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Title: Effects of Single Upright, Double Upright and Lace-up Ankle Braces on Vertical Jump Performance in Female College Volleyball Players

Abstract:

Background/Purpose: Ankle braces are often used to stabilize the ankle joint of an athlete to reduce the risk of initial injury while participating in athletic activity or to protect the joint from re-injury when returning to play. The purpose of this study was to examine the effects of application of three different braces on vertical jump performance in collegiate female volleyball players. A secondary aim was to compare participant preference and satisfaction on selected characteristics of each of the three different braces.

Subjects: 31 female varsity/club college volleyball players >18 years of age (mean: 19.9 yrs).

Materials/Methods: Health History Assessment and a dynamic warm-up were administered prior to performing vertical jump testing in four randomized conditions: unbraced, lace-up, single upright semi-rigid, and double upright semi-rigid ankle braces worn bilaterally. Vertical jump was calculated using the Just Jump® mat and the VERT® instrumented systems. Repeated measures ANOVA was employed to determine main effects on outcome variables of vertical jump performance (VERT® and Just Jump®) and t-tests were implemented to assess brace satisfaction (7-point Likert Scale and questionnaire completed following the test protocol on brace characteristics and satisfaction).

Results: When comparing the four conditions in vertical jump performance, the braced conditions resulted in similar but slightly lower vertical jump height than the unbraced condition (~2.5%). The lace-up brace was rated higher by the participants in overall user satisfaction in the majority of characteristics (5 of 7). The double upright semi-rigid brace was reported by the participants to provide the *greatest stability* and believed to be *most effective at preventing a future injury.*

Conclusions and Clinical Relevance: Female volleyball players often wear ankle braces during practice or competition to prevent new or recurrent ankle injury. The braces used in this study appeared to have minimal impact on vertical jump performance of less than 2.5% compared to the unbraced condition. Whether this small effect on performance is an acceptable trade-off for reducing the risk of ankle injuries may be a matter of opinion especially at high levels of performance and requires future investigation.

Key Words: ankle injury, prevention, prophylactic orthoses, vertical jump performance

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Background and Introduction

Ankle injuries are the number one injury occurrence in sports (Kaminski et al., 2013; Leonard, Rotay, Paulson, & Sanders, 2014; Rosenbaum et al., 2005) accounting for 18-40% of all injuries (Bot & van Mechelen, 1999). Lateral inversion ankle sprains are the most common ankle injury (85%) primarily arising in sports such as volleyball, basketball, and soccer (D. T.-P. Fong, Hong, Chan, Yung, & Chan, 2007; Van den Bekerom et al., 2016). While performing movements such as jumping, cutting, or running, an athlete's ankle may be subjected to abnormal forces or positions increasing the chances of ankle injury.

An inversion ankle sprain occurs when the joint is forced into plantarflexion (PF) and inversion (IV), resulting in stretched and potentially torn lateral ligaments of the ankle. Most commonly injured is the anterior talofibular ligament (ATFL), involved in over 73% of lateral ankle sprains (Ferran & Maffulli, 2006; Martin et al., 2013). Risk factors contributing to an ankle sprain include previous ankle sprains, limited dorsiflexion (DF), imbalance issues, strength deficits, late peroneal muscle reactions, and no exterior support (D. T. Fong, Chan, Mok, Yung, & Chan, 2009; Hadzic et al., 2009; Kaminski et al., 2013; Martin et al., 2013). When an ankle ligament sprain occurs, an athlete is likely to cease participation in his or her sport for a period of time in order to recover from the pain, swelling, and decreased mobility (D. T. Fong et al., 2009)

The main types of interventions used to stabilize an ankle joint to prevent or treat an ankle sprain are taping and bracing. Although still a widely used method, taping has been reported by some investigators to be more difficult to apply, is more costly over time with repeated application as it cannot be reused, and less effective than other types of orthosis (Bot & van Mechelen, 1999; Parsley, Chinn, Lee, Ingersoll, & Hertel, 2013; Verhagen & Bay, 2010). According to Herrington and Al-Shebli (2006), taping does not have an effect on vertical jump performance, or other agility tasks, despite its restrictions on range of motion (Halim-Kertanegara, Raymond, Hiller, Kilbreath, & Refshauge, 2016). Also, when comparing the effectiveness of taping and bracing on treating and protecting an ankle joint, both methods are shown to have similar results and impact (Van den Bekerom et al., 2016; Verhagen & Bay, 2010).

Due to the high number of ankle sprains in sports, ankle braces are used to prevent an initial injury, used during the rehabilitation process following an ankle injury, and used when an athlete returns to sport (McGuine, Brooks, & Hetzel, 2011; Parsley et al., 2013). Ambegaonkar et al. (2011) suggest that the support from the braces and the restriction of excessive movement help reduce the risk of injury to the joint. Another reason for the effectiveness of a brace in preventing an ankle sprain is to provide mechanical support, assist with joint proprioception, and protect against neuromuscular deficits (D. T. Fong et al., 2009; Verhagen & Bay, 2010).

There are many different types of ankle braces available, but most are generally classified into one of three categories: rigid, semi-rigid, and lace-up ankle braces. The rigid brace is typically not used during practice or competition. The semi-rigid ankle braces typically have a hard outer covering in the shape of a stirrup with foam padding on the inside for added comfort for the medial and lateral malleolus. Lace-up braces more closely resemble taping with their cloth or fabric exterior—normally designed with laces and Velcro straps to fasten and keep the laces in place. The semi-rigid brace combines elements from the rigid and lace-up braces. The semi-rigid double upright design has been used by athletes for a higher level of protection. The single-upright design is similar, but only has one upright on the lateral side of the foot to prevent inversion, a motion involved in the most common mechanisms of ankle injury. Lace-up braces have also been reported to provide comfort and less protection than other semi-rigid braces (Rosenbaum et al., 2005).

Studies have shown that using a brace for protection is most effective in preventing a reoccurring ankle sprain (Martin et al., 2013; Verhagen & Bay, 2010). However, a 2011 study assessing lace-up braces and their effect on injury rates in over 1,400 high school basketball players demonstrated a lower incidence of injury in the braced condition both for players with and without previous ankle sprain history (McGuine et al.). A 2003 study also resulted in two semi-rigid braces reported to have a significantly higher success rate of resisting forced inversion when compared to a lace-up and a normal unbraced condition (Ubell, Boylan, Ashton-Miller, & Wojtys, 2003). The National Athletic Trainers Association published a position statement on management and prevention of ankle sprains stating that ankle braces are effective in both prevention and reducing the incidence of reoccurring ankle sprains (Kaminski et al., 2013).

