical jump, hip, knee and ankle joint moments were multiplied with the joint angular velocity to calculate joint power then integrated with respect to time to obtain discrete periods of positive and negative mechanical work. From the discrete periods of mechanical work, the total positive joint work at the ankle was calculated from initiation of the countermovement until take-off of the jump.

Statistical Analysis:

For the sudden inversion event, ankle kinematics related to the excessive inversion implicated in injury of the ankle were selected for statistical comparison. For analysis, peak ankle inversion angle (°), range (peak angle – initial angle) of ankle inversion and plantarflexion (°), and time to peak ankle inversion (sec) were calculated during the sudden inversion event (0% - 100%). For the vertical jump, parameters related to functional joint and whole-body performance were selected for statistical comparison. Specifically, jump height (m), range (peak angle – initial angle) of ankle plantarflexion, and total positive work (J) at the ankle were calculated for statistical comparison. For each participant, the dependent variables were averaged across all successful trials to create a subject-based mean. The subject-based means was then submitted to separate one-way repeated measures ANOVA to test the effect of each ankle prophylactic (ARG, Brace, Control and Tape). In instances where statistically significant differences between

ankle prophylactics were observed, a Bonferroni correction procedure was used. Further, Pearson correlations were run to determine whether functional performance of the ankle (total positive work) had a significant relation to whole-body performance (jump height) during the vertical jump. All statistical analyses were performed using SPSS v24.0 software (IBM, Armonk, NY, USA) with alpha level set *a priori* at 0.05 to denote statistical significance.

RESULTS

Sudden Inversion:

The ankle inversion angle quantified during the sudden inversion event for each ankle prophylactic is presented in Figure 3.

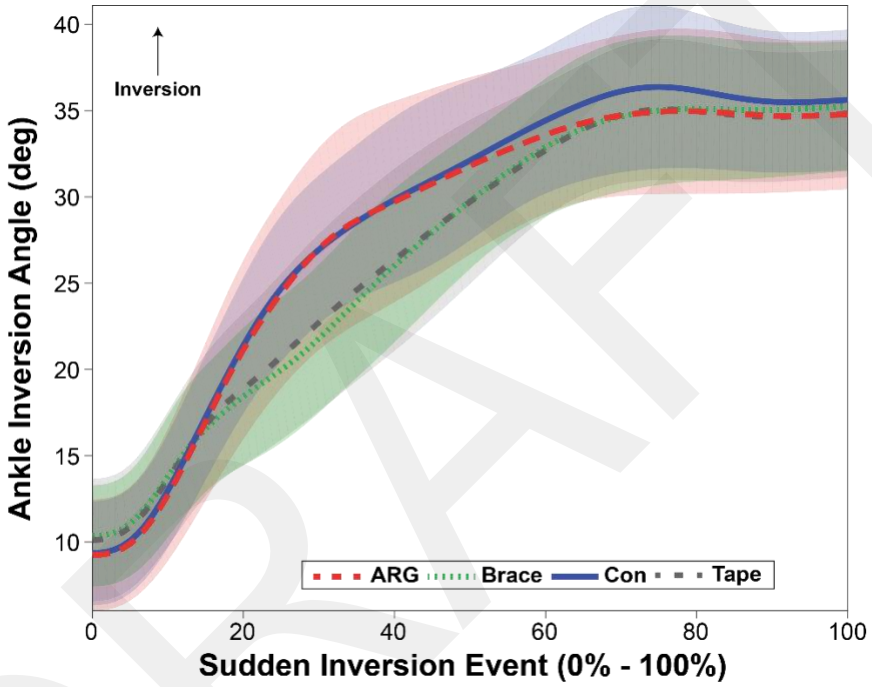

Figure 3: A plot depicting the mean (± SD) of ankle inversion angle recorded during the sudden inversion event (0% - 100%) for each ankle prophylactic device (ARG (red), Brace (green), Control (blue) and Tape (dark grey)) tested.

The mean (± SD) peak ankle inversion angle quantified with each ankle prophylactic device during the sudden inversion event are presented in Figure 4. The peak ankle inversion angle exhibited during the sudden inversion event was 35.3 ± 4.8 ° with the ARG, 35.3 ± 4.2 ° with the Brace, 36.3 ± 5.1 ° with the Control, and 35.0 ± 4.1 ° with the Tape. The ANOVA revealed no significant effect of ankle prophylactic on the peak ankle inversion angle ($p = 0.571$) exhibited during the sudden inversion event.

