The Effects of Bilateral Ankle Bracing and Sex on Swing Block Jump Height, Agility, and Sport Related Anxiety in Volleyball Players

by

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Abstract

Introduction: Ankle braces are commonly worn in the athletic community both as a method of rehabilitation after sustaining an ankle injury, and prophylactically to prevent an injury. Within court sports such as volleyball, athletes are at a heightened risk of sustaining common and reoccurring ankle injuries. Research on how ankle braces affect athletic performance variables such as vertical jump height and agility speed has mixed results, with some studies reporting no change in performance, while others reporting reductions in performance. With studies citing factors such as ankle range of motion, muscle activation, and changes in lower body kinematics as the cause for changes in athletic performance, more research is needed to fully understand this relationship between bracing and performance. Additionally, differences between sexes has been proposed on some of these identified factors. Also, it has been shown that after sustaining an injury, athletes generally experience higher levels of anxiety when returning to sport participation, with female athletes showing even greater levels of anxiety than males. It has also been suggested that while using supportive ankle devices, such as athletic tape or ankle braces, during rehabilitation, athletes then depend on these devices for psychological support even after their injury has fully healed. As such, the purpose of this study was to examine the effects of bilateral soft-shell ankle bracing and sex on swing block vertical jump height, normalized ground reaction force (GRF) in the Z-plane, agility time, and measures of sport related anxiety as measured by the Sport Anxiety Scale-2 (SAS-2).

Methods: 36 volleyball players (24 male, 12 female) were recruited into the study. Over the course of two separate days, participants completed a swing block vertical jump test and the Modified X Running Test under two conditions: no ankle braces and while wearing bilateral ankle braces. Vertical jump height (cm) and normalized GRF (N) in the Z-plane during takeoff were collected during the swing block vertical jump test. During the Modified X Running Test, time to complete the test in seconds (s) was recorded. After each testing condition on each day, participants were asked to complete the SAS-2 Questionnaire under the verbal prompt "*How did you feel during that condition*". For each dependent variable, a two-way mixed factorial analysis of variance (ANOVA) was used to compare the interaction effect of the independent variables, brace condition (brace or no brace) and sex (male or female).

Results: There was a significant main effect with a large effect size of brace condition seen with decreases in vertical jump height when wearing ankle braces, (F(1,33)=11.00, p=.002, η^2=.25), and a significant main effect of sex on jump height, (F(1,33)=31.21, p=.001, η^2=.49), with male participants jumping higher (M=58.88cm, SD=10.65cm) than female participants (M=39.87cm, SD=7.21cm). There was no statistically significant interaction effect between sex and brace condition on maximum vertical jump height. There was a significant interaction effect with a large effect size between sex and brace condition on values of GRF in the Z-plane, (F(1,33)=7.71, p=.009, η_p^2=.19). When examining the simple main effects of sex on ankle brace conditions, male participants produced statistically significantly less force in the Z-plane respective to bodyweight, t(22)=2.139, p=.044, d=.45. CI:[0.602, 39.154] while not wearing ankle braces (M=279.83%BW, SD=38.48) compared to when they were wearing ankle braces (M=299.70%BW, SD=46.72). There were no other statistically significant simple main effects. There was no statistically significant effect of ankle brace condition on time to complete the

Modified X Running Test, or on scores of the SAS-2 questionnaire during either the swing block vertical jump test or Modified X Running Test.

Conclusion: Based on the results of this study, bilateral soft-shell ankle bracing significantly decreases vertical jump height when using a swing block approach. Furthermore, bilateral ankle bracing reduces normalized GRF in the Z-plane for male athletes. Further research is needed to determine exactly how ankle braces affect athletic performance, and if ankle braces affect sport related anxiety during a competition-like environment between the sexes. This will empower clinicians, athletes, trainers, coaches, and other decision-makers to make well-informed choices regarding the recommendation and utilization of ankle braces in the context of athletic participation.

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"A failure is not always a mistake. It may simply be the best one can do under the circumstances. The real mistake is to stop trying."

- B.F. Skinner

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List of Abbreviations

%BW – Percent Body Weight

AE – Athlete Exposures

AMTI – Advanced Medical Technologies Incorporated

ANOVA – Analysis of Variance

ATFL – Anterior Talofibular Ligament

CAI – Chronic Ankle Instability

CFL – Calcaneofibular Ligament

CM – Centimeters

EMG - Electromyography

GRF – Ground Reaction Force

IZOFT – Individual Zones of Optimal Functioning Theory

M – Meters

N – Newtons

NCAA – National Collegiate Athletics Association

PAR-Q – Physical Activity Readiness Questionnaire

PTFL – Posterior Talofibular Ligament

S – Second

SSC – Stretch-Shortening Cycle

Chapter 1 - Review of the Literature

Overview

In the world of collegiate and recreational sport, injuries are a common obstacle that athletes must overcome. Specifically, ankle injuries are among the highest reported injury sustained during athletic participation (Crowley et al., 2019; Gulbrandsen et al., 2019; Lytle et al., 2021; Tummala et al., 2018). Within a 5-year span, 1.5 million ankle sprains related to athletic participation presented to United States emergency departments (Waterman et al., 2010). Additionally, 22% of sport related emergency room visits in the United Kingdom presented as ankle injuries and defined as ankle sprain or fracture (Boyce & Quigley, 2004). These statistics are similar in Canada, where approximately 35% of injuries reported in the general public occurred during athletic participation. Much higher incidence rates were reported in adolescents aged 12 to 19 years, with the majority of injuries across all age groups being sprains and strains (Injury Lawyers of Ontario, 2022). After sustaining an ankle injury, athletes are more likely to experience greater levels of sport related anxiety (Ford et al., 2017).

There are various theoretical models to explain the relationship between anxiety and sport performance. The Individual Zones of Optimal Functioning Theory (IZOFT) states that individuals perform optimally at different levels of arousal (Welsh Joint Education Committee, 2019). The differences that influence the individual's zone of optimal functioning include factors such as personality, task, and the stage of learning (Welsh Joint Education Committee, 2019). Alternatively, The Inverted-U Hypothesis and Catastrophe Theory each differ slightly but both acknowledge that when arousal is too high, performance decreases (Ford et al., 2017). This becomes problematic as some research suggests that after returning to sport activities from injury, athletes experience higher levels of anxiety related to the fear of reinjury (Ford et al, 2017). Moreover, an individual’s personality, history of stressors, and available coping resources, all interact to create a response to stressors that may be an antecedent to sport injury (Ford et al., 2017; “Psychological Issues Related to Illness and Injury in Athletes and the Team Physician: A Consensus Statement—2016 Update,” 2017).

The relationship between stress and anxiety has been shown to be influenced by an individual's sex (Altemus et al., 2014; Beynnon et al., 2002; Tomczak et al., 2022). Typically, females experience higher levels of stress, anxiety, and depression than their male counterparts and this is no different for female athletes (Kessler et al., 2012). Alongside this, female athletes are also at a greater risk of sustaining lower body injuries such as anterior cruciate ligament tears and grade I ankle sprains due to hormonal differences (Beynnon et al., 2002). To compound this, it has been shown that after sustaining an injury, athletes experience higher levels of performance anxiety and psychological distress than athletes who have not sustained a prior injury (Ford, 2017).