Despite the effectiveness in reducing the risk of injury, there are certain concerns often expressed regarding the application/use of ankle braces. First, some stakeholders such as coaches, players, and clinicians are concerned with the potential of an increased risk of injury to the knee joint due to the principle of proximal transfer of kinematic rotary motion. For example, if the ankle joint becomes fixed due to restriction of motion and the force applied to it is great enough, a rotary motion may occur at the next movable point, which in the case of the lower extremity, is the knee (Hamilton et al., 2012). This would theoretically cause a possible knee ligament injury, which may be more clinically and functionally significant as knee ligament injuries sometimes require surgical reconstruction (e.g. anterior cruciate ligament) and normally requires more recovery time than an ankle ligament sprain; however, there is limited evidence to support this theory due to limited retrospective, longitudinal and randomized controlled studies available.

In 2006, investigators attempted to test torque on the knee when a semi-rigid ankle brace (Active Ankle-T2; Cramer Products, Inc., Gardner, KS) was applied and the participant drop landed onto a slanted surface, simulating an inversion stress. They found an increased eversion and external rotational torque on the knee during the braced condition. Valgus torque was similar in both conditions (Venesky, Docherty, Dapena, & Schrader, 2006). In 2014, when the same ankle brace was tested for effects on knee kinematics and forces while performing volleyball-related tasks, results showed smaller forces during the braced condition in contrast to the previous study (West, Ng, & Campbell). The data collected by McGuine et al. (2011) supported the belief that ankle braces do not affect forces on the knee joint as the 28 knee injuries that occurred during this study were split almost evenly between the braced and unbraced participants. Kaminski et al. (2013) agreed on the difficulty in making conclusions about effects of ankle braces on knee injuries due to the inconsistency in the literature and limited safe testing techniques, indicating this topic requires more research.

Another concern expressed is that braces may weaken the muscles in the ankle joint but it is not known to what extent or how much time it would take to create this weakness. As was previously stated, muscle weakness and neuromuscular deficits are reported risk factors for ankle sprains. This would be a more pressing concern if an athlete were to wear braces long term and then suddenly discontinue use; or wear the braces continuously throughout each day. This could be a reason for neuromuscular training being a recommended treatment along with ankle bracing in order to speed up recovery time and increase muscular strength back to its baseline (Martin et al., 2013).

Ankle braces are designed to control motions of the ankle joint in order to prohibit the motions that would cause an ankle sprain. Some have suggested that wearing ankle braces may restrict too much motion and impede performance. Cutting, planting, and jumping require neuromuscular control and flexibility of a joint to perform quick movements. Investigators have studied this effect of restriction in motion caused by ankle braces on different sport-related motions. A previous study comparing two different ankle braces, the semi-rigid and the lace-up, found that the lace-up braces restricted the plantarflexion and inversion motions more than the semi-rigid brace (Brosky, 2017). In a study performed by Parsley et al. (2013), lace-up braces were found to significantly restrict plantarflexion and dorsiflexion. As one may recall, reduced dorsiflexion range of motion and strength were determined to be risk factors of ligament sprain injuries (de Noronha, Refshauge, Herbert, & Kilbreath, 2006; Willems et al., 2005). The concern of the impact of ankle braces on athletic performance has important implications and is the primary focus of this current study.

Supporting Literature

In 1999, Bot and Mechelen reviewed the literature determining the effects of ankle bracing on athletic performance. Using vertical jump height as an outcome variable, the numbers for the Swede-O Universal® brace and the Kallassy® brace demonstrated a decrease by 4.6 and 3.4%, respectively. One other study demonstrated a decrease in vertical jump by 5.4% using similar braces. These two previous studies each involved only male, college-aged participants. The other six studies reported on in this systematic review testing vertical jump performance found no effect and used a sample of male and female participants. Speed and agility were generally unaffected by application of ankle braces in most of these previous studies. It was suggested by the reviewers that ankle braces be tested over an extended period of time to determine any long-term effects.

A more recent study performed using 34 participants with reported chronic ankle instability and testing ten different braces and effects on performance in an agility course demonstrated a significant negative effect on the vertical jump performance for the rigid brace only. The investigators noted that this rigid brace would normally not be worn by an athlete and therefore, this finding had limited impact on effects on sports related performance activities. The other braces, semi-rigid and lace-up, demonstrated no significant effects on performance. Researchers again suggested a longer activity requirement. The soft braces (e.g. lace up, cloth, fabric) were perceived by the users as more comfortable and to have less performance impairment than the semi-rigid braces (Rosenbaum et al., 2005).

A 2013 study examining the effects of three different ankle braces on functional performance in healthy men discovered a significant reduction in each brace condition from the normal condition. All braces were found to restrict inversion, as designed to do. The lace-up brace was also found to restrict both plantarflexion and dorsiflexion range of motion. It is worth noting that these measurements were found by use of goniometer with shoes donned. Normally, range of motion is measured without shoes due to the need for visualization of anatomical landmarks. All braces, the prototype brace (Seattle Ankle Orthosis; R&D Medical, Lake Forest, California), the lace-up brace, and the semi-rigid brace, significantly reduced vertical jump performance by a mean difference of 1.3-1.8 cm. This calls into question any clinical relevance, as less than two centimeters is a small difference in jump height, especially when considering potential sources of measurement error. When testing agility and balance, no significant effect was discovered between any of the conditions (Parsley et al.).

Ambegaonkar et al. (2011) tested ankle braces and their effects on agility, balance, and vertical jump performance in four males and six females. The braces used included the Swede-O® lace-up, the Air-Cast Stirrup ®, a taping basket weave technique, and a control condition. Balance scores did not differ between the conditions. Vertical jump performance results revealed the same findings, as no significant differences were found between the vertical jump conditions. Investigators believe this result can be explained by the braces' range of motion restriction occurring in the frontal plane and the main motions involved with vertical jump occur primarily in the sagittal plane. The semi-rigid brace was shown to result in a significantly slower performance time than the control condition in the agility test (Right Boomerang Run Test).

Leonard and Rotay (2014) chose to use the Vertec® to measure vertical jump, as this apparatus is a popular choice with investigators due to its relative inexpensive cost, reported ease of use, and reliability. Effects of ankle taping and bracing were tested on agility, vertical jump, and power in 10 athletes and nine non-athletes. A standard Mueller® lace-up brace was applied. All discrepancies were seen between these two groups in performance; however, no significant differences between braced, taped, and unbraced condition were found for vertical jump, agility, or power.