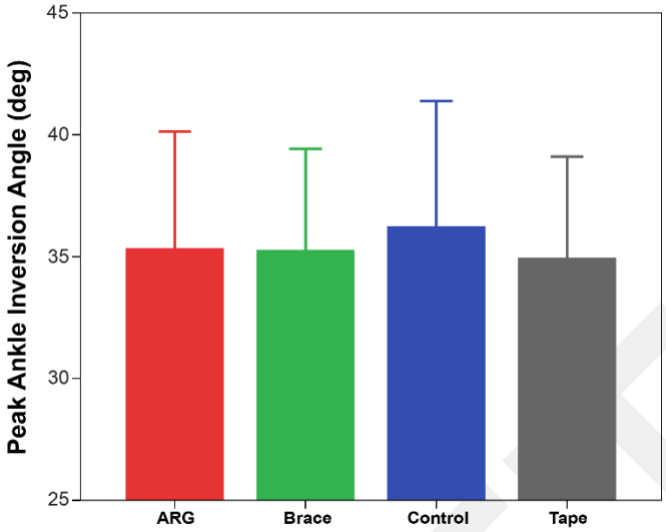

Figure 4: The mean (± SD) of peak ankle inversion angle exhibited during sudden inversion event (0% - 100%) for each ankle prophylactic device (ARG, Brace, Control and Tape).

The mean (± SD) range of ankle inversion quantified with each ankle prophylactic device during the sudden inversion event are presented in Figure 5. The range of ankle inversion exhibited during the sudden inversion event was 26.1 ± 3.2 ° with the ARG, 24.9 ± 2.9 ° with the Brace, 26.9 ± 4.0 ° with the Control, and 24.8 ± 3.3 ° with the Tape. The ANOVA revealed a significant effect of ankle prophylactic on range of ankle inversion ($p = 0.001$) exhibited during the sudden inversion event. During the Control condition, participants exhibited significantly greater range of ankle inversion compared to Tape ($p = 0.004$); however, after controlling for type I error, a significant difference was not evident between Control and Brace ($p = 0.060$), or between ARG and Brace ($p = 0.187$) or Tape ($p = 0.159$).

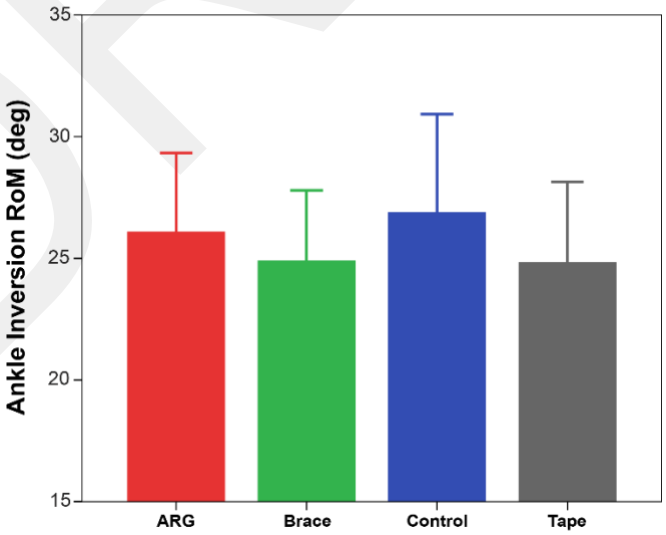

Figure 5: The mean (± SD) of the range of ankle inversion exhibited during sudden inversion event (0% - 100%) for each ankle prophylactic device (ARG, Brace, Control and Tape).

The mean (± SD) time to peak ankle inversion quantified with each ankle prophylactic device during the sudden inversion event are presented in Figure 6. The time to peak ankle inversion angle during the sudden inversion event was 0.19 ± 0.04 seconds with the ARG, 0.24 ± 0.06 seconds with the Brace, 0.20 ± 0.04 seconds with the Control, and 0.23 ± 0.04 seconds with the Tape. The ankle prophylactic device had a significant effect on time to peak ankle inversion ($p < 0.001$). Further analysis revealed that it took significantly longer to reach peak ankle inversion angle with the Brace and Tape compared to ARG ($p < 0.001$ and $p = 0.002$), and Brace compared to the Control condition ($p = 0.037$). No significant difference in time to peak ankle inversion ($p > 0.05$) was evident between any other ankle prophylactic device.