Psychological distress refers to the broad symptoms of stress, anxiety, and depression (Viertiö et al., 2021). Interestingly, between 5% and 19% of athletes experience psychological distress after a lower extremity injury, and these percentages are comparable to patients who receive treatment for mental health (Gribble & Hertel, 2003). The application of ankle braces reduces the likelihood of sustaining both novel and reoccurring ankle injuries (de Noronha, 2019). It has also been suggested (Hunt and Short, 2006) that once an athlete uses supportive devices such as medical tape or ankle braces to facilitate rehabilitating an injury, they may depend on that device for psychological support even after the injury has fully healed. There is little research examining the influence that ankle braces have on sport related anxiety. As many athletes turn to external support devices as both a prophylactic and therapeutic intervention for ankle injuries, this gap must be addressed.

Devices such as semi-rigid ankle braces, elastic bandages, athletic tape, and Softcast™ are often prescribed by healthcare providers to provide functional support to the ankle joint without completely immobilizing the joint (Lin et al., 2010). In athletic contexts, the most frequently applied braces are for the ankle, knee, shoulder, elbow, and wrist (Perrin, 2012). As the ankle is one of the most injured joints during athletic participation, it will be the focus of this thesis. To improve understanding of injury mechanisms and treatment, a review of the anatomy of the ankle is important.

Ankle Joint

Anatomy of the Ankle

The lateral ankle ligamentous complex consists of three key structures including the anterior talofibular ligament (ATFL), calcaneofibular ligament (CFL), and posterior talofibular ligament (PTFL) as seen in Figure 1. During forced inversion of a plantarflexed foot, the ATFL is the first ligament to be stressed, and often the only ligament injured (D'Hooghe et al., 2020). If the mechanism of injury is forceful enough, the stress will flow around the lateral aspect of the ankle, injuring the CFL, and consequently least frequently, the PTFL (D'Hooghe et al., 2020).

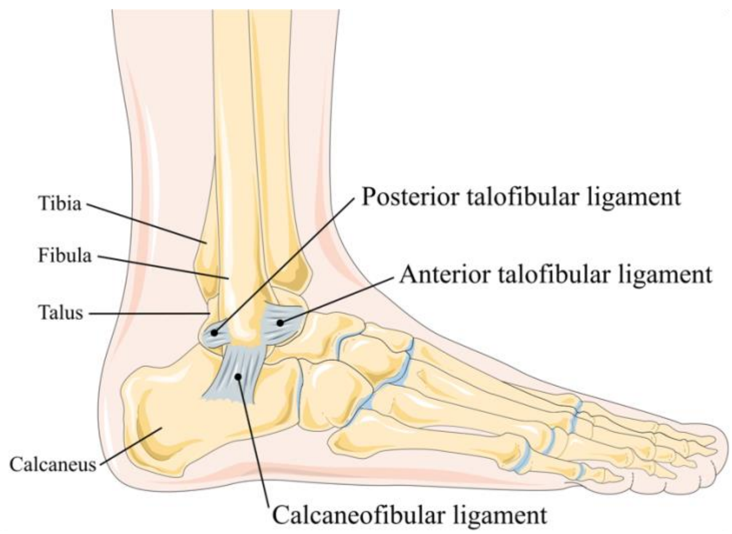
Due to the structural anatomy of the lateral ankle, there is a lower incidence of eversion ankle sprains. When the ankle is forced into eversion, the distal end of the fibula comes into contact with the calcaneus, halting eversion before the medial ankle ligaments are stressed (Lowe, 2018). Contact between the calcaneus and fibula may result in a fracture of the lateral malleolus more frequently than deltoid ligament sprains during forced eversion (Lowe, 2018).

Lateral Ligament Injuries of the Ankle

While the ankle is in a neutral position, much of the stability in the joint is produced through contact of the tibia and fibula into the talus, however, this is not the case when there is increased plantarflexion (Stormont et al., 1985). With the reduction of osseous constraint, stability of the ankle relies on the soft tissue structures as defined above, and this is where they become more susceptible to injury (Aicale & Maffulli, 2020).

Figure 1.

Anatomy of the Lateral Ankle



Wikipedia. (2006). Lateral Ligaments of the Ankle Joint. Lateral Collateral Ligament of Ankle Joint. Retrieved October 12, 2022, from https://en.wikipedia.org/wiki/Lateral_collateral_ligament_of_ankle_joint.

The most common structure involved with acute ankle injury is the ATFL, accounting for approximately three quarters of recorded ankle injuries (Herzog et al., 2019). There is a higher incidence of injury to the ATFL while the ankle is in a plantarflexed position as there is decreased joint stability reported in this position (McKay et al., 2001).

Lateral ligament injuries are characterized by the stretching or tearing of the ligamentous structures found in the ankle and the severity of the injury is dependent on the amount of stretching or tearing (Herzog et al., 2019). Ligament injuries, or sprains, are categorised into three grades (Al-Mohrej & Al-Kenani, 2016). A grade I ligament injury is a mild injury where the ligaments are stretched slightly beyond normal length, but still provides the joint with adequate support. A grade II ligament injury is more severe, where there is a partial tear along with the stretching of the ligament. A grade III ligament injury occurs when a ligament is completely severed, providing no support to the joint post-injury (Al-Mohrej & Al-Kenani, 2016). The signs and symptoms and clinical presentation for these injuries range from the presence of no swelling or loss in function (grade I), to gross swelling and near total loss in function, as seen in grade III.

Following a grade I injury, Malliaropoulos and colleagues (2009) observed a 14% reinjury rate in track and field athletes aged 19 (± 4.1) years of age, and a reinjury rate of 29% in track and field athletes of similar age who had sustained a previous grade II injury. Similarly, Alawna and Mohamed (2020) reported that 41% of all injuries to volleyball players are sprains of the ankle, with 20% of acute sprains turning into chronic sprains. This cycle of injury-reinjury is often referred to as chronic ankle instability (CAI).

Chronic Ankle Instability

After an initial ankle joint injury, many athletes are at risk of developing CAI. CAI is characterized as a predisposition to recurrent sprains, frequent perception or episodes of the ankle giving way, and persistent symptoms of pain, swelling, weakness, limited range of motion, and self-reported diminished function (Hertel & Corbett, 2019). These distinguishing features of ankle instability must be observed more than 12 months post initial injury to be classified as CAI. Michael Freeman, a pioneer in the theory of CAI, explains that the afferent nerve fibres in the capsule and ligaments of the foot and ankle stimulate reflexes, which help to stabilize the foot during locomotion. When the foot or ankle is sprained, partial deafferentation of the joint occurs. As such, reflex stabilization of the foot is impaired and the foot tends to give way (Freeman et al., 1965).

It is estimated that up to 70% of individuals who sustain an acute ankle injury will develop the long-term symptoms that are associated with CAI (Herzog et al., 2019). Through epidemiological study, it was determined that in the United States, there is an incidence rate of 2.15 ankle sprains per 1000 person years in the general population, a statistic that means if 1000 people were studied for one year, researchers would expect to see 2.15 ankle sprains (Waterman et al., 2010). The number of ankle sprains increased to 7.2 per 1000 person years when examining the most at-risk age cohort, which includes males and females between the ages of 15 and 19 years (Waterman et al., 2010). Finally, it was observed that nearly half of these injuries were associated with athletic activity.

Both acute and chronic ankle injuries are extremely prominent in the general population, however, there is a sub-cohort within the population that is more at risk of developing these injuries. According to an epidemiological study by Doherty et al. (2014), athletes who compete on indoor courts have been observed to be at an increased risk of ankle joint injury. At a rate of 7 ankle sprains per 1000 athlete exposures (AE), court sports exhibited a higher risk for ankle injury than ice/water sports (3.7 per 1000 AE), field sports (1.00 per 1000 AE), and outdoor sports (0.88 per 1000 AE). As indoor volleyball is a court sport, the risk of ankle injury is much higher for volleyball athletes when compared to other sports.

