

The Effect of Ankle Brace Use on a 3-Step Volleyball Spike Jump Height



Daniel Z. You, M.D. M.Sc., Mike Tomlinson, B.Eng., Greg Borschneck, B.Kin., Andrew Borschneck, Mark MacDonald, M.D., F.R.C.S.C., Kevin Deluzio, Ph.D., and Dan Borschneck, M.D., F.R.C.S.C.

Purpose: The purpose of this study was to determine whether ankle brace use in university-level varsity volleyball athletes affected their 3-step spike jump height and whether certain types of ankle braces have a greater effect on jump height. **Methods:** Nine male university-level varsity volleyball athletes participated in a repeated-measures design study in which each athlete performed three 3-step volleyball spike jumps in 3 ankle brace conditions (soft, rigid, and no brace). Vertical jump height was measured by the Vertec device and video motion analysis at a university biomechanics research laboratory. **Results:** Vertical jump heights were significantly lower in both brace conditions (soft, 2.3 cm, standard deviation [SD] 1.2 cm, $P < .001$; rigid, 1.7 cm, SD 0.9 cm, $P < .003$) compared with the no-brace condition, and no differences in vertical jump height were observed between the brace conditions (0.6 cm, SD 0.3, $P = .3$). There was a negative correlation between body fat percentage and vertical jump height ($r = -0.075$, $P = .02$). The Vertec device reliably measured vertical jump in all 3 conditions. The no-brace vertical ground reaction forces during the loading phase were significantly greater than brace conditions. Ankle range of motion was greatest in the no-brace condition. **Conclusions:** Results from this study suggests that high-performance athletes wearing ankle braces experience a significant decrease in vertical jump height independent of the type of ankle brace worn. **Clinical Relevance:** Sports physicians and health care providers caring for high-level athletes should counsel athletes on the trade-offs of wearing protective equipment in sport, as potential decreases in sports performance can lead to increased injury prevention. **Level of Evidence:** III.

Introduction

Ankle injuries are among the most common types of injury in sports. Incidence is especially high in court and field sports such as volleyball, soccer, and basketball.¹⁻³ A systematic review by Fong et al.⁴ showed that ankle injuries account for 45.6% of all

injuries in volleyball, with ankle sprains accounting for 99.3% of ankle injuries. The most common mechanism of ankle sprain involves a combination of inversion and adduction of the foot in plantarflexion, commonly resulting in a rupture or tear of the ankle's anterior talofibular ligament.⁵

A variety of external ankle support devices and measures, including ankle taping and braces (rigid and soft), are used by athletes to prevent ankle injuries. These protective measures have been proven to be effective in reducing sports-related ankle injuries.² To protect athletes from injury, volleyball teams at all levels strongly encourage or make mandatory ankle brace use in an effort to prevent injuries. Athletes are often reluctant or choose not to use external ankle supports because of the perception that they inhibit athletic performance, especially vertical jump height.⁶

The degree of triceps surae (gastrocnemius and soleus) activation has been demonstrated to significantly affect vertical jump height.⁷ As the triceps surae attaches just distal to the ankle joint on the Achilles tendon/calcaneus, the ankle joint plays a key role in power release during jumping movements.⁷⁻¹⁰

From the Queen's University School of Medicine, Kingston, ON (D.Y., M.M., D.B.); Section of Orthopaedic Surgery, University of Calgary, Calgary, AB (D.Y.); Faculty of Engineering and Applied Sciences, Queen's University, Kingston, ON (M.T., A.B., K.D.); and Faculty of Kinesiology, University of Toronto, Toronto, ON (G.B.), Canada.

The authors report that they have no conflicts of interest in the authorship and publication of this article. Full ICMJE author disclosure forms are available for this article online, as [supplementary material](#).

Received December 3, 2019; accepted April 28, 2020.