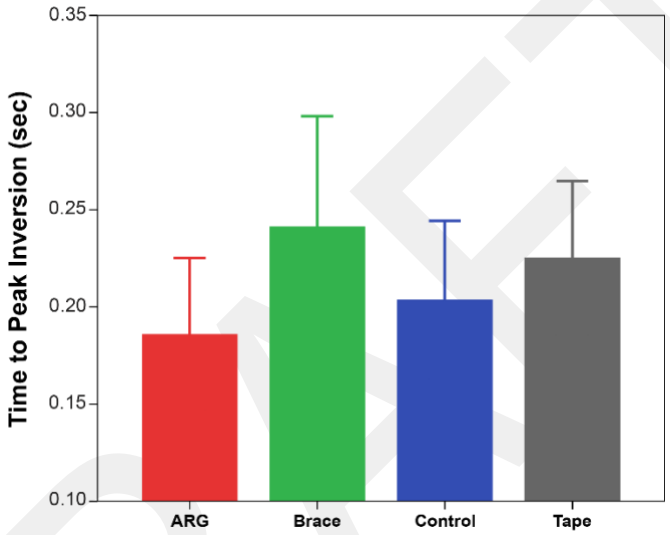

Figure 6: The mean (± SD) of the time to peak ankle inversion angle exhibited during sudden inversion event (0% - 100%) for each ankle prophylactic device (ARG, Brace, Control and Tape).

The mean (± SD) range of ankle plantarflexion quantified with each ankle prophylactic device during the sudden inversion event are presented in Figure 7. The range of ankle plantarflexion exhibited during the sudden inversion event was 34.9 ± 4.3 ° with the ARG, 30.5 ± 5.0 ° with the Brace, 34.8 ± 3.4 ° with the Control, and 32.1 ± 5.5 ° with the Tape. The ANOVA revealed a significant effect of ankle prophylactic on range of plantarflexion ($p < 0.001$) exhibited during the sudden inversion event. Participants exhibited significantly greater range of ankle plantarflexion with the ARG and Control compared to Brace ($p = 0.001$ and $p < 0.001$), but a significant difference was not evident ($p > 0.05$) between any other ankle prophylactic device.

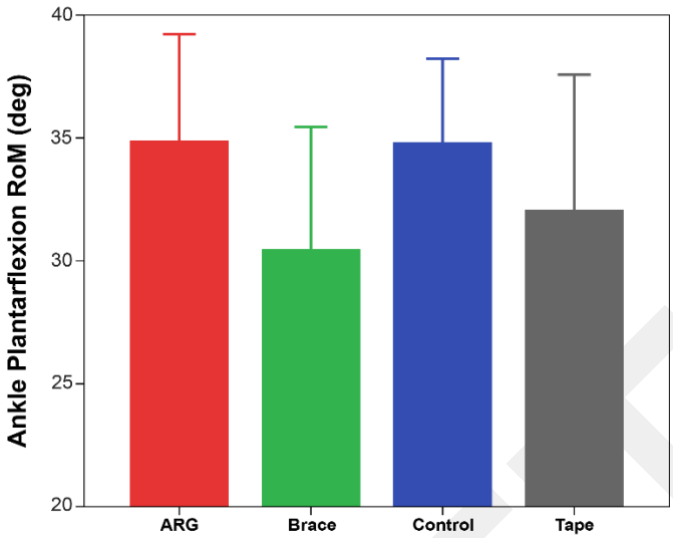

Figure 7: The mean (± SD) of the range of ankle plantarflexion exhibited during sudden inversion event (0% - 100%) for each ankle prophylactic device (ARG, Brace, Control and Tape).