Ankle Joint Injury in Volleyball Athletes

Through a review of the National Collegiate Athletic Association (NCAA) injury reporting database, it was determined by Lytle et al. (2021) that ankle injuries accounted for over 50% of all documented athletic injuries. Furthermore, sports that require a combination of jumping and rapid directional change produced a higher likelihood of ankle injury, more specifically, lateral ankle ligament sprains (McKay et al., 2001; Verhagen et al., 2004).

Volleyball is a sport that is highly dependent on the ability of an athlete to jump maximally to block and spike. Hadzic et al. (2009) identified that the majority of ankle injuries in volleyball players occurred at the net during spiking and blocking. Sheppard et al. (2009) observed and reported that players typically complete between 200 and 300 maximal vertical jumps during a five-set match. These jumps are typically distributed evenly between both attack-based approaches (spiking), and defensive-based jumps (blocking; Sheppard et al., 2009). In the 2019-2020 Ontario University Athletics season, each volleyball team was scheduled for 20 matches, with each match to be the best-of-five sets. If on average, each game ended in a three-to-one score, that would produce a season consisting of an estimated 6000 vertical jumps per player. As ankle injuries have been observed to occur during vertical jumping (Hadzic et al., 2009), there is an abundance of opportunity for ankle injuries to occur. It has also been demonstrated by Ericksen and Gribble (2012) that due to hormonal differences, female athletes experience higher levels of inversion-eversion laxity and less dynamic postural control. These two factors put female volleyball athletes at a higher risk of sustaining ankle sprain injuries than male volleyball athletes. Historically volleyball has been a female dominated sport, and although there are now higher numbers of male participation, it must be noted that while participating in this sport female athletes are at an increased risk to ankle injury. In response to ankle injuries, there are a variety of treatments and prevention strategies available to athletes. Between surgical repair, cast or splint immobilization, and functional treatment with the use of ankle bracing or taping, ankle bracing is one of the preferred treatment options following an ankle sprain (Kannus & Renström, 1991).

Ankle Bracing

Types of Ankle Braces

Ankle bracing is a widely used treatment practice in the world of sports. The idea behind bracing is to provide the ankle with extraneous support to reduce the likelihood of an inversion ankle sprain, which is the cause of lateral ligament injuries. Proprioception is the ability to sense the position and movement of the limbs and body (Mahnan et al., 2020). Alongside providing structural support to the soft tissues of the ankle, bracing provides proprioceptive feedback to the wearer to increase control and decrease excessive motion (Surve et al., 1994). With these supportive measures, bracing is effective in reducing and treating ligament sprains, muscle strains, joint dislocations, tendon tears, and/or nerve injuries (Sprouse et al., 2018). Furthermore, bracing has become a commonly used prevention strategy and treatment option following an injury as it is a simple, and a relatively low-cost alternative to surgery (Sprouse et al., 2018). There are a variety of braces used in rehabilitation that offer varying levels of rigidity and comfort. Semi-rigid ankle braces often include a plastic shell that provides support on the medial and lateral aspects of the ankle and are adjustable using Velcro® straps (Rosenbaum et al., 2002). The hard plastic and Velcro® offer a tight fit and high degree of support for the wearer, at the cost of comfort. Soft-shell braces, such as lace up braces, include a lace up nylon sock, figure-8 strapping for lateral and medial support, and an elastic cuff (Eils et al., 2002). This style of brace offers a medium level of support and is more comfortable than the semi-rigid braces.

Prophylactic Bracing

Prophylactic ankle bracing is a method used to prevent ankle injuries by applying a brace prior to sustaining an injury. Untreated or poorly managed acute lateral ankle injuries can result in CAI, therefore, reducing novel acute ankle injuries is best practice (Aicale & Maffulli, 2020).

Pedowitz et al. (2008) examined prophylactic ankle bracing in a varsity women's volleyball program and observed an injury rate of 0.07 per 1000 AE after the team instituted a mandatory bilateral ankle bracing policy. In comparison, the average incident rate for the NCAA was 0.98 per 1000 AE when there was no bilateral bracing policy in effect. Similar findings were found by Shaw et al. (2008) with regards to the utility of prophylactic ankle bracing in preventing ankle injuries. They demonstrated that fatigued volleyball players experienced increased stability when wearing a lace up ankle brace when compared to not wearing an ankle brace at all. As higher levels of fatigue are associated with increased injury rates (de Noronha, 2019), prophylactic ankle bracing has shown to be effective in reducing the likelihood of sustaining an inversion ankle sprain by providing the wearer with increased lateral support. These findings support the 2001 meta-analysis by Handoll et al. who stated that there was sufficient evidence that semi-rigid ankle braces aid in the prevention of ankle sprains.

Ankle braces have been shown to aid in preventing ankle sprains through prophylactic use, however, this is not their only use. Ankle braces are also commonly used for treatment following an ankle sprain as they provide the wearer with external support, aiding in the recovery of injured ligaments.

Treatment for Ankle Injury

As ankle injuries are the most common injury seen among athletes across all sports, understanding the treatment process is crucial. A systematic review with meta-analyses conducted by Peterson et al. (2013) concluded that the majority of lateral ligament ruptures could be treated without surgery and long-term immobilization. Instead, they proposed that grade I and II ligament sprains should be treated using a semi-rigid ankle brace to protect against inversion. Grade III lateral ligament injuries, however, should be treated with a maximum of 10 days of immobilization followed by the application of a semi-rigid ankle brace for the remainder of the treatment period (Peterson et al., 2013). Beynnon et al. (2006), Boyce et al. (2005), and Cooke et al. (2009) all observed better short-term results when using a semi-rigid ankle brace during treatment when compared to the use of an elastic tensor bandage. Additionally, Kerkhoffs et al. (2002) concluded that lace-up ankle braces appear to be more effective in reducing swelling in the short term when compared to wearing a semi-rigid ankle brace, elastic tensor bandage, or applying zinc oxide tape.

Due to the effectiveness in reducing initial and reoccurring ankle sprains, wearing ankle braces is a common practice among court athletes. Although some varsity programs strongly recommend the use of ankle braces to prevent injury, athletes are often reluctant or choose not to use external ankle supports. This concern is because of the perception that ankle braces inhibit athletic performance, especially vertical jump height (Hiller & Beckenkamp, 2023; Pienkowski et al., 1995). The ability of an athlete to jump to their maximum potential to spike the ball is fundamental in the sport of volleyball, but it is not the only aspect of athleticism that leads to the success of a volleyball player. Constructs such as hand-eye coordination, reaction time, agility speed, volleyball IQ, and technique all contribute to the success of a volleyball player.