Jumping Mechanics and Instrumentation

Because jumping is an athletic, repetitive action in volleyball and requires complex inter-related motions of the lower extremity, including the ankle joint, vertical jump performance was identified as an important athletic motion in the present study. An athlete requires the ability to adequately dorsiflex and plantarflex the feet in an explosive manner to reach a maximum jump height. Now, in order to determine whether a restriction in these motions caused by bracing would have a significant effect on vertical jump displacement, measurement of jump performance would need to be compared.

Vertical jump performance can be tested utilizing a number of different methods. The gold standard of vertical jump measurement is the three-dimensional motion analysis system, which uses video analysis to capture the jump performance using reflective markers at the baseline height and maximum trajectory height. Despite being considered the gold standard, the motion analysis system tends to be time consuming, labor intensive, costly, and limited to a lab setting (Charlton, Kenneally-Dabrowski, Sheppard, & Spratford, 2016). Other devices have been developed with the purpose of being simpler to use, more portable and cost-effective.

For example, the Just Jump System® (Probotics, Inc., Huntsville, AL, USA) includes a platform connected to a device that displays the measurement of time off of the mat and estimates vertical jump height in inches (Klavora, 2000). It uses the equation "jump height = [t^2 x g]/8 where t=flight time and g=gravitational acceleration (9.81m/s^2). When using flight time as the basis for measuring vertical jump, one understands that a source of error may come from manipulation of staying in the air longer by flexing the ankles, knees and hips during flight, or jumping forward slightly on the mat. Despite this potential error, the Just Jump® demonstrates intersession and intrasession reliability and comparable values to the gold standard (Markovic, Dizdar, Jukic, & Cardinale, 2004; McMahon, Jones, & Comfort, 2016), and was used to assess vertical jump height in collegiate volleyball players in the current study.

Another device often used to measure jump height is the Vertec® (Sports Imports, Hilliard, OH, USA). The Vertec® uses the distance between standing reach height and the maximum jump reach height marked by plastic "vanes." A participant displaces the vanes out of line as a visual representation of where the participant touched. Ideally, the participant moves these vanes at the highest vertical point; however, there are sources of error related to this method. Each vane is separated by 1.27 cm (Nuzzo, Anning, & Scharfenberg, 2011), so if they were to reach in between the vanes, the reading is not precisely representative of the true height jumped. In addition, this device depends on the participant's consistent reach technique and ability to reach the target at maximal displacement. For example, the participant would need to reach with the same amount of arm extension each time, and the variability in upper extremity mobility and its many degrees of freedom is another source of error. Although the Vertec® has a high reliability, it is less than that reported in studies that used the Just Jump (Charlton et al., 2016; Leard et al., 2007), and therefore was not used to assess vertical jump height in the current study.

In a study conducted in 2011 at Slippery Rock University, Pennsylvania (Nuzzo et al.), researchers tested the reliability of three different jump tests—Just Jump®, Vertec®, and Myotest®. In both males and females, results for maximum jump height was greatest when measured by the Just Jump® and significantly higher than the Vertec® and the Myotest®. The Myotest® demonstrated the greatest reliability followed by the Just Jump®, then the Vertec®. A similar device to the Myotest® is the VERT® device (Mayfonk Athletic, Florida, USA) in the fact that they are both portable and have the capacity to measure not only jump height but also number of jumps.

The VERT® is a small device that is connected by Bluetooth to an Apple® device to display vertical jump height (in centimeters or inches). The device is worn inside a belt that attaches by Velcro® just below the participant's navel, which more closely approximates an individual's center of mass. When compared to the gold standard, the VERT® showed high correlations and excellent validity, yet VERT® data displayed slight overestimations and larger biases (Charlton et al., 2016). The device is recently developed technology; however, due to its validity, its gaining popularity with coaches with its ease of use, and its comparability to the Myotest®, the VERT® device was used in the current study.

Because the vertical jump is a common athletic motion in volleyball, it has been used by coaches, recruiters, and researchers to assess an athlete's lower body power and explosiveness (Alemdaroğlu, 2012; Balsalobre-Fernández, Glaister, & Lockey, 2015; Peterson, Alvar, & Rhea, 2006; Reiser, Rocheford, & Armstrong, 2006). As has been mentioned, the jumping motion involves explosive movements at the ankle joint in order to propel an athlete upwards to a maximal height. To create the greatest amount of vertical displacement, athletes need to extend their hips, knees, and ankles (Reiser et al., 2006). In theory, if these movements are restricted, the ability to jump could be restricted as well.

The previous literature suggests that when tested under experimental conditions, ankle bracing has either little or no effect on athletic performance (Bot & van Mechelen, 1999; Leonard et al., 2014; Parsley et al., 2013); however, other studies have presented limitations related to small sample sizes, non-homogenous participants, or sources of error in instrumentation or methodology. This has prevented researchers from obtaining conclusive evidence. The following thesis was developed with the previous literature in mind in hopes of creating a convergent design using both qualitative and quantitative data. The purpose of the current study was to analyze the effect of three different braces on vertical jump performance in collegiate female volleyball players. A secondary purpose is to collect these same participants' feedback on preference and reaction to the different braces' characteristics.

Previous Research Involvement at Bellarmine:

2015

Before the present study was developed, researchers at Bellarmine University had been testing ankle braces and their effect on other agility performance tests. First, they compared semi-rigid double upright and lace-up ankle braces. They tested differences between the two braces on range of motion, functional performance, and user satisfaction. Thirty regularly physically active, college-aged adults without lower extremity injuries took part in the study. The investigators first measured ankle range of motion for each brace using a universal goniometer and fluid goniometer. Participants then went through a series of agility tests such as a figure 8 hop, side-to-side hop, 6 meter- single limb-crossover, and square-hop tests. No significant differences were found between conditions and hop performances.

This previous study demonstrated the lace-up brace significantly limited plantarflexion and inversion more than the double upright rigid brace. Not surprisingly, both braces significantly limited range of motion more than the unbraced condition. There were no statistically or clinically significant effects on dorsiflexion or eversion. This is understandable and desirable because plantarflexion and inversion are the combined motions that are the most common mechanism of a lateral ankle sprain. This is the primary purpose of the braces—to mechanically restrict these motions in order to protect the ankle from an initial or recurrent ankle injury. Participants in that study also expressed a general preference for the lace-up brace in several categories. This previous study, while contributing to the understanding of ankle braces, did exhibit some methodological limitations, which influenced the design of the main research question for the current study: what effect do different ankle braces have on vertical jump performance in female collegiate volleyball players and, which braces do they seem to prefer?