Address correspondence to Dan Borschneck, M.D., F.R.C.S.C., Department of Surgery, Division of Orthopaedic Surgery, Kingston General Hospital, Victory 3, Kingston, ON K7L 2V7, Canada. E-mail: dan.borschneck@kingstonhsc.ca

© 2020 THE AUTHORS. Published by Elsevier Inc. on behalf of the Arthroscopy Association of North America. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>). 2666-061X/191453

<https://doi.org/10.1016/j.asmr.2020.04.015>

Therefore, it is believed that significant restrictions in ankle range of motion (ROM) may lead to decreased vertical jump height, affecting volleyball athletes' performance.¹¹ Several studies have supported this hypothesis by showing significant decreases in standing vertical jump height with ankle braces and ankle taping.^{1,12,13} However, results from other studies have concluded no significant decrease in standing vertical jump height with ankle brace use.^{1,3,6,14}

Previous studies in the literature focused primarily on the effects of ankle brace use on a static vertical jump. Because of the dynamic nature of the sport of volleyball, rarely are players jumping from a static position. The majority of volleyball players follow a dynamic 3- or 4-step spike approach before jumping to gain momentum and increase jump height.¹⁵ Therefore, it is imperative to study the effects of ankle brace use on a sport-specific jump such as the volleyball spike jump.

The purpose of this study was to determine whether ankle brace use in university-level varsity volleyball athletes affects the 3-step spike jump height and whether certain types of ankle braces have a greater effect on jump height. The hypothesis of this study is that ankle brace use will decrease vertical jump height compared with no ankle brace during volleyball 3-step spike jumps. Secondary objectives of the study included (1) to determine whether there is a relationship between anthropometric parameters and jump height; (2) to assess the reliability of the Vertec device as a measure of true vertical jump height; (3) to determine whether ankle braces affect vertical ground reaction forces (vGRFs) during take-off; and (4) to determine whether ankle braces impact ankle ROM in the sagittal, transverse, and coronal planes.

Methods

Participants

Participants for the study were recruited via e-mail invitation sent to local university-level volleyball teams. To participate, potential participants were required to be varsity-level male volleyball players 18 to 25 years old within 5 years of the study start date. Additionally,

all participants were required to be able to demonstrate a 3-step volleyball spike jump. Signed informed consent was received from all participants before testing.

Exclusion criteria for the study were based on Davis et al.'s study¹⁶ on factors that can affect vertical jump height. Potential participants with chronic lower-extremity injuries, lower-extremity fracture within the past year, lower-extremity soft tissue injury (e.g., muscle strain, ligament sprain, tendinitis) within the past 6 months, history of lower back pain or pain extending to the legs resulting from a herniated disc, history of lower-extremity reconstructive surgery (e.g., anterior cruciate ligament reconstruction) within the past 12 months, or use of performance-enhancing drugs within the past 6 months were excluded from the study.

In total, 9 varsity volleyball players meeting the inclusion and exclusion criteria were selected to participate in the study.

Design

Before commencing the study, ethics approval was obtained through the university research ethics board. The study protocol (Fig 1) followed a randomized repeated-measures design, in which all participants performed volleyball spike jumps under all 3 study conditions (soft brace, rigid brace, and no brace). Computer randomization of jump condition order was used to avoid order bias. All testing was completed at a university biomechanics research laboratory. Upon arrival to the laboratory, written informed consent, baseline demographics, and anthropometric data were collected from each participant.

All participants took part in a standardized 10-minute dynamic exercise warm-up adapted from the local university's men's volleyball team warm-up. After the warm-up, each participant was outfitted by a lab technician with specialized reflective markers for video motion analysis (VMA) using the Visual3DTM tracking system (Qualysis Motion Capture Systems, Göteborg, Sweden). Six force plates were embedded into the floor of the laboratory for vGRF analysis.