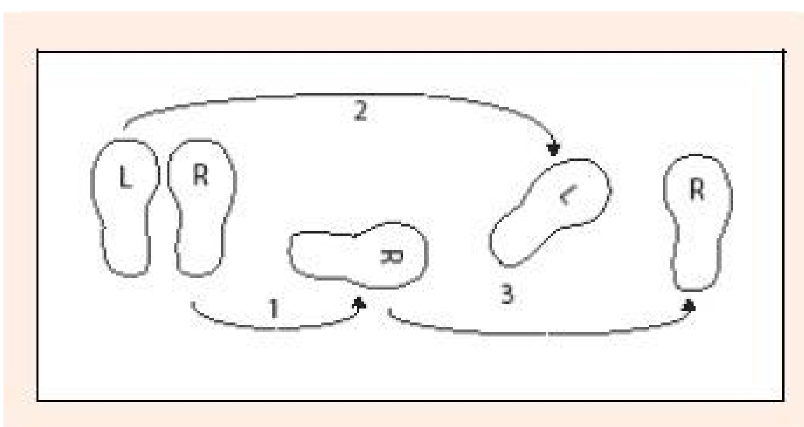
Volleyball Performance

Swing Blocking in Volleyball

In volleyball, there are multiple ways a player can approach a block attempt. The most common approach is the shuffle block, where a player identifies where the set is going, then shuffles laterally into position before a making countermovement vertical jump to block the attack (Neves et al., 2011). A swing block is a more complicated type of block that is typically seen in higher level players. The timing and coordination needed to execute a swing block properly increases the complexity. The swing block utilizes a full arm swing where the arms are initially swung backward and then moved forward with the elbows fully extended throughout the entire blocking motion. This technique is different than the traditional block where the hands are kept at shoulder height throughout the whole blocking movement, and the chicken wing block, where the arms are bent at a 90-degree angle throughout the blocking movement (Neves et al., 2011). All three types of blocking use the same 3-step approach seen in Figure 2. If done correctly, swing blocking is a technique that helps blockers gain more speed and height due to the momentum generated by swinging the arms (Neves et al., 2011). By swinging the arms, an individual can increase the total work of the lower extremity joints (ankles, knees, and hips thereby increasing the power production, producing a higher vertical jump (Hara et al., 2006). Additionally, when measuring vertical jump height via change in centre of mass, any additional velocities generated by the body (with an approach or arm swing) adds momentum to the centre of mass and consequently increases vertical jump height (Hara et al., 2006).

Figure 2.

Steps to Complete a Swing Block



From "Comparison of the traditional, swing, and chicken wing volleyball blocking techniques in NCAA division I female athletes" by Neves et al., 2011, Journal of Sports Science & Medicine, 10(3), 452.

Agility in Volleyball

There are many ways that agility has been defined. The theme of *speed* and *accuracy* remain consistent throughout all definitions, however, no precise definition is agreed upon (Sheppard & Young, 2007). Sheppard and Young (2007) defined agility as a rapid whole-body movement, with a change of velocity and direction in response to a stimulus, and this definition is agreed upon as one that holistically describes the concept (Šimonek, 2019).

This definition of agility is appropriate for the sport of volleyball, as a defender often relies on quick accurate movements to set up in the right position following a stimulus (i.e., attacker hitting the ball). A volleyball athlete needs to be extremely agile to be in the best position defensively to receive an opposing attack (Bradford et al., 2007).

The highest rates of acute ankle sprains were typically reported in sports that were characterized by running, cutting, and jumping (Herzog et al., 2019). This combination of movements may yield a higher number of ankle injuries when compared to other non-contact and non-jumping sports. Bere et al. (2015) observed data from the Fédération Internationale de Volleyball Injury Surveillance System over a 4-year span. They discussed that compared to other elite level team sports professional volleyball players experienced fewer injuries overall, but of the injuries sustained, over 25% were to the ankle. This supports Herzog et al. (2019) regarding the movement patterns of running, cutting, and jumping and how those specific actions produce high numbers of ankle injuries in the sport of volleyball as compared to other sports where those actions are not seen.

Both blocking ability and agility are important aspects of defensive play that ultimately lead to success during a volleyball match. Although these skills can be observed visually via jump height and foot speed, being able to quantify an individual’s performance is a much more powerful tool in research as it can explain changes in performance rather than accepting an observable change.

Indicators to Quantify Vertical Jump Performance

Power

From a sport performance standpoint, power is defined as the product of an individual's ability to produce mechanical work over a period of time (Noffal & Lynn, 2012). There is a strong positive relationship between the power output of an individual and vertical jump height (Kraska et al., 2009). This is because vertical displacement is the product of power multiplied by time and divided by force ($displacement = \frac{Power\ X\ Time}{Force}$). In the current study power was not computed for ease of data analysis, however, given the strong association found between power and vertical jump height, the researcher decided to use measures of vertical jump height to assess vertical jump performance

During a five-set match of volleyball, players have been observed to complete between 250 and 300 maximal vertical jumps. Sheppard et al. (2009) reported that these jumps are typically distributed evenly between both attack-based approaches (spiking), and defensive-based jumps (blocking). The ability of an individual to successfully spike the ball largely depends on the highest point of their vertical jump in which they can contact the ball. Contacting the ball at the peak of one's vertical jump is crucial in creating the best angle of attack to hit the ball to the open court. Empirically, even a slight decrease in jump height could be the difference between getting blocked and spiking the ball successfully for the point. Conversely, the same goes for blocking. Differences of just 5 cm could be the difference between shutting down an opponent's attack or having the point scored against your team.

Therefore, it is important for a volleyball player to attain the highest possible vertical jump throughout the entire match when jumping. Recent research (Boulanger, 2022; Gross et al., 1994; Henderson et al., 2018; Macpherson et al., 1995; Pienkowski et al., 1995; You et al., 2020), however, has indicated contradictory results when examining the effect of ankle bracing on athletic performance.

Ankle Bracing and Athletic Performance

Due to the increased support that they provide, ankle braces are commonly used to reduce the number of ankle injuries seen in court sport athletes, however, some potential draw backs have come to light in recent research due to the restrictive nature of the brace. Mann et al. (2018) identified the impact of different types of soft-shell ankle braces on performance in the standing long jump, vertical jump, 40-yard sprint, and T-agility tests. They concluded that there was no difference in braced versus unbraced conditions for the speed and agility functional performance tests, however, a decrease in standing long jump distance and vertical jump height was seen. They continued to rationalise that these decreases in performance were due to restrictions in the range of motion at the ankle joint. The success of a volleyball player in their attempt to spike and block is contingent on their ability to jump as high as possible, therefore, any reduction in jump height due to a range of motion restriction as a result of wearing the brace could negatively affect performance.

Similar to Mann et al. (2018), Koyama and colleagues (2014) investigated the effects of closed basket weave ankle taping had on ground reaction force (GRF) during the take-off phase of vertical jumping. They suggested that ankle taping impaired countermovement vertical jump performance by impeding the range of motion of the ankle, hindering the athlete’s ability to quickly develop large amounts of force before takeoff.

Alternatively, Yamauchi and Koyama (2021) suggested that when used prophylactically, ankle support constructed with elastic properties can provide appropriate stabilization supported without a large decrease in the individual's overall force production. The researchers examined peak power across two types of vertical jumps (countermovement and squat jumps), along with three conditions of ankle bracing (barefoot, soft-shell brace, and semi-rigid brace). No statistically significant differences in peak power were seen between barefoot and soft-shell brace conditions during the squat jump trials. This result was not the case for the countermovement vertical jump trials, however, as there was a statistically significant reduction in peak power when comparing both the semi-rigid and soft-shell braces to the barefoot condition. The researchers proposed that the decrease in performance during the countermovement jump was due to the ankle brace restricting the effectiveness of the stretch-shortening cycle (SSC). The SSC is a process where elastic energy created in the muscle belly and tendons is utilized to create more force during rapid flexion and extension (Bobbert et al., 1996).