2016

I joined this research team in a previous ankle brace study as it was related to some of my current interests on the effects of ankle braces on performance, as a collegiate volleyball student. The same participant criteria, range of motion measurement techniques, and agility tests were administered to test the Eclipse I® and Eclipse II® semi-rigid upright braces. Because I was particularly interested in examining the effect of the braces on vertical jump, I suggested adding a single-leg vertical jump test using the Just Jump® platform. This study also implemented a randomized order of all conditions to prevent familiarization and learning effect from accounting for the differences in performance, which was noted as a limitation in a previous study where the unbraced condition was the first condition tested (2015 study). The failure of a true randomization limited the capacity to determine if the effects were related to the braces or more likely to a learning effect.

Results demonstrated that the single upright has a similar range of motion to the unbraced condition. The double upright appeared to restrict more motion than both the unbraced and single upright condition, though with an accepted margin of error for the goniometer (+/- 5 degrees), these small differences were determined to be clinically negligible. The side hop and the vertical jump showed significant differences between the no brace condition and the double-upright brace. In addition, the double-upright braced condition performance times were slower and the vertical jump performance height lower. These differences were also deemed clinically insignificant. The single upright was reported to be more comfortable and easier to apply, yet was perceived by the users to provide less stability than the double upright semi-rigid brace.

My Contribution

The current study was designed in part as a result of the limitations noted with these previous studies and other previous literature on the effects of ankle braces on performance. The resulting changes in the design were made: I decided to narrow the participant sample to competitive female collegiate volleyball players in order to create a homogenous group in which ankle braces are commonly used. Another limitation of the previous studies was ankle range of motion assessment by a common clinical method in non-weight bearing which does not simulate the braces effects on motion when in a functional position. I decided not to examine ankle range of motion in the current study as appropriate instrumentation to assess range of motion in a weight-bearing, functional position was not readily available. The study was advertised to local female collegiate varsity and club volleyball players within the Louisville community.

The primary outcome variables were limited in the current study to only testing vertical jump performance. Vertical jump performance was recorded using the Just Jump® platform and the VERT® device. While vertical jump performance was assessed in the 2016 study, it was realized the single leg hop test procedure used did not emulate the natural jump technique encountered in volleyball; therefore, it was decided that the participants would use their normal, three-step attack approach commonly used in volleyball players and other jumping sports. The participant was encouraged to jump straight up as high as possible to achieve their maximal jump height. Randomization of the different conditions was continued (unbraced, lace-up, single upright, double upright brace). All 31 participants received randomized order of the four conditions using the Excel® randomization function. A dynamic warm-up was added to simulate normal conditions for a volleyball player and to prepare the participants for the procedures. In addition to height, weight, and age, position played such as Libero (L), defensive specialist (DS), outside hitter (OH), middle blocker (MB), right side hitter (OPP), and setter (S) was recorded. Lastly, participants were asked if they currently wore ankle braces during competition, and if so, to list what type of brace.

The purpose of this study was to examine the effect on vertical jump height with the application of three different ankle braces commonly worn by female collegiate volleyball players. This study provided insight from a population that commonly uses ankle braces for protection and prevention of ankle sprains during volleyball activities. A secondary aim was to obtain feedback from the study participants on preferences of brace type. Specific feedback on brace characteristics included features such as comfort, appearance, stability, and ease of application.

Because ankle braces are so commonly used in volleyball, there is value in determining what effect if any, ankle braces have on vertical jump performance. The results could possibly be useful in determining which of the braces had the least effect on performance. Understanding how each of the different braces were rated by the participants on comfort, stabilization, and overall satisfaction, a volleyball athlete could use this information to influence their decision on brace type. Previous research has indicated that ankle braces reduce the risk of injury, but is that enough reason for an athlete to choose to wear ankle braces? Is it worth taking the chance of spraining an ankle if it means not sacrificing any athletic ability in order to perform at the highest level? If braces were shown to have no effect on athletic performance while at the same time reducing the risk of ankle sprain, then athletes may feel more confident in wearing a brace in order to reduce the risk of injury to the ankle.

Methods:

The study was reviewed and approved by the Bellarmine University Institutional Review Board (IRB #415-3). Participants were recruited from local universities, were at least 18 years of age, and participating in collegiate practice and/or competitions. Testing took place during March in 2017. The equipment and braces were stored and set up on basketball court number one in the Student Recreation Facility (SuRF) on the campus of Bellarmine University in Louisville, Kentucky. The surface was sport court, and lines for a volleyball court were labeled on the surface. After explaining the risks and benefits and obtaining consent, each participant completed a lower extremity health history form. Participants were asked to list each injury for left and/or right hip, thigh, knee, ankle, and foot (**Figure 1**). If an injury occurred, participants were asked to list treatment for the stated injury. When participants completed their health history, they performed a dynamic warm up consisting of knee-to-chest lunge, high knees, butt kicks, toe touch leg swings, T-stand walk, and power skips—each down and back the width of half of the volleyball court.

Participants were then randomly assigned each of the four conditions: the rigid single-upright brace **(Figure 2a)**, rigid double-upright brace **(Figure 2b)**, lace-up brace **(Figure 2c)**, and unbraced (or natural condition, not shown).

The participants were given the manufacturer's instructions for applying the braces along with the correct brace size that corresponded to the participants shoe size. The participants applied the braces on each foot (bilaterally) and reapplied their shoes. The participants then performed three separate vertical jumps from a basic three-step volleyball spike approach to the best of their abilities for each condition. They were instructed to jump as high as possible. Immediately at the conclusion of each condition tested, participants answered an 8-item satisfaction survey using a 7-point Likert Scale ranging from 1(*"extremely dissatisfied")* to 7 (*"extremely satisfied")* to display satisfaction of the brace and demonstrate which condition is preferred (**Figure 3).**

Vertical jump performance was measured via VERT® devices and a Just Jump® platform. Researchers measure vertical jump using the VERT® by connecting the device via Bluetooth to a phone or tablet, then placing it inside the belt worn by the participant. The investigator instructed the participant to place the belt just below their umbilicus close to the location representing the individual's approximate center of mass (COM). The Just Jump® is a flat square force platform that calculates vertical jump height by measuring the time the participant is in the air. Both tests were assessed simultaneously and recorded in the participant's data collection forms. Averages were calculated for the three jumps in each condition for each jump test **(Figure 4)**. Participants received up to a 30-second rest period between each jump. Twelve jumps were performed in totality, three for each of the four different conditions.