Vertical Jump:

The mean (± SD) vertical jump height quantified with each ankle prophylactic device are presented in Figure 8. Vertical jump height was 0.33 ± 0.10 m with the ARG, 0.32 ± 0.10 m with the Brace, 0.33 ± 0.10 m with the Control, and 0.32 ± 0.10 m with the Tape. The ankle prophylactic device had a significant effect on vertical jump height ($p = 0.014$). When wearing the Tape, participants vertical jump height was significantly lower than when wearing the ARG ($p = 0.036$), but after controlling for Type I error no significant difference in jump height was evident between Brace and ARG ($p = 0.063$). No significant differences in vertical jump height ($p > 0.05$) were evident between any other ankle prophylactic device.

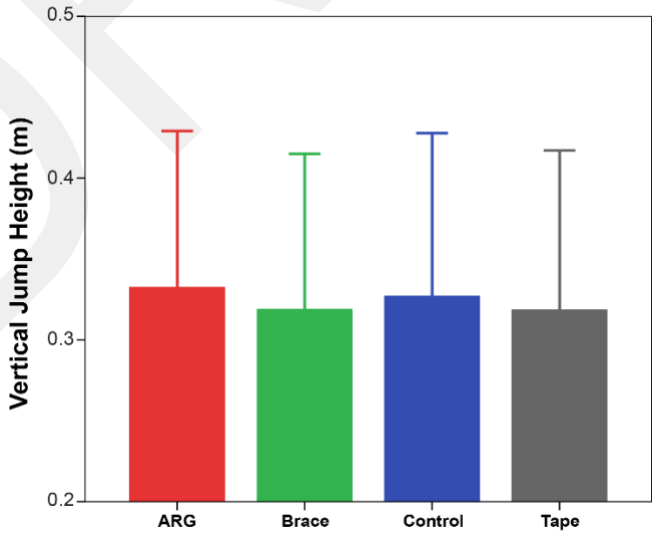

Figure 8: The mean (± SD) of the maximal vertical jump recorded with each ankle prophylactic device (ARG, Brace, Control and Tape).

The mean (± SD) positive work performed by the ankle during the vertical jump with each ankle prophylactic device was: 63.4 ± 15.3 Joules with the ARG, 55.5 ± 13.5 Joules with the Brace, 65.1 ± 14.0 Joules with the Control, and 57.5 ± 15.7 Joules with the Tape, respectively (Figure 9). The ANOVA revealed a significant effect of ankle prophylactic on positive ankle work ($p < 0.001$) exhibited during the vertical jump. Further analysis indicated participants performed greater positive work at the ankle with both the ARG and Control compared to the Brace ($p = 0.004$ and $p = 0.002$,) and Tape ($p = 0.028$ and $p = 0.001$) conditions, respectively. There were no significant differences ($p > 0.05$) between the ARG and Control, or Brace and Tape conditions.

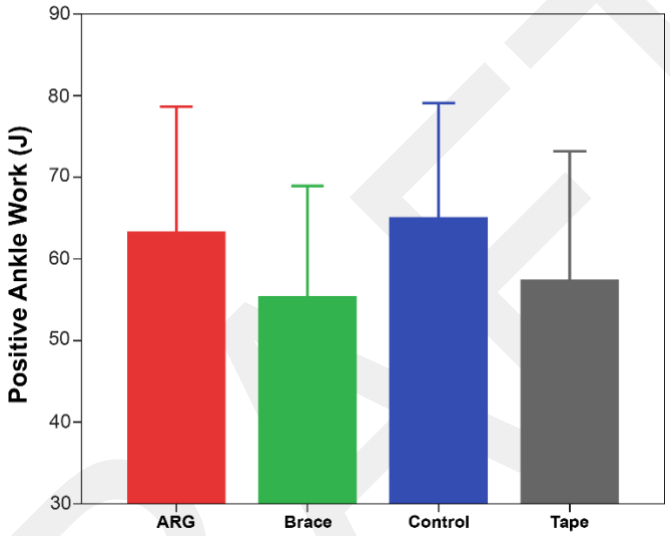

Figure 9: The mean (± SD) of positive work performed by the ankle joint during the vertical jump with each ankle prophylactic device (ARG, Brace, Control and Tape).