There are many studies that investigated the kinematic effects of ankle bracing on sport performance with varying results. Gross et al. (1994), Macpherson et al. (1995), and Pienkowski et al. (1995) all concluded that there was no effect in kinematic measures of vertical jump, speed, or agility when comparing braced trials and non-braced trials. The vertical jump tests between these three studies used similar methodologies. Participants were asked to stand perpendicular to a wall and perform a countermovement vertical jump. The participants had a marking on their fingers consisting of chalk (Gross et al., 1994; Macpherson et al., 1995) or ink (Pienkowski et al., 1995) and were instructed to touch the wall with their marked digit at the peak of their jump. Jump height was recorded as the difference between a participant's standing reach height and the measurement of the floor to the marking on the wall to the nearest .05 cm, however, each study used different methodologies to assess agility. Gross et al. (1994) used a figure-8 running test, which required participants to run in a figure-8 pattern three times as quickly as possible around cones in an area 5 meters (m) wide and 10 m long. Macpherson et al. (1995) assessed agility using an 18 m shuttle course, where participants shuffled 4.5 m to their right, 9 m to their left, and then 4.5 m to their right as quickly as possible. Lastly, Pienkowski et al. (1995) used a cone running drill to assess agility during their study. This test required participants to run through 6 cones in a vertical line spaced 1.22 m apart. Participants ran the figure-8 patterns around each cone without knocking them over, returning to the starting position where the timer was stopped once they crossed the finish line. All tests were quantified by using a handheld stopwatch and recording the time between the start and finish.

More recently and similarly, Leonard et al. (2014) concluded that there was no significant difference between vertical jump height or agility speed when wearing ankle bracing compared to when not wearing ankle braces. To measure vertical jump height, Leonard et al. (2014) asked participants to complete 3 trials of a maximal effort jump with a 30 second (s) rest in between. Total height was measured using a Vertec™ device, with the participant's standing reach height being subtracted to calculate the overall jump height. Leonard et al. (2014) also used a different agility test than the previously mentioned researchers. This research group used the Illinois Agility Test. The Illinois Agility Test begins with the participant lying prone on the floor. On the command of the researcher, the participant runs straight ahead 10 m, then runs back to the baseline before performing a figure-8 around four cones spaced 3.3 m apart. Once the participant finishes the figure-8 patterns, they run 10 m and loop around a second cone on the opposite side, then sprinting back to the baseline.

Henderson et al. (2018) and Boulanger (2022) observed results contrary to Gross et al. (1994), Macpherson et al. (1995), and Pienkowski et al. (1995). Boulanger (2022) observed a significant decrease in vertical jump height in both unilateral and bilateral brace conditions regardless of the type of brace (soft-shell or semi-rigid braces). Henderson et al. (2018) reported a significant decrease in vertical jump height when using two ankle brace conditions including the use of a soft-shell and semi-rigid brace compared to the no brace condition. Henderson et al. (2018) recorded muscle electromyography (EMG) and GRF during the completion of a countermovement vertical jump and agility cutting task. They reported a statistically significant decrease in jump height and a statistically significant increase in agility time when participants were wearing either ankle brace including the semi-rigid or soft-shell ankle braces. Henderson and colleagues (2018) reported that these differences in performance might be attributed to decreases in muscle activation in the lateral gastrocnemius muscle during take-off.

The evidence supporting the use of prophylactic bracing during volleyball is contradictory as many studies have demonstrated a decrease in performance particularly related to jump height and agility. As such, more research is needed to fully examine and understand the influence of ankle bracing on vertical jump height and agility performance.

Ankle bracing is typically used in two scenarios, prophylactically or post-injury. Regarding bracing and post-injury sport participation, there is another interaction that may play a role in athletic performance that must be considered. After sustaining an injury, it has been shown that athletes experience heightened levels of sport related anxiety (Ford, 2017) that may be expressed differently between sexes. The interaction between anxiety and sport performance is a field of study that has been gaining traction in recent years, however, there is limited research available on the effect of ankle bracing on sport related anxiety and even less exploring sex-based differences.

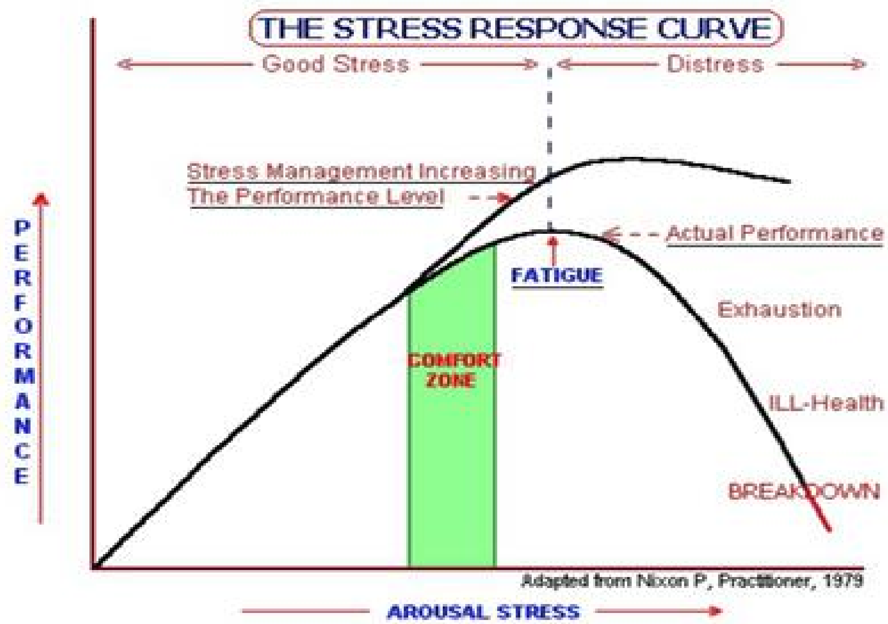
Sports Injury and Anxiety

Anxiety is typically described as an unpleasant psychological state in reaction to perceived stress concerning the performance of a task under pressure (Cheng et al., 2009). Stress is defined as a non-specific response of the body to any demand (Fink, 2010). When an individual appraises that the demand exceeds their coping mechanisms, they experience physical manifestations of stress such as anxiety.

Stress and anxiety play an important role in the overall outcome of sport performance and have both positive and negative effects on performance (Bali, 2015). The Stress Response Curve (Nixon 1979; see Figure 3) demonstrates how stress theoretically affects athletic performance. Every athlete has a certain stress level that is needed to optimize their performance. That level depends on factors such as past experiences, coping responses, and genetics (Bali, 2015). Up until the peak of the comfort zone, increased arousal (stress) allows for improvements in performance. Once the arousal level becomes too high, performance rapidly decreases.

Figure 3.

Stress Response Curve



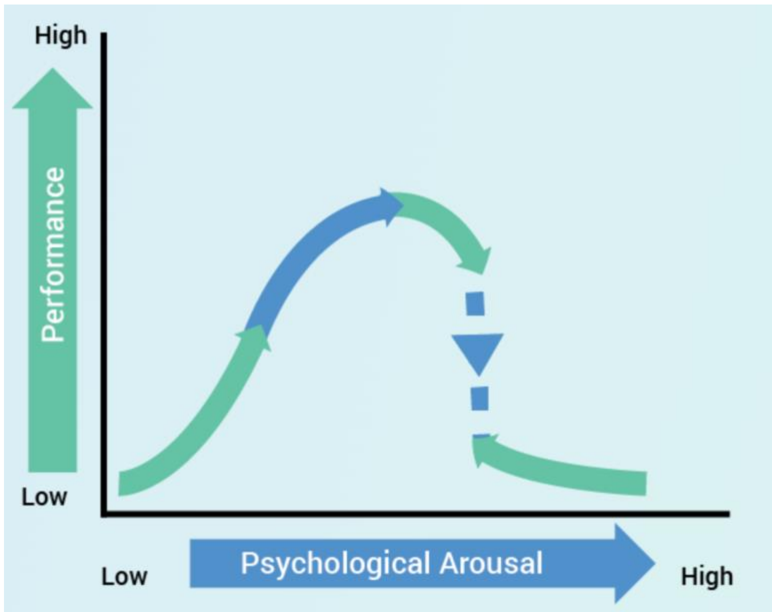
From "Psychological factors affecting sports performance" by Bali, (2015), International Journal of Physical Education, Sports and Health, 1(6), 92–95.