Statistical Analysis: Repeated measures ANOVA was employed to determine differences between each condition's jump heights. Tukey's LSD post hoc comparisons were conducted on significant effects ($p<0.05$) to observe differences between conditions. Paired t-tests were employed to analyze the satisfaction questionnaires.

Results:

Thirty-one female collegiate volleyball players participated in the study. The average age was 19.9, and average weight was 147.7 lbs with average height 5'8". BMI were indicative of a typical female college athlete (22.8 ± 2.93). Fifteen of the thirty-one participants had reported previous ankle sprains (48%). Only 29% of participants had no reported previous lower extremity injuries. The percentage of participants who did not wear ankle braces for practice or competition was 36% (11 out of 31). Through self-report it was observed the most common brace worn among participants was the double upright brace (13 out of 31; 42%). The next most common brace was the lace-up brace, reportedly worn by 6 out of the 31 participants (19%). One participant (3%) reportedly wore a different type of brace, Ultra Ankle Ultra Zoom®, which has a "hinged cuff and a soft shell" (Ultra Ankle).

Vertical Jump Performance: The VERT® device measures show the unbraced condition mean of 18.54 inches (± 2.29). The next highest vertical jump performance mean was the double upright brace at 18.14 (± 2.27). Full results are shown in **Tables 1 & 2** and **Figure 5**. The Just Jump® System shows similar results as seen in **Tables 3 & 4** and **Figure 6**.

Brace Satisfaction: When asked which of the three braces the participants preferred, 22 of the 31 participants (71%) indicated a preference for the lace-up brace. The next highest preferred brace was the double upright with 5 participants (16%), followed by the single upright brace with 3 participants (10%) and one participant who had no preference (3%). Participants indicated their preference for the lace-up brace in 5 out of 7 characteristics: appearance, application, fit, comfort, and overall satisfaction. The double upright brace was reportedly preferred for its stability and belief in its ability to prevent an injury. Overall brace satisfaction is shown in table (**Table 5**) and graph **(Figure 7**).

Discussion:

Considering the primary dependent variable of the current study, vertical jump performance, wearing the three braces resulted in a minimal impact on jump height performance when compared to the unbraced condition. When examining the magnitude of this effect, the VERT® device resulted in a range of approximately 0.40 inches between the unbraced condition (18.54 inches), and the double upright (18.14 inches) and single upright (18.11 inches) braces. A maximum range of 0.47 inches difference was found between the unbraced condition and the lace-up brace (18.07 inches). The Just Jump® System measured a range of 0.42 inches difference between the unbraced condition (19.35 inches) and the single upright (18.93 inches). The double upright brace was about 0.48 inches lower than the unbraced condition (18.87 inches), and the maximum range of 0.52 inches was observed between the unbraced condition and the lace-up brace (18.83 inches). Both measures of vertical jump demonstrated approximately a half an inch of difference between the unbraced condition and the braced conditions. Though a small overall difference (2-3%), the question remains, is this tradeoff in vertical jump performance worth the decreased risk of ankle injury? The authors believe it is worth the decreased risk in this population; however this position might be contested by others where these small differences could be significant such as in professional or Olympic levels of competition.

Our results are consistent with the previous literature that examined effects of ankle bracing on vertical jump performance that found little to no effect. For example, the systematic review by Bot and van Mechelen (1999) noted only two of the studies demonstrated a negative effect on vertical jump height both by approximately less than 5%. However, six other studies found no effect on performance. The current study demonstrated a 2-3% decrease which is less than the 5% reported by Paris et. al, (1992) and Burks et. al (1991). One of the reasons for this slight difference may be related to the instrumentation used in the measurement of jump height. Earlier studies utilized what the authors believed were less sophisticated methods such as using the Sergeant Chalk Jump or the Vertec®. The potential error associated with measuring vertical jump height using overhead reach methods are dependent upon the upper extremity, while meaningful in volleyball activities such as blocking and hitting, these methods may not be valid in regards to examining actual effects of ankle bracing on jump performance. Vertical jump performance methods that are dependent on upper extremity flexibility and timing of external markers (e.g. chalk mark on a wall, displacement of a 1.27 cm plastic vane, etc.) may not accurately demonstrate actual magnitude of jumping.

In regards to the satisfaction scores, the lace-up clearly appeared to be the preferred brace by the participants in this study, which correlates with the overwhelming response of participants (71%) choosing the lace-up as their preferred brace out of the three (22 of 31 participants). When compared to the results from the first Bellarmine study testing the AS1 Pro® lace-up and a double upright brace, the T2® (Cramer Products, Inc., Gardner, KS), the preferences for the lace-up brace were similar. The double upright brace was the second most preferred brace at 5/31 participants (16%). The lace-up brace demonstrated better ratings in *appearance, application, fit, comfort*, and *overall satisfaction*. The double upright brace topped the scores in *stability* and *belief the brace could prevent a future injury* as is advertised. This may be an important indicator of which factors are most important to athletes when looking for a brace. Most participants indicated preference for the lace-up even though the double upright was shown to feel more stable and be better able to prevent a future injury, which is an ankle brace's primary purpose.

When asked whether or not the braces interfered with the ability to jump, the double upright brace received the most "yes" votes at n=5 (16%). Most participants reported that the braces did not affect their ability to jump. This is an important element for an athlete who is required or chooses to wear an ankle brace. If an athlete feels that they cannot perform at a maximal level, and they feel that the braces hinder their performance, then an athlete may be reluctant to wear the braces for protection.

There were some subjective comments by some of the participants indicating some difficulty with threading the Velcro straps through the sides of the single and double upright braces, determining the correct heel lock technique on the lace-up brace and complaints about pressure/discomfort over the medial malleolus with the double upright brace. Both the double upright and single upright brace were deemed somewhat "bulky" in appearance and fit by several participants; and some felt that the single upright brace was missing the element of stability. Comments regarding the lace-up brace state that it was "mostly comfortable," which is consistent with a previous study comparing rigid and soft braces demonstrating that soft braces are more comfortable (Rosenbaum et al., 2005).

Though not a primary purpose, one could also use the data formulated from the VERT® device and the Just Jump® system to determine the reliability of the different devices. The two devices were highly correlated with one another (r =.87-.90). The VERT® device read consistently lower than the Just Jump system by approximately 4%. While the two vertical jump devices correlated well, it is not known from the current study which is more accurate in assessing vertical jump performance. Future study is needed to compare the precision and accuracy of these devices.