Positive work performed by the ankle during the vertical jump exhibited a significant relation to jump height for all ankle prophylactic devices (Figure 10). Specifically, positive ankle work has a significant positive relation during vertical jump height with ARG ($r = 0.735$ and $p < 0.001$), Brace ($r = 0.693$ and $p < 0.001$), Control ($r = 0.744$ and $p < 0.001$), and Tape ($r = 0.830$ and $p < 0.001$).

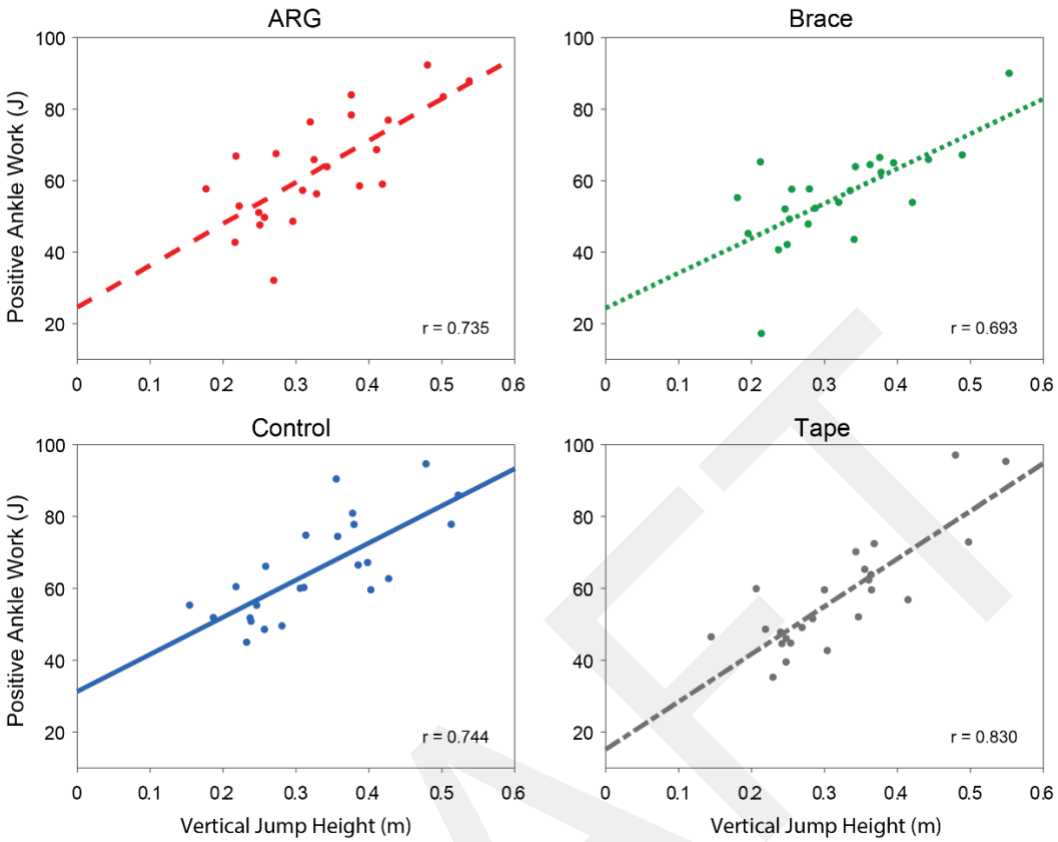

Figure 10: Relation between positive work performed by the ankle joint and maximum vertical jump height with each ankle prophylactic device (ARG, Brace, Control and Tape).

The mean (± SD) range of ankle plantarflexion quantified with each ankle prophylactic device during the vertical jump are presented in Figure 11. The range of ankle plantarflexion exhibited during the maximum vertical jump was 64.4 ± 8.5 ° with the ARG, 57.8 ± 6.5 ° with the Brace, 64.5 ± 8.8 ° with the Control, and 59.1 ± 5.1 ° with the Tape. The ANOVA revealed a significant effect of ankle prophylactic on range of plantarflexion ($p < 0.001$) exhibited during the maximum vertical jump. Participants exhibited significantly greater range of ankle plantarflexion with the ARG and Control compared to Brace ($p < 0.001$ and $p = 0.004$) and Tape ($p = 0.007$ and $p = 0.013$); however, no significant difference was evident between the ARG and Control ($p = 1.000$), or between Brace and Tape ($p = 1.000$) conditions during the vertical jump.