An important component of the Stress Response Curve is cognitive arousal, which Bali (2015) described as an essential ingredient of any competitive situation. Without a certain level of arousal, there cannot be competitive performance. As per the Stress Response Curve, arousal levels that are either too high or too low are not favourable to sports performance, therefore, moderate levels of arousal produce the best results. If an athlete is inadequately aroused, they may become less motivated, bored, or disengaged. The opposite may also be detrimental, as excess arousal can lead to high levels of anxiety, leading to gradually decreased overall performance.

Catastrophe Theory is similar to the Stress Response Curve, with one significant difference between the two theories. In the Catastrophe Theory, once the athlete reaches peak performance any additional increases in psychological arousal results in a dramatic, or catastrophic, decrease in performance (see Figure 4).

Figure 4.

Catastrophe Theory Model

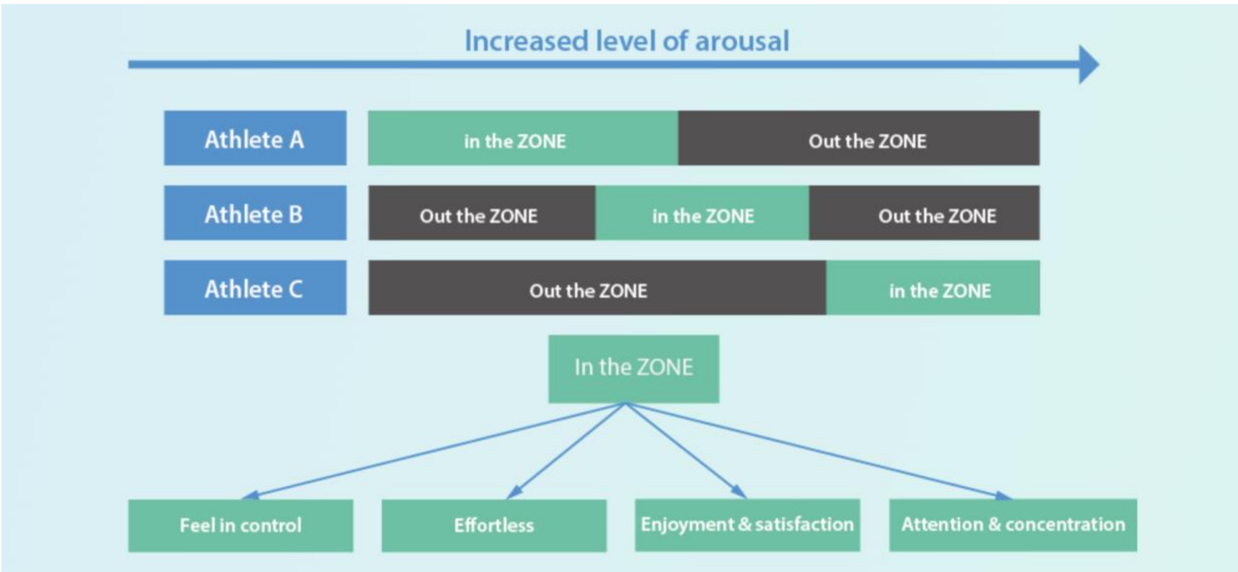


From "Sports Psychology" by Welsh Joint Education Committee, 2019, AS/A Level Physical Education.

Another updated model in the field of sports psychology is the IZOFT. This theory (see Figure 5), states that different levels of cognitive arousal affect athletes differently based on a variety of factors. These factors include personality, the task required, and the athlete's stage of learning. Hanin (2000) continued to explain that simple/gross tasks are performed better in high arousal situations, while fine/complex tasks are performed better during low arousal. Lastly, Hanin (2000) stated that during the autonomous stage of learning, where performance becomes automatic after being mastered, higher levels of performance are seen in accordance with high arousal, this is exemplified as "Athlete C" in Figure 5. Conversely, when athletes are still learning skills in the cognitive and associative stages, increased performance is seen during low arousal, as shown by "Athlete A" in Figure 5 (Hanin, 2000).

Figure 5.

Individual Zones of Optimal Functioning Model



From "Sports Psychology" by Welsh Joint Education Committee, 2019, AS/A Level Physical Education.

Athletes must learn to recognize what level of arousal is conducive with their best performance and learn to cope with stressful competitive situations by managing anxiety. Facing levels of anxiety that are at or above peak performance levels during training allows athletes to acclimate to levels of anxiety that are seen in competition.

There is very little research regarding the influence of ankle bracing on sport related stress and anxiety. Through qualitative analysis, the application of taping the ankle resulted in self-reported feelings of increased confidence, strength, and decreased anxiety for injury or reinjury (Hunt & Short, 2006). Hunt and Short (2006) interviewed 11 NCAA athletes from five collegiate teams (men's football, women's basketball and volleyball, and men's and women's ice hockey). These athletes completed semi-structured interviews with the research team to answer open ended questions regarding their feelings on the use of ankle taping. Each interview was recorded and the participants' answers were transformed into raw data for inductive content analysis. To the question, "*Do you feel that you need to be continued to be taped?",* recurring responses identified that taping of the ankle relieved pain and prevented injury. Additionally, there were responses that frequently identified psychological preference to wearing tape such as "superstition" and "habit". The findings from Hunt and Short (2006) suggested that once an athlete starts wearing supportive measures such as ankle tape, it may become a psychological crutch that they then depend on to maintain their level of performance.

Further research is needed to reach conclusive results on the psychological effect that wearing supportive devices has on athletes. Creating a greater understanding of this relationship can allow for an improved rehabilitation protocol that is applied to injured athletes. Various measures have been used to identify sport related anxiety, and recent research by Smith et al. (2006) has facilitated this development by providing researchers with a tool used to measure anxiety in athletes.

Sport Anxiety Scale-2

The Sport Anxiety Scale-2 (SAS-2; see Appendix 1) is a multidimensional measure of cognitive and somatic trait anxiety in sport performance settings (Smith et al., 2006). The second edition of the scale was produced after it was discovered that the original structure of the SAS had to be changed to avoid conflicting results in children and adults (Smith et al., 2006). The SAS-2 is comprised of three separate subscales that measure different aspects of anxiety including somatic (5 items; e.g., "I feel tense in my stomach."), concentration disruption (5 items; e.g., “I lose focus on the game.”), and worry (5 items; e.g., “I worry that I will let others down.”). These subscales are measured on a 4-point Likert scale ranging from 1 (not at all) to 4 (very much so), with each of the three subscales having five questions. For each subscale, high scores indicate higher levels of anxiety and low scores indicate lower levels of anxiety. Each subscale is measured out of 20, for a total score measuring out of 60. Smith et al. (2006) demonstrated that the SAS-2 had stronger psychometric properties than the original SAS and produced results that were sensitive to age and anxiety reducing techniques. Using confirmatory factor analysis, a method used to assess construct validity and how accurately different systems measure and evaluate a concept, the researchers observed a comparative fit index above 0.95 across ages of four years old to college aged level. Test-retest reliability also produced positive results in the SAS-2, with a Cronbach alpha of .91 in the total scores based on the 15 items. Tomczak et al. (2022), examined the content validity of the SAS-2 questionnaire via the relationships of SAS-2 scale scores to other scales dedicated to measure anxiety in sport as well as general anxiety. These researchers established that the SAS-2 questionnaire is suitable for measuring sport related anxiety.