Participants were asked to perform 6 practice 3-step spike jumps without braces to familiarize themselves

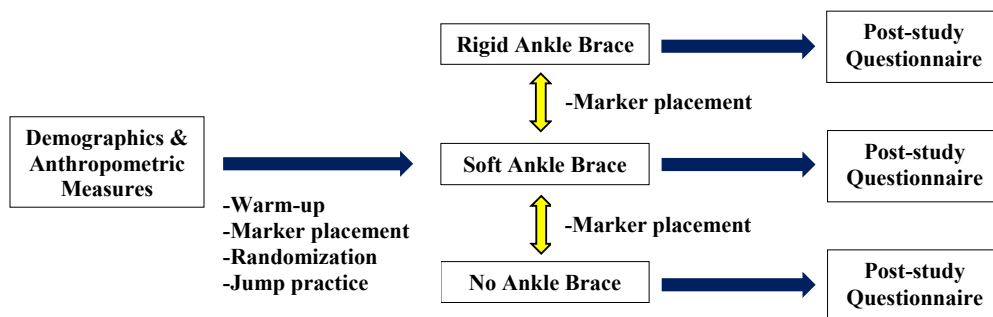


Fig 1. Study design.

with the Vertec device setup. A lab technician adjusted the Vertec device after each practice jump and marked each participant's approach start point, with each foot on different force plates for vGRF measurements. Participants were blinded to force plate location during the study to prevent subconscious adjustments in spike approach.

Participants completed three 3-step volleyball spike jumps in each of the following conditions, totaling a series of 9 jumps: (1) no brace; (2) soft ankle brace (ASO-Evo Ankle Stabilizer, Charlotte, NC); and (3) rigid ankle brace (Active Ankle T2, Akron, OH).

Procedures

Vertical Jump Height (Primary Outcome)

Vertical jump height from the 3-step spike jump was measured using (1) the jump and reach method and (2) the VMA method. Vertical jump height from the jump and reach method was measured using the Vertec device. The Vertec device is constructed with horizontal vanes in half-inch increments that are rotated out of the way by the hand of the participant at the peak of his jump. Vertical jump height using the VMA method was measured by calculating the maximum vertical displacement of the sacral reflective marker from take-off, captured by the lab's 12 motion capture cameras. The highest vertical jump in each condition was recorded (Fig 2).

Anthropometric Parameter Analysis (Secondary Outcome)

Several anthropometric parameters including height (cm), weight (kg), standing reach (cm), body mass index (BMI) (kg/m^2), and body fat percentage were measured before testing. Body fat percentage was measured by a trained lab technician with skin calipers using the Durnin and Womersley method. The anthropometric parameters were used in the assessment of correlation with vertical jump height.

Jump and Reach Method Reliability (Secondary Outcome)

Reliability of the jump and reach method using the Vertec device as a measure of jump height was compared with the gold standard VMA method. Vertical jump heights in all 3 conditions were used in the calculation of reliability.

vGRF (Secondary Outcome)

Data from 6 force plates embedded in the floor of the laboratory were used to calculate the peak vGRF during the take-off phase. Mean peak vGRFs between the 3 conditions were evaluated for differences.

Ankle ROM (Secondary Outcome)

Ankle ROM was recorded in the sagittal, transverse, and coronal planes in all 3 conditions. The mean ROM in each condition was recorded.



Fig 2. Demonstration of peak vertical jump following a 3-step spike approach. Vertical jump height is measured by Vertec device (left) as well as reflective markers attached to participant's midsection using video motion analysis.

Statistical Analysis

Results from vertical jump analysis were presented in the form of means, ranges, and correlations. Paired *t* tests were used to compare the differences in vertical jump height and vGRF. Multiple linear regression analysis was used to determine the contribution of each anthropometric parameter toward vertical jump height. Cronbach's alpha analysis was used to assess the reliability of the Vertec measuring device. Multivariate analysis of variance and subsequent post hoc paired *t* tests were used to evaluate how different ankle braces impacted ROM in the sagittal, transverse, and coronal planes of the ankle.

Results

Baseline Demographics

Nine varsity volleyball players ranging from 18 to 25 years old were recruited and completed the study. Of

Table 1. Baseline Demographics and Anthropometric Parameters

Characteristic	Minimum	Maximum	Mean	Standard Deviation
Age (y)	18	25	21.3	2.6
Height (cm)	182.0	207.0	193.3	8.2
Weight (kg)	76.5	102.5	88.9	8.9
Standing reach (cm)	230.0	270.0	248.8	11.5
Body mass index (kg/m ²)	21.8	25.5	23.8	1.2
Body Fat (%)	10.3	21.0	15.6	4.0

the 9 volleyball players, 6 had previously worn a soft ankle brace, and 1 had suffered an ankle sprain while wearing a soft ankle brace in the past. Eight participants had previously worn a rigid ankle brace, and 3 had suffered ankle sprains while wearing a rigid braces in the past. Six of the participants had a history of ankle sprains while wearing no brace. None of the participants had suffered any ankle fractures or ligamentous injury requiring surgical fixation (Table 1).