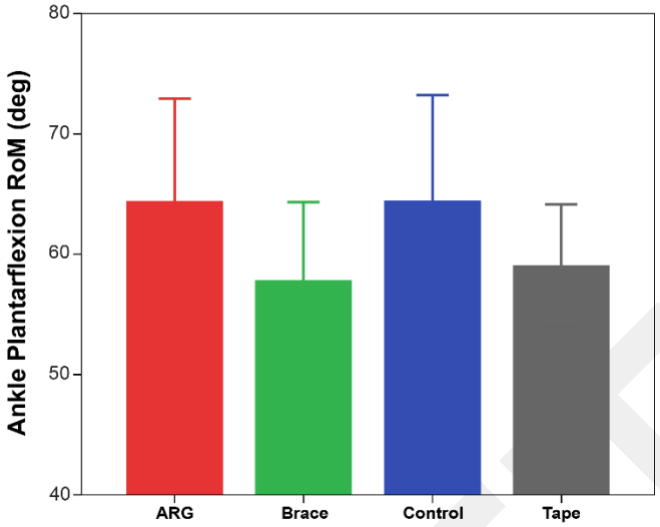

Figure 11: The mean (± SD) of the range of ankle plantarflexion exhibited during vertical jump for each ankle prophylactic device (ARG, Brace, Control and Tape).

DISCUSSION

This effort sought to quantify and compare the ARG's effectiveness with existing prophylactic products, including external brace, athletic tape and unbraced, control ankle, during a sudden inversion event of the ankle and performance of a maximum vertical jump. The current experimental outcomes demonstrate no significant difference in the ability of any tested ankle prophylactic device (ARG, Brace or Tape) to prevent the excessive ankle inversion related to injury. The difference in peak ankle inversion angle recorded for each prophylactic device during the sudden inversion event was 1° or less. This finding suggests each "Brace" provides similar ability to prevent ankle inversion. However, in contradiction with previous experimental evidence (Anderson et al., 1995; Bruns et al., 1996; Eils and Rosenbaum, 2003), none of the chosen ankle prophylactic devices (ARG, Brace and Tape) produced a statistically significant reduction in the peak ankle inversion angle as compared to the unbraced ankle (Control). While the reason for the discrepancy with existing literature is not immediately evident, each ankle prophylactic device (ARG, Brace and Tape) prevented peak ankle inversion angle from exceeding 36°. While these angles are consistent with values previously reported for ankle prophylactic devices during a similar inversion event, the peak inversion angle currently exhibited during the Control condition was 3° smaller than reported by Eils and Rosenbaum (2003) for unbraced ankles. It may be the current lack of statistical significance between the "Braced" and Control conditions stems from design of the wooden platform used for testing. The wooden platform contained mechanical stops to prevent the participant from suffering an actual ankle injury. These mechanical stops prevented participants from exhibiting ankle inversion significantly greater than 36° and may account for the lack of statistical significant between the "Braced" and Control conditions, as well as, the discrepancy between peak values exhibited with previous research on unbraced ankles.

Current participants exhibited a reduction, albeit non-significant, in the peak ankle inversion of 1.0°, 1.0°, and 1.3° with the ARG, Brace, and Tape compared to the Control condition. Considering ankle prophylactic products are effective at reducing the frequency of injury at the

joint (Alves et al., 1992; Jerosch et al., 1996; Shapiro et al., 1994), including the external brace and athletic tape presently tested, it may be the small reductions in peak ankle inversion currently evident during the sudden inversion event (~1 to 2°) have significant practical and/or clinical meaning. It may be the tested ankle prophylactic devices, including ARG, provide sufficient mechanical stability to prevent the excessive inversion of the joint that leads to ligament damage and injury when worn outside of the laboratory (i.e., "real-world"); but, do not meet the *a priori* standard for statistical significance during laboratory testing.