In a study completed in 2010, Días et al. discovered significant sex differences in measured scores of sport related anxiety. Días et al. (2010) assessed sport related anxiety in 550 Portuguese athletes from a variety of both individual and team sports using the SAS-2. The research team discovered that female athletes experienced significantly higher levels of worry, concentration disruption, and somatic anxiety compared to male athletes as measured by the SAS-2. This result is similar to that of previous studies examining anxiety across sex, showing that female athletes consistently display higher levels of anxiety than their male counterparts.

The previously discussed psychometric results showed that the SAS-2 is an effective tool in assessing sport related anxiety in people of different sexes and ages, and can be applied to gather information on the effects of bracing on sport related anxiety and fill the gaps in existing literature.

Purpose of the Research

Research findings are unclear regarding the effect of ankle bracing on athletic performance and across sexes suggesting that more research is required to fully understand the relationship between ankle bracing, sex, and volleyball performance. Athletes experience anxiety during return to sport following an injury however, the relationship between anxiety and sex, where women have shown to experience higher levels of anxiety during return to sport are less known. It is important to identify the relationship between anxiety and performance, subsequent to wearing a brace during volleyball, as it will assist in facilitating a transdisciplinary approach to return to sport and support all aspects of an athlete's recovery and determine the utility or negative effects of the use of the brace. This study aims to address some of the gaps in the literature to contribute to the existing knowledge on ankle bracing with respect to athletic performance and sport related anxiety. Therefore, the purpose of this study was to examine the effects that ankle bracing and sex have on maximum vertical jump height with a swing block approach, normalized GRF in the Z-plane during a swing block vertical jump, agility, and sport related anxiety.

The following questions will guide the research study:

1. Is there an interaction effect between ankle brace condition (brace versus no brace) and sex (male versus female) on measures of vertical jump performance including: maximum height acquired, normalized GRF in the Z-plane during takeoff, and sport related anxiety, respectively, for a swing block approach?

2. Is there an interaction effect between ankle brace conditions (brace versus no brace) and sex (male versus female) on time and sport related anxiety respectively during the completion of the Modified X Running Test?

Chapter 2 – Methods

Participants

Recruitment

After ethical approval was received by the Lakehead University Research Ethics Board, participants were recruited via purposive and convenience sampling. Prospective male and female participants were included in this study if they:

1) Self-identified as volleyball players at either a high school, intermediate or collegiate level;

2) Were between the ages of 17 and 30 years; and

3) Were able to pass the Physical Activity Readiness Questionnaire for Everyone (PAR-Q+; see Appendix 2) screening tool to assess their readiness to participate in physical activity.

Any participants who did not pass the PAR-Q were required to be cleared by a medical physician prior to participating in the study. Participants were excluded from this study if they self-reported a lower body injury in the past 6 months that hindered their athletic performance (e.g., sprain, fracture, or tendonitis).

As determined by an a-priori power analysis and pilot work, 64 participants were needed to be recruited to achieve a medium effect size, .80 statistical power, and probability level of .05. Recruitment for this study involved a poster being distributed through social media (e.g., Lakehead University Kinesiology Facebook™ and Instagram™ platforms, and the student researcher's Facebook™ and Instagram™ platforms) and emails to local coaches and Thunder Bay Volleyball League members. Participants were also recruited from the Lakehead University Men's Club Volleyball and Lakehead University Women's Varsity teams via word of mouth as the student researcher had an affiliation with the team. no incentive was provided to prospective participants.

Instrumentation

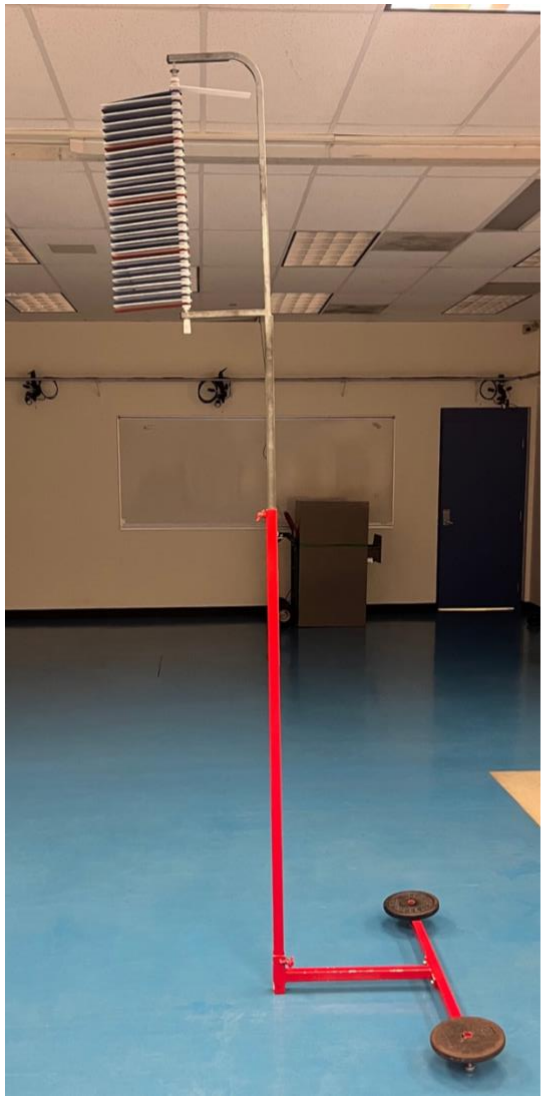
The performance factors included in the study were vertical jump height (cm), normalized GRF in the Z-plane (N), and agility time (s). The following are the instrumentation used to measure these factors.

VERTEC™

The Vertec™ device is a commonly used tool to measure vertical jump height. This tool consists of a metal frame, telescopic arm, and plastic veins spaced 1.25 cm apart (see Figure 6). When the participant jumps, they swipe at the veins reaching for the highest possible vein. The height of the last contacted vein is where the researcher measures the maximal jump height in inches, which was then converted to cm. This system is commonly used because of its ease of use and portability, along with its strong reliability. VanderZanden et al. (2010) compared the measurements of jump height between the Vertec™ device and the gold standard laboratory force plate in 21 recreationally active adults to assess concurrent validity. They found that although the Vertec™ device consistently measured jump heights higher than the force plate, there was strong reliability between trials following an intra-class correlational analysis (R^2 = .73).

Figure 6.

Vertec^{TM} Jump Measurement Device



Brower© Infrared Timing Gates for the Modified X Running Test

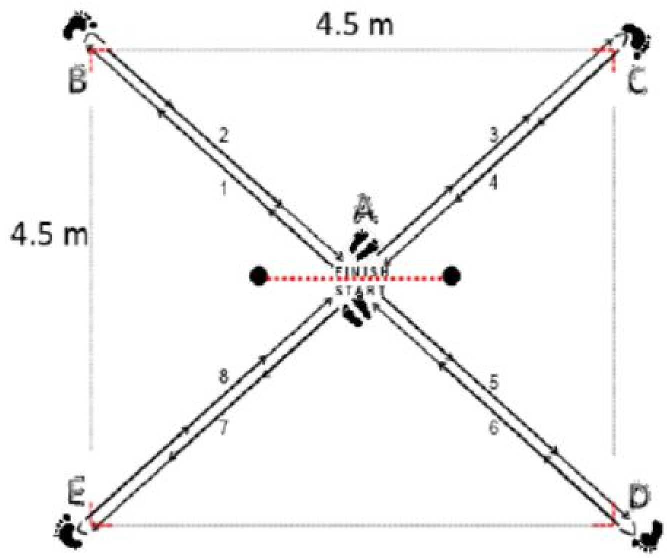
To measure agility, Brower© infrared timing gates were used to measure the time (s) it took to complete the Modified X Running Test. The timing gates created a starting line using an infrared signal. When the line was crossed by the participant, the timer started. The participant then finished the agility test by crossing the same line again, which stopped the timer.