Limitations:

As with all studies, there were limitations. First, the sample size was limited to 31 participants. The 31 participants were limited to a local population of female collegiate volleyball players, which supports internal validity, but is not generalizable to the entire at-risk-for-ankle-sprain population. This sample did include both varsity volleyball players and competitive club volleyball players. There may be a difference in performance and effort between these two groups but this was not a focus of the current study, and since each subject essentially served as their own control, may not be relevant. Another limitation is whether all participants performed each jump with a maximum effort.

Another potential source of error may have been related to aberrant movement of the VERT when secured around the waist of the participants. This could be a source of error for the VERT® device. Developers should consider other methods to secure the device to the center of mass of a participant.

The participants' brace preference may have also been influenced by their previous brace use and history. Along with this observation, there is also the question of whether or not the participants had enough time to adequately familiarize themselves with the braces. Future research should be conducted from longer duration of wear experiences of using the braces. Additionally, brace studies should be conducted on other athletic populations with a high risk for ankle sprains in their sports. Concerns such as effects on how ankle braces influence ground reaction forces, forces on the knee joint, ankle weakness, and other known performance deficits should continue to be tested as new braces are developed.

Conclusions and Clinical Relevance:

The results of this study indicate there is a minimal negative effect of the three different ankle braces on vertical jump performance. While the current study did not examine ROM limitations caused by the different braces, it is possible the different braces did have an effect on limiting ROM, and how these differences may have impacted vertical jump performance is unknown.

The information collected during this study may be beneficial to coaches, athletes, and clinicians regarding brace selection and use. Knowing the properties and features of each of the braces that a collegiate volleyball player prefers may help in deciding which brace is most appropriate for each situation. Research should continue as ankle braces continue to develop and new designs are introduced.

References

Alemdaroğlu, U. (2012). The relationship between muscle strength, anaerobic performance, agility, sprint ability and vertical jump performance in professional basketball players. *Journal of human kinetics, 31*, 149-158.

Balsalobre-Fernández, C., Glaister, M., & Lockey, R. A. (2015). The validity and reliability of an iPhone app for measuring vertical jump performance. *Journal of sports sciences, 33*(15), 1574-1579.

Bot, S. D., & van Mechelen, W. (1999). The effect of ankle bracing on athletic performance. *Sports Medicine, 27*(3), 171-178.

Brosky, J., Joseph A., Elizabeth Levay, Kristin Dierker, Robert V. Topp. (2017). A Comparison Between Rigid Double Upright and Lace-up Ankle Braces on Ankle Range of Motion, Functional Performance, and User Satisfaction of Brace Characteristics *Journal of Performance Health*.

Charlton, P. C., Kenneally-Dabrowski, C., Sheppard, J., & Spratford, W. (2016). A simple method for quantifying jump loads in volleyball athletes. *Journal of Science and Medicine in Sport*.

de Noronha, M., Refshauge, K. M., Herbert, R. D., & Kilbreath, S. L. (2006). Do voluntary strength, proprioception, range of motion, or postural sway predict occurrence of lateral ankle sprain? *British Journal of Sports Medicine, 40*(10), 824-828.

Ferran, N. A., & Maffulli, N. (2006). Epidemiology of sprains of the lateral ankle ligament complex. *Foot and ankle clinics, 11*(3), 659-662.

Fong, D. T.-P., Hong, Y., Chan, L.-K., Yung, P. S.-H., & Chan, K.-M. (2007). A systematic review on ankle injury and ankle sprain in sports. *Sports Medicine, 37*(1), 73-94.

Fong, D. T., Chan, Y.-Y., Mok, K.-M., Yung, P. S., & Chan, K.-M. (2009). Understanding acute ankle ligamentous sprain injury in sports. *BMC Sports Science, Medicine and Rehabilitation, 1*(1), 14.

Hadzic, V., Sattler, T., Topole, E., Jarnovic, Z., Burger, H., & Dervisevic, E. (2009). Risk factors for ankle sprain in volleyball players: a preliminary analysis. *Isokinetics and Exercise Science, 17*(3), 155-160.

Halim-Kertanegara, S., Raymond, J., Hiller, C. E., Kilbreath, S. L., & Refshauge, K. M. (2016). The effect of ankle taping on functional performance in participants with functional ankle instability. *Physical Therapy in Sport*.

Kaminski, T. W., Hertel, J., Amendola, N., Docherty, C. L., Dolan, M. G., Hopkins, J. T., . . . Richie, D. (2013). National Athletic Trainers' Association position statement: conservative management and prevention of ankle sprains in athletes. *Journal of athletic training, 48*(4), 528-545.

Klavora, P. (2000). Vertical-jump tests: a critical review. *Strength & Conditioning Journal, 22*(5), 70.

Leard, J. S., Cirillo, M. A., Katsnelson, E., Kimiatek, D. A., Miller, T. W., Trebincevic, K., & Garbalosa, J. C. (2007). Validity of two alternative systems for measuring vertical jump height. *The Journal of Strength & Conditioning Research, 21*(4), 1296-1299.

Leonard, T., Rotay, J., Paulson, S., & Sanders, J. (2014). *The Effects of Ankle Taping and Bracing on Agility, Vertical Jump, and Power.* Paper presented at the International Journal of Exercise Science: Conference Proceedings.

Markovic, G., Dizdar, D., Jukic, I., & Cardinale, M. (2004). Reliability and factorial validity of squat and countermovement jump tests. *The Journal of Strength & Conditioning Research, 18*(3), 551-555.

Martin, R. L., Davenport, T. E., Paulseth, S., Wukich, D. K., Godges, J. J., Altman, R. D., . . . Fearon, H. (2013). Ankle stability and movement coordination impairments: ankle ligament sprains. *Journal of Orthopaedic & Sports Physical Therapy*.

McGuine, T. A., Brooks, A., & Hetzel, S. (2011). The effect of lace-up ankle braces on injury rates in high school basketball players. *The American journal of sports medicine, 39*(9), 1840-1848.

McMahon, J. J., Jones, P. A., & Comfort, P. (2016). A correction equation for jump height measured using the just jump system. *International journal of sports physiology and performance, 11*(4), 555-557.

Nuzzo, J. L., Anning, J. H., & Scharfenberg, J. M. (2011). The reliability of three devices used for measuring vertical jump height. *The Journal of Strength & Conditioning Research, 25*(9), 2580-2590.

Parsley, A., Chinn, L., Lee, S. Y., Ingersoll, C., & Hertel, J. (2013). Effect of 3 different ankle braces on functional performance and ankle range of motion. *Athletic Training and Sports Health Care, 5*(2), 69-75.