Vertical Jump Height

Vertical jump height data from VMA was used in the comparison of vertical jump height in the 3 conditions. The mean maximum vertical jump heights using the VMA method were 77.4 cm (standard deviation [SD] 6.1 cm), 75.7 cm (SD 6.2 cm), and 75.1 cm (SD 5.6 cm) in the no brace, rigid brace, and soft brace conditions, respectively (Table 2). The mean maximum vertical jump heights were significantly lower in the soft brace (2.3 cm, SD 1.2 cm, $P < .001$) and rigid brace (1.7 cm, SD 0.9 cm, $P < .003$) conditions compared with the no-brace condition (Fig 3). The mean maximum vertical jump height in the rigid brace condition was 0.6 cm higher (SD 0.3, $P < .3$) than in the soft brace condition, which was not statistically significant (Fig 3).

In the Vertec measurements, both the rigid and soft brace conditions had mean maximum vertical jump height measurements 1.9 cm lower than the no-brace condition. There was no difference in mean maximum vertical jump height between the 2 brace conditions using the Vertec.

Anthropometric Parameter Analysis

Of the 5 anthropometric parameters measured, only body fat percentage was found to have a statistically significant correlation with vertical jump height. Body fat percentage had a negative correlation ($r = -0.075$, $P = .02$) with vertical jump height (Fig 4).

vGRF

vGRF during the take-off phase was found to be greatest in the no-brace condition (193,619.5 N), followed by soft brace (193,142.1 N) and rigid brace (193,021.8 N). Mean peak GRF in the Y-direction during

the loading phase were found to be significantly higher in the no-brace condition than either the rigid brace ($P = .03$) or soft brace ($P = .01$) condition. There was no significant difference in vGRF between the 2 brace conditions ($P = .31$) (Fig 5).

Vertec Reliability

Mean vertical jump height measurement differences between the VMA and Vertec device were 2.7 cm (SD 1.4), 2.9 cm (SD 1.5), and 2.3 cm (SD = 1.2) in the no-brace, rigid brace, and soft brace conditions, respectively (Table 2). Cronbach's α analysis of vertical jump height using the Vertec compared with the gold standard VMA in rigid brace ($\alpha = 0.981$), no-brace ($\alpha = 0.990$), and soft brace ($\alpha = 0.956$) conditions was significant for the Vertec device being a reliable measure of one's true vertical jump height.

Ankle ROM

The no-brace condition allowed for the greatest mean ROM in all planes of motion except for left ankle ROM in the coronal plane, where the rigid ankle braces condition allowed for greater coronal ROM than the no-brace condition (no brace, 11.9°; rigid brace, 12.5°) (Table 3).

Discussion

Wearing an ankle brace has been shown to significantly decrease vertical jump height in the sport-specific, 3-step volleyball spike jump. The type of ankle brace (rigid or soft) did not seem to make a difference. Although not statistically significant in this study of 9 participants, there was a decrease of 0.6 cm in mean vertical jump height in the soft brace condition compared with the rigid brace condition. We predict that this difference may be due to the hinge design of the rigid brace allowing for greater ankle ROM in dorsiflexion and plantarflexion. In the soft ankle brace, the laces and stirrups have a more restricting effect on ankle dorsiflexion and plantarflexion.