For the purposes of this research project, the Modified X Running Test was the protocol used to measure the agility of the participants and time (s) to complete the task. This agility test was reported by Majstorović and colleagues (2019) to be a statistically reliable and valid measurement tool for assessing volleyball specific agility. During their trial-to-trial analysis, Majstorović et al. (2019) reported a Cronbach's alpha coefficient of .82 and .83 for males and females, respectively. They observed similar results in their day-to-day analysis, revealing a Cronbach's alpha coefficient of .89 and .83 for men and women, respectively. Additionally in the current study, using data from the five trials of the Modified X Running Test, a reliability analysis was conducted to examine the Intraclass Correlation Analysis (ICC) across trials. A high reliability was found between trials for the Modified X Running Test with an ICC of .987 and a 95% confidence interval from .979 to .993 with no statistically significant differences noted ($p > .05$). These statistics show a strong reliability and support for the use of the Modified X Running Test protocol to examine agility in the participants.

Majstorović and colleagues (2019) modified the original X Running Test by altering the dimensions of the box size to better simulate the area that a single athlete was responsible for defensively in the sport of volleyball. This test encompassed each aspect of agility as mentioned above. In response to a stimulus, which was the verbal command "*Go*", the participant touched each cone in the circuit (accuracy) as fast as possible (speed) in order to stop the clock as fast as possible. During this test, the participant was instructed to start in the middle of a square (see Figure 7) marked by the plastic cones. Beginning from the start location, the participant moved to touch each cone as fast as possible moving in a clockwise rotation, returning to the centre after each cone was touched. Once the participant touched all four cones and returned to the centre, the infrared signal was triggered, stopping the clock.

Figure 7.

Modified X Running Test



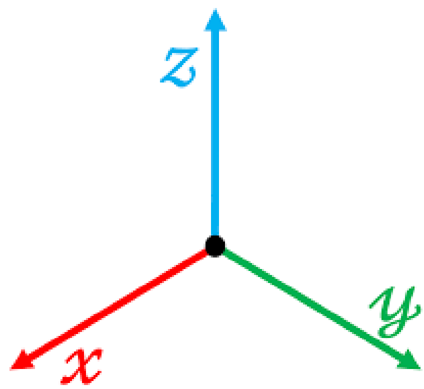
From "Assessment of specific agility in volleyball: Reliability and validity of modified X running test" by Majstorović et al., 2019, 4th International Conference on Innovations in Sports, Tourism and Instructional Science, 143-146

Advanced Medical Technologies Incorporated Force Plate. The Advanced Medical Technologies Incorporated (AMTI©) force plates are a commonly used instrument when measuring the GRF of a vertical jump. Force plates are considered the gold standard when measuring vertical GRF during take-off and landing in the laboratory setting (Carlos-Vivas et al., 2018; Hatze, 1998).

Force plates collect data in 3 planes including the F_x, F_y, and F_z (see Figure 8) and three moments in the x, y and z. These planes apply to movement in the anteroposterior, mediolateral, and vertical directions, respectively. The GRF from these data points are collected and can then be manipulated to calculate numerous variables such as impulse, maximum jump height, maximum GRF, rate of force development, power and energy, for example (Koyama et al., 2014). For the purpose of this research project, GRFs in the Z-plane during takeoff were analyzed. This plane pertains to movement in the vertical direction. Due to the strong positive relationship between power and jump height, this research study focused on maximum jump height as a measure of performance.

Figure 8.

Planes of movement



Ganti, Nav. *Example 3D Coordinate Frame.* 2020. An Intro to 3D Coordinate Frames for Augmented Reality. https://placenote.com/blog/an-intro-to-3d-coordinate-frames-for-augmented-reality/

Procedures

Data were collected during two 60-minute testing sessions, with at least 24 hours (Sporer & Wenger, 2003) between each session to reduce the effect of participant fatigue. Participants performed the Modified X Running Test during the first session and the swing block vertical jump test during the second session. Both the agility test and the vertical jump test were conducted under two testing conditions wearing bilateral ankle braces, and with no brace. Agility testing was completed in the Wolf Den Gymnasium at Lakehead University, and vertical jump testing took place in the School of Kinesiology's Multipurpose Lab at Lakehead University. Participants were asked to wear appropriate athletic clothing, similar to what they would wear to play volleyball. At the first testing session, the student researcher provided a verbal overview of the study and answered any questions that the participant had. Once verbal consent was obtained, the participant signed the consent form and filled out the PAR-Q to determine if they were fit to exercise and be included in the study. Following written consent and the completion of the PAR-Q, demographic and anthropometric data were recorded including age (years), height (cm), sex, body weight (Newtons; N), foot dominance, injury history, and history with ankle bracing (see Appendix 3).

After obtaining written informed consent, the participant was asked to complete a 7-minute supervised warm up on a cycle ergometer, at an intensity of 10-11 on the Borg Scale of Perceived Exertion (CSEP, 2013; see Appendix 4). The participant was then introduced to the Modified X Running Test, given verbal instructions on how to complete the test, and given two submaximal attempts of the test for familiarization. Each participant was randomly assigned to a test condition (brace or no brace) via a Latin square method (Daily, 2017), a method that ensures an equal number of participants in each order group (i.e., condition 1 and then 2 for the first participant enrolled in the study; followed by the next participant enrolled in the study receiving condition 2 and then 1). When assigned a test condition, the participant was then asked to complete five trials of the Modified X Running Test with a 1-minute rest between each attempt. Time to complete the test was recorded using Brower® infrared timing gates at the location illustrated in Figure 7 and the mean time between the five trials was calculated. After completing the five trials under bracing condition 1, the participant was then given the SAS-2 self-report questionnaire. The participant was instructed to complete this questionnaire with the verbal prompt "*How did you feel during that test condition*?". Following a 5-minute rest period, the participant then completed the same steps under the opposite brace condition.

Participants were asked not to participate in vigorous physical activity in the 24 hours before the second session to reduce the effects of fatigue. In the vertical jump testing session on day 2, participants followed a similar procedure. They began the session by standing on the force plate so their weight (N) could be recorded. This procedure was done in order to normalize the GRF data as a factor of force-to-bodyweight so it could be comparable across participants. Next, they stood on the force plate while the Vertec™ device was placed above them and adjusted to the correct height to record their standing reach height (inches). The Vertec™ device was then raised to the appropriate height to record the participants jump height as seen in Figure 9. The Vertec™ system uses inches as a unit of measure, therefore, all jump heights were recorded using inches and converted to cm. The participant then began the same supervised warm up including a 7-minute cycle ergometer at an intensity of 10-11 on the Borg Scale of Perceived Exertion. Following the warm up, the participant was brought towards the jump testing area (see Figure 9).

Next, the participant was introduced to the step sequence for completing a swing block (see Figure 2), given verbal instructions, and allowed three familiarization trials to get comfortable with the sequencing and proper positioning related to the distance relative to the AMTI© force plate Vertec™ device.

A methodological structure similar to the agility testing was adopted for the swing block vertical jump testing. The participant was given five jump attempts under each brace condition, the order of which was consistent with the first testing day, with mean jump height being