Peterson, M. D., Alvar, B. A., & Rhea, M. R. (2006). The contribution of maximal force production to explosive movement among young collegiate athletes. *The Journal of Strength & Conditioning Research, 20*(4), 867-873.

Reiser, R. F., Rocheford, E. C., & Armstrong, C. J. (2006). Building a Better Understanding of Basic Mechanical Principles Through Analysis of the Vertical Jump. *Strength & Conditioning Journal, 28*(4), 70-80.

Rosenbaum, D., Kamps, N., Bosch, K., Thorwesten, L., Völker, K., & Eils, E. (2005). The influence of external ankle braces on subjective and objective parameters of performance in a sports-related agility course. *Knee surgery, sports traumatology, arthroscopy, 13*(5), 419-425.

Ubell, M. L., Boylan, J. P., Ashton-Miller, J. A., & Wojtys, E. M. (2003). The effect of ankle braces on the prevention of dynamic forced ankle inversion. *The American journal of sports medicine, 31*(6), 935-940.

Ultra Ankle, L. Retrieved from https://www.ultraankle.com/about-us

Van den Bekerom, M., van Kimmenade, R., Sierevelt, I., Eggink, K., Kerkhoffs, G., van Dijk, C., & Raven, E. (2016). Randomized comparison of tape versus semi-rigid and versus lace-up ankle support in the treatment of acute lateral ankle ligament injury. *Knee surgery, sports traumatology, arthroscopy, 24*(4), 978-984.

Venesky, K., Docherty, C. L., Dapena, J., & Schrader, J. (2006). Prophylactic ankle braces and knee varus-valgus and internal-external rotation torque. *Journal of athletic training, 41*(3), 239.

Verhagen, E., & Bay, K. (2010). Optimising ankle sprain prevention: a critical review and practical appraisal of the literature. *British Journal of Sports Medicine, 44*(15), 1082-1088.

West, T., Ng, L., & Campbell, A. (2014). The effect of ankle bracing on knee kinetics and kinematics during volleyball- specific tasks. *Scandinavian journal of medicine & science in sports, 24*(6), 958-963.

Willems, T. M., Witvrouw, E., Delbaere, K., Mahieu, N., De Bourdeaudhuij, I., & De Clercq, D. (2005). Intrinsic risk factors for inversion ankle sprains in male subjects a prospective study. *The American journal of sports medicine, 33*(3), 415-423.

APPENDIX

Table 1: VERT® Mean Vertical Jump Scores Comparison

Condition	Mean Vertical Jump Height (in.)	Standard Deviation
Unbraced (Control)	18.5452	2.29954
Eclipse I® (single upright)	18.1097	2.51706
Eclipse II® (double upright)	18.1419	2.27929
AS1 Pro® (lace-up)	18.068	2.5019

Table 2: Just Jump® Mean Vertical Jump Scores Comparison

Condition	Mean Vertical Jump Height (in.)	Standard Deviation
Unbraced (Control)	**19.35**	**2.61**
Eclipse I® (single upright)	**18.93**	**2.55**
Eclipse II® (double upright)	**18.87**	**2.78**
AS1 Pro® (lace-up)	**18.82**	**2.55**

Table 3: Brace Overall Satisfaction Mean Differences

This table shows a significant difference (p<0.5) between means when comparing the double upright brace (1) and the single upright brace (2) to the lace-up brace (3).

Pairwise Comparisons

Measure: MEASURE_1

(I) Brace_Type	(J) Brace_Type	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-.065	.241	.790	-.556	.427
	3	-.871*	.261	.002	-1.405	-.337
2	1	.065	.241	.790	-.427	.556
	3	-.806*	.256	.004	-1.329	-.284
3	1	.871*	.261	.002	.337	1.405
	2	.806*	.256	.004	.284	1.329

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Figure 1: Past Injury Questionnaire

	Have you ever experienced an injury to your Lower Extremity? If YES, provide brief details (sprain, strain, fracture, etc.).	Did you seek or require medical attention for this injury/problem? If YES, provide details (surgery, medication, brace, etc.)
Right Hip/Thigh		
Right Knee		
Right Ankle/Foot		
Left Hip/Thigh		
Left Knee		
Left Ankle/Foot		

Figure 2: a.) Eclipse I (single upright brace); b.) Eclipse II (double upright brace); c.) AS1 Pro (lace-up brace)

a.) **b.)** **c.)**

Figure 3: Feedback Form Example

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Single Upright Brace (Eclipse I) Feedback Form

Please rate the Single Upright Brace (Eclipse I) on the following scale using:

1- Extremely Dissatisfied
2- Very Dissatisfied
3- Dissatisfied
4- Somewhat Satisfied
5- Satisfied
6- Very Satisfied
7- Extremely Satisfied

Appearance and look of the brace:

1 2 3 4 5 6 7

Ease of Application of the brace:

1 2 3 4 5 6 7

Fit of the brace:

1 2 3 4 5 6 7

Comfort of the brace:

1 2 3 4 5 6 7

Stability provided by the brace:

1 2 3 4 5 6 7

Your belief in the ability of the brace to prevent an ankle injury:

1 2 3 4 5 6 7

Overall satisfaction of the brace:

1 2 3 4 5 6 7

Did the brace interfere with your ability to jump? (circle one)

YES **NO**

Any additional comments regarding the Single Upright (Eclipse I) Brace:

Figure 4: Data Collection Table

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Single Upright Brace (Eclipse-1)

Eclipse I (Single Upright)	**JUST JUMP MAT©**	**VERT©**
Trial 1		
Trial 2		
Trial 3		
Average		

Figure 5: This graph compares each condition’s vertical jump performance as measured by the VERT® device. Brace type “1” is unbraced. Brace type “2” is the single upright. Brace type “3” is the double upright. Brace type “4” is the lace-up brace.