One can argue the clinical significance of the decrease in vertical jump height observed in this study and how it may affect in-game sports performance. However, at

Table 2. Comparison of Vertical Jump Height Measurements Between Vertec Device and Video Motion Analysis (VMA)

Condition	Minimum (cm)	Maximum (cm)	Mean (cm)	Mean Difference (cm)	Standard Deviation (cm)
No brace				2.7	1.2
Vertec	65.3	86.3	74.7		
VMA	67.0	87.5	77.4		
Rigid brace				2.9	1.5
Vertec	62.7	85.0	72.8		
VMA	65.7	85.6	75.7		
Soft brace				2.3	1.4
Vertec	64.0	85.0	72.8		
VMA	65.4	85.0	75.1		

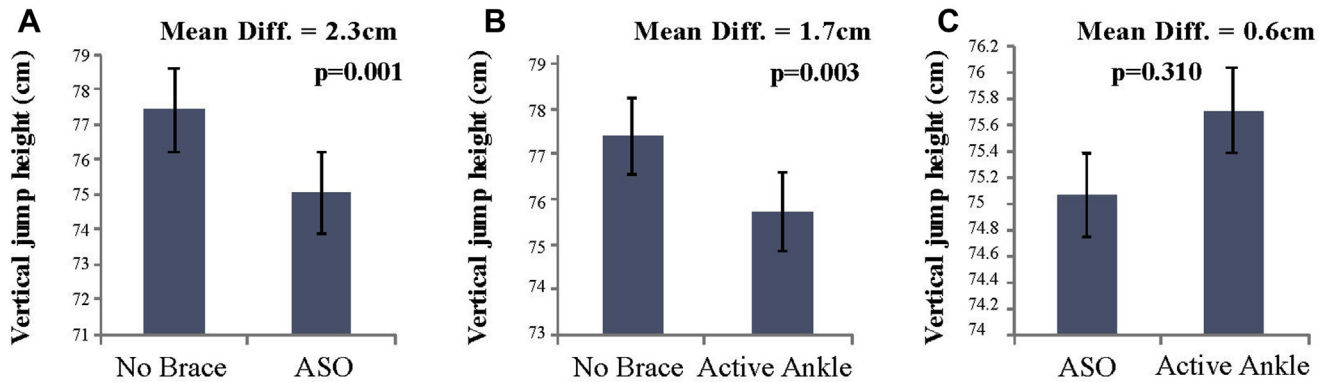


Fig 3. Mean vertical jump height differences as measured by video motion analysis between no brace and soft ankle brace condition (A); no brace and rigid ankle brace condition (B); and soft and rigid ankle brace conditions (C).

higher levels of sport, athletes train and seek any competitive advantage over their opponents. The men's volleyball net height is set at 243 cm, and the mean spike jump height of the Canadian Men's National Volleyball Team is almost a meter higher, at 331.4 cm. At this level, contacting the ball 2 cm higher than the opponents' block may be the difference between scoring or getting blocked. We believe that the decrease in vertical jump height translates not only to other volleyball-specific movements such the block jump, but also to other sports in which having a higher dynamic vertical jump is advantageous, such as basketball.

It is important to consider the risks and benefits of not wearing ankle braces while playing sports with a high

prevalence of ankle injury. Prophylactic ankle bracing has been previously shown to be effective in reducing ankle injury, especially in athletes with a history of ankle sprain.¹⁷ This is especially the case in younger athletes, who have increased susceptibility to injury compared with adults because of decreased balance and coordination.¹⁸ Therefore, we agree with Soomro et al.¹⁹ that ankle braces along with injury prevention programs should be considered in youth and adolescence.

Among the anthropometric parameters measured, only body fat percentage had a significant correlation with vertical jump performance. The negative effect of body fat on vertical jump height is supported by several previous studies^{7,20}; however, compared with findings