Ideal design of an ankle prophylactic device would not restrict typical ankle joint motions, while only preventing excessive motions that lead to ligament damage, and subsequent injury (Garrick and Requa, 1973). All prophylactic devices (ARG, Brace and Tape) prevented the excessive ankle inversion that is thought to lead to injury. But only the ARG appears to allow the user normal ankle motion (i.e., typical anatomical joint motions), while preventing excessive ankle inversion. The fact that ankle prophylactic devices had a significant effect on the range of ankle plantarflexion during the sudden inversion event supports this contention. During the sudden inversion, participants exhibited significantly greater range of ankle plantarflexion with the ARG (34.9°) compared to Brace (30.5°) and Tape (32.1°), but only the Brace was significantly different than the Control condition (34.8°). This data support the contention that the ARG does not prevent "other" typical ankle motions during the sudden inversion event. Ankle braces that impair these ankle motions may increase the chances of mechanical and functional instabilities at the joint (Gutierrez et al., 2009). As such, the ARG may have an advantage for the user and reduce the likelihood they develop either mechanical or functional instability at the joint when worn. The current kinematic analysis of the sudden inversion event, however, suggests that the ARG may be limited in its ability to stabilize the joint as compared to more restrictive braces – such as the Brace and/or Tape. Supporting this contention is the fact that participants took significantly longer to reach the peak inversion angle while wearing both the Brace (0.24 sec) and Tape (0.23 sec) compared to the ARG (0.19 sec). Taking longer to reach the peak inversion angle may be indicative of greater mechanical restriction provided by an ankle prophylactic and potentially results in a decreased risk of suffering an ankle injury when wearing that particular device. But, it also may represent a reduction of the user's natural joint motion. This restriction may lead to mechanical and functional instabilities of the joint and reduce whole-body performance for the user. However, further study is needed to determine whether the increased mechanical restriction on the ankle provided by the Brace and Tape leads to a reduction in injury risk, or conversely, has deleterious effect on the wearer's physical performance as compared to the ARG.

The current outcomes suggest an ankle prophylactic device can have a significant effect on the wearer's physical performance. Current participant's maximum vertical jump height was 0.33 m with the ARG and Control conditions, and 0.32 m with both the Brace and Tape conditions, respectively. This significant reduction in vertical jump performance may be attributed to two things: (1) a decrease in the plantarflexion (i.e., natural) motion at the ankle; and (2) the subsequent reduction in positive work performed by the ankle that results when wearing a restrictive ankle prophylactic device, such as the Brace or Tape, during the vertical jump. Specifically, participants exhibited greater range of ankle plantarflexion with the ARG (64.4°) and Control (64.5°) compared to both the Brace (57.8°) and Tape (59.1°) conditions. Permitting

the user greater, or more natural, plantarflexion motions at the ankle allows the joint to perform more positive work. Positive ankle work is an estimate of total muscular effort performed by the joint that contributes to raising and/or accelerating the body's center of mass (Cavagna and Kaneko, 1977). Thus, performing greater work at the ankle should then relate to vertical jump height, with more work predicting a higher jump. Performing more positive work at the ankle is indicative of greater muscular effort and subsequently producing a larger change (i.e., increase) in the body's velocity. The fact that positive ankle work exhibited a significant relation with vertical jump height during all ankle prophylactic conditions supports this contention (Figure 10). This contention is further supported by the fact that participants performed significantly greater positive work at the ankle, and exhibited higher vertical jumps, with both the ARG and Control compared to the Brace and Tape conditions. Thus, it appears that the ARG and Control conditions, because they afford for greater range of ankle plantarflexion during the vertical jump than the Brace or Tape, allows the wearer to produce more muscular effort at the ankle and subsequently better vertical jump performance.

Conclusion:

In conclusion, the current results demonstrate no difference in the ability of any tested ankle prophylactic device (ARG, Brace or Tape) to prevent the excessive ankle inversion related to injury. The ARG may provide similar prevention of excessive inversion as either the Brace or Tape, but without the mechanical restriction of the joint that reportedly limits physical performance when wearing ankle prophylactic devices. With the ARG, participants exhibited more natural ankle motions (i.e., plantarflexion) during both the sudden inversion event and vertical jump. This motion allowed the participants to perform better during the vertical jump with the ARG as compared to the more restrictive braces (i.e., Brace and Tape). But, only preventing ankle inversion may be a limitation that results in a reduction of the overall mechanical stability applied to the joint by the ARG. Further work is needed to determine if the users of the ARG exhibit similar reduction in risk of ankle injury as more restrictive ankle braces.

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