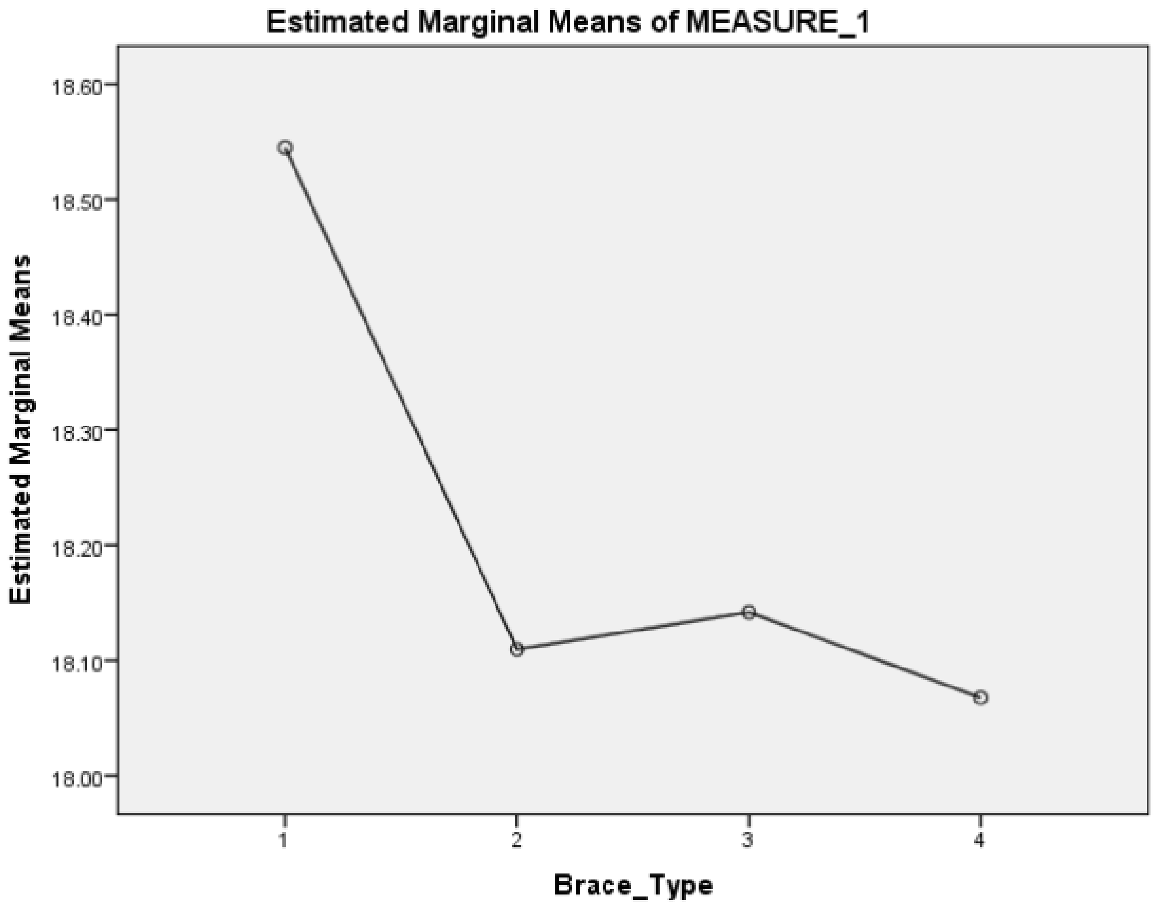

Figure 6: This graph compares each condition's vertical jump performance as measured by the Just Jump® system. Brace type "1" is unbraced. Brace type "2" is the single upright. Brace type "3" is the double upright. Brace type "4" is the lace-up brace.

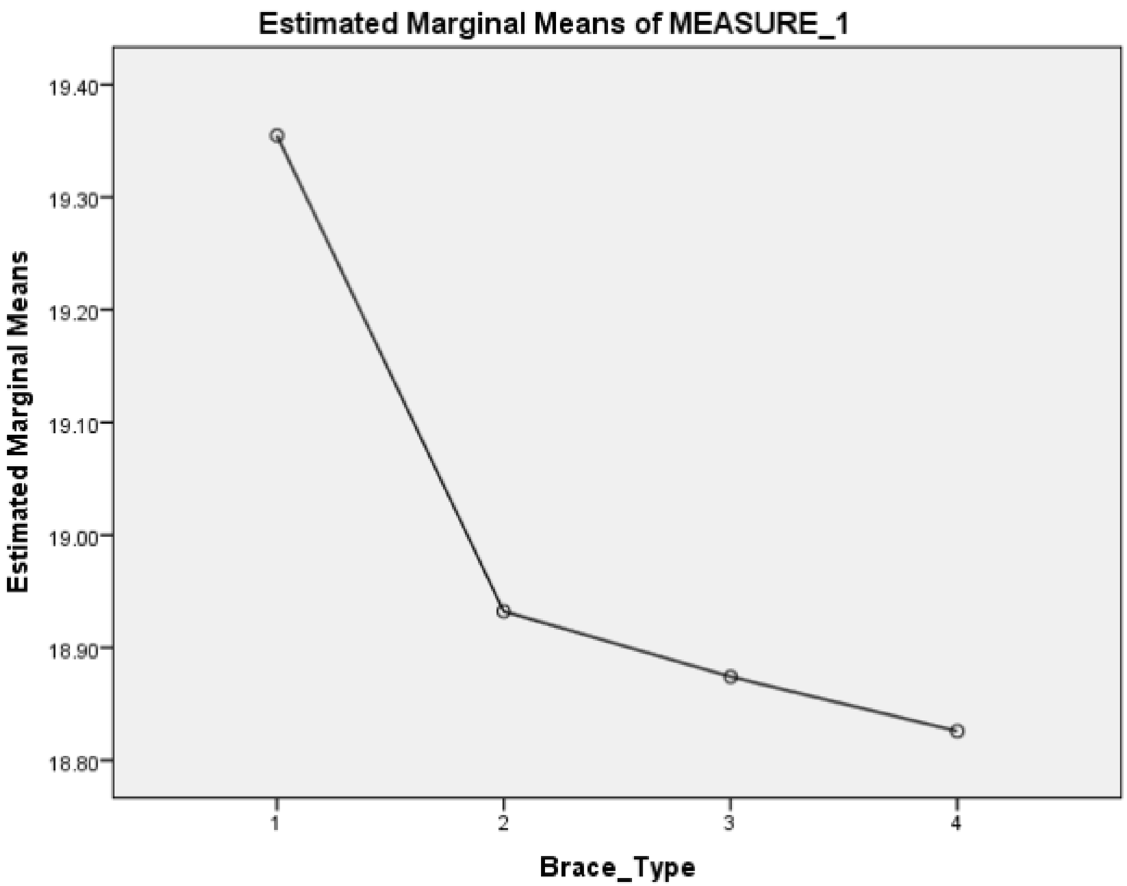

Figure 7: This graph compares the overall satisfaction between the three brace conditions: single upright brace (1), double upright brace (2), and the lace-up brace (3).