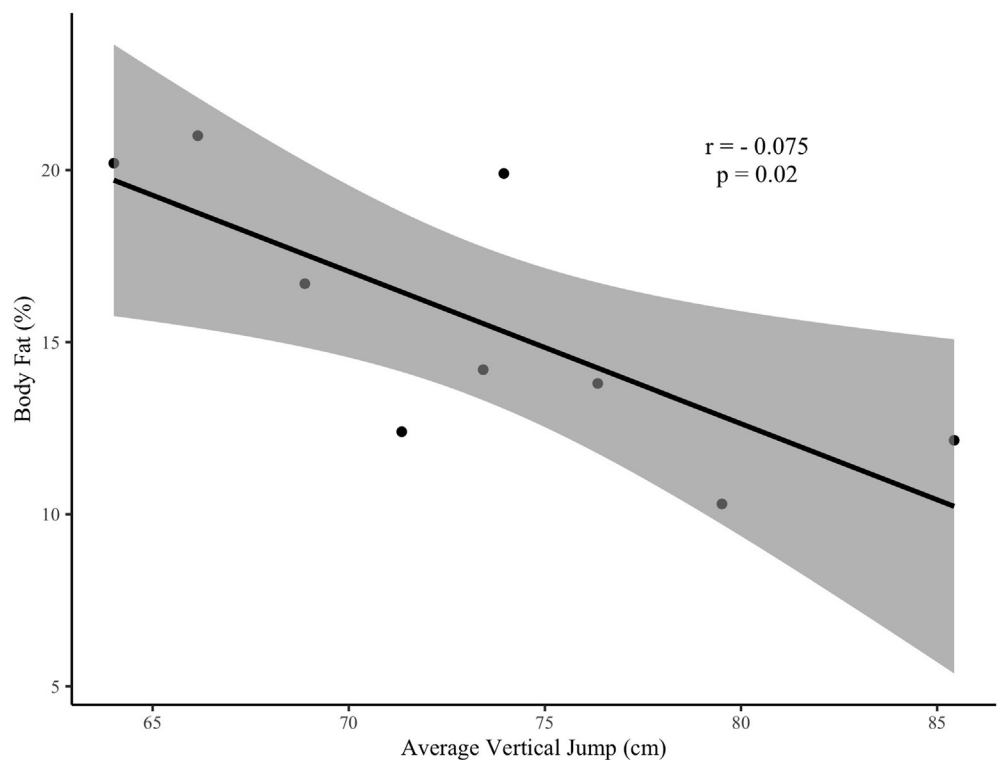


Fig 4. Correlation between participant body fat percentage and vertical jump height.

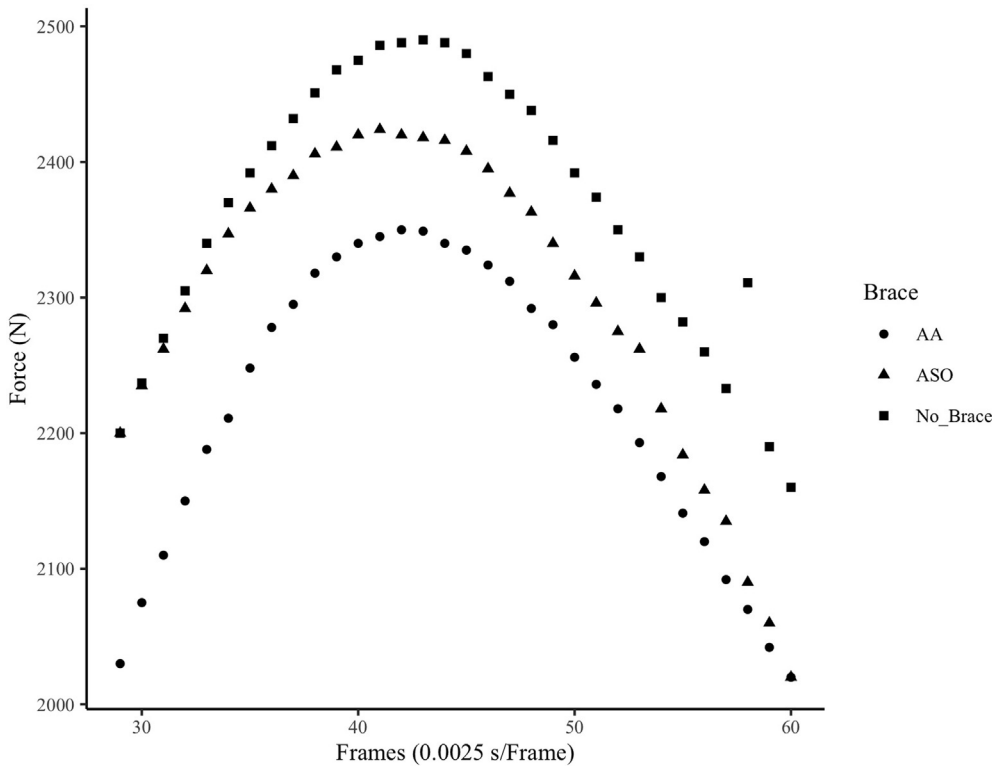


Fig 5. Mean maximum vertical ground reaction forces during take-off phase of jump. AA, active ankle (rigid ankle brace); ASO, ankle stabilizing orthosis (soft ankle brace).

by Nikolaidis et al.,²⁰ we did not find a similar negative correlation between vertical jump height and BMI, a predictor of body fat percentage. This difference may be due to differences in body composition between male and female athletes, as both sexes were studied by Nikolaidis et al. Additionally, BMI is overestimated in athletes with high lean body mass, affecting the linear regression analysis in this study.²¹

Participants were able to generate significantly higher peak vGRF in the no-brace condition compared with the 2 brace conditions. This difference is likely representative of the difference in vertical jump height between the 3 conditions. Further studies investigating the associations between the timing of peak vGRF achieved with restricted ankle ROM are required.

Lastly, the use of ankle braces significantly impacted ankle ROM only in the transverse plane. This result indicates that the braces used in this study successfully reduced adduction and abduction of the foot segment during 3-step spike jumps. Any direct relationship between change in ROM, change in vGRF, and vertical jump height should be evaluated in future studies.

Future studies should investigate the effect of ankle braces on athletic performance in other sports in which ankle braces are commonly used, as well as in female athletes. Ankle taping was not included as one of the study conditions in this study. To have consistency with ankle taping during the study, a single athletic therapist would be required to perform all ankle tapings, and taping tends to loosen with subsequent jumps. As restriction of ankle ROM decreases with subsequent jumps, a difference in performance may be more difficult to detect. Nonetheless, we acknowledge that future studies evaluating ankle taping on dynamic vertical jump performance are required, as taping is a common method used to prevent ankle injury.

Limitations

There were several limitations of this study. Because of athlete availability, only 9 volleyball players meeting the inclusion criteria were tested. A priori power analysis based with an effect size of 0.5 indicated that this study would require a sample size of 24 participants. Because of the involved nature of each trial and strict

Table 3. Mean Ankle ROM (°) During Spike Jumps in the Sagittal, Transverse, and Coronal Planes in the 3 Study Conditions

Condition	Left Ankle (°)			Right Ankle (°)		
	Sagittal	Transverse	Coronal	Sagittal	Transverse	Coronal
No brace	62.6	18.1	11.9	71.4	28.6	21.6
Soft brace	56.8	13.0	9.7	59.7	20.1	13.1
Rigid brace	60.7	12.2	12.5	62.1	19.4	14.1

inclusion and exclusion criteria (specifically that participants be uninjured male university-level volleyball athletes), the study recruited only 9 participants. This level of recruitment resulted in a post hoc β error of 0.44, indicating that the study was underpowered. Ultimately, it is important to consider that certain results, specifically when significance was not demonstrated, may present differently among a group of 24 participants. As the study was underpowered because of the small sample size and large number of statistical tests, the likelihood that the study contains either α (false positive) or β (false negative) error is increased.

Conclusions

Results from this study suggests that high-performance athletes wearing ankle braces experience a significant decrease in vertical jump height independent of the type of ankle brace worn.

Acknowledgments

These data were previously presented at the Canadian Orthopaedic Association Annual Meeting, 2015, Vancouver, BC, and the International Conference for Resident Education, 2015, Vancouver, BC, Canada.

References

1. Bot SDM, van Mechelen W. The effect of ankle bracing on athletic performance. *Sports Med* 1999;27:171-178.
2. Dizon J, Reyes J. A systematic review on the effectiveness of external ankle supports in the prevention of inversion ankle sprains among elite and recreational players. *J Sci Med Sport* 2010;13:309-317.
3. Günay S, Karaduman A, Oztürk BB. Effects of Aircast brace and elastic bandage on physical performance of athletes after ankle injuries. *Acta Orthop Traumatol Turc* 2014;48:10-16.
4. Fong DTP, Hong Y, Chan LK, Shu-Hang P, Chan KM. A systematic review on ankle injury and ankle sprain in sports. *Sports Med* 2007;31:73-94.
5. Petersen W, Rembitzki I, Koppenburg A, Ellermann A, Liebau C, Brüggemann G, Best R. Treatment of acute ankle ligament injuries: A systematic review. *Arch Orthop Trauma Surg* 2013;133:1129-1141.
6. Pienkowski D, McMorrow M, Shapiro R, Caborn DN, Stayton J. The effect of ankle stabilizers on athletic performance. A randomized prospective study. *Am J Sports Med* 1995;23:757-762.
7. Arakawa H, Nagano A, Hay DC, Kanehisa H. The effects of ankle restriction on the multijoint coordination of vertical jumping. *J Appl Biomech* 2013;29:468-473.
8. Bobbert M. Dependence of human squat jump performance on the series elastic compliance of the triceps surae: A simulation study. *J Exp Biol* 2001;204:533-542 (pt 3).
9. Farris DJ, Lichtwark GA, Brown NA, Cresswell AG. The role of human ankle plantar flexor muscle-tendon interaction and architecture in maximal vertical jumping examined in vivo. *J Exp Biol* 2016;219:528-534 (pt 4).
10. Stefanyshyn DJ, Nigg BM. Contribution of the lower extremity joints to mechanical energy in running vertical jumps and running long jumps. *J Sports Sci Med* 1998;16:177-186.
11. Graydon R, Fewtrell D, Atkins S, Sinclair J. The effects of ankle protectors on lower limb kinematics in male football players: a comparison to braced and unbraced ankles. *Comp Exerc Physiol* 2017;13:251-258.
12. Ozer D, Senbursa G, Baltaci G, Hayran M. The effect on neuromuscular stability, performance, multi-joint coordination and proprioception of barefoot, taping or preventative bracing. *Foot* 2009;19:205-210.
13. Parsley A, Chinn L, Lee S, Ingersoll C, Hertel J. Effect of 3 different ankle braces on functional performance and ankle range of motion. *Athl Train Sports Health Care* 2013;5:69-75.
14. MacKean LC, Bell G, Burnham RS. Prophylactic ankle bracing vs. taping: Effects on functional performance in female basketball players. *J Orthop Sports Phys Ther* 1995;22:77-81.
15. ChengTu H, Christiansen CL. Research Notes: The effect of approach on spike jump height for female volleyball players. *Int J Sports Sci Coach* 2010;5:373-380.
16. Davis S, Briscoe DA, Markowski CT, Saville SE, Taylor CJ. Physical characteristics that predict vertical jump performance in recreational male athletes. *Phys Ther Sport* 2003;4:167-174.
17. Olmsted LC, Vela LI, Denegar CR, Hertel J. Prophylactic ankle taping and bracing: A numbers-needed-to-treat and cost-benefit analysis. *J Athl Train* 2004;39:95-100.
18. Franklin CC, Weiss JM. Stopping sports injuries in kids: An overview of the last year in publications. *Curr Opin Pediatr* 2012;24:64-67.
19. Soomro N, Sanders R, Hackett D, Hubka T, Ebrahimi S, Freeston J, Cogley S. The efficacy of injury prevention programs in adolescent team sports. *Am J Sports Med* 2016;44:2415-2424.
20. Nikolaidis PT, Gkoudas K, Afonso J, Clemente Suarez V, Knechtle B, Kasabalis S, Kasabalis A, Douda H, Tokmakidis S, Torres Luque G. Who jump the highest? Anthropometric and physiological correlations of vertical jump in youth elite female volleyball players. *J Sports Med Phys Fit* 2017;57:802-810.
21. Atlanta (GA): Center for Disease Control and Prevention. About Adult BMI. https://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/. Accessed June 22, 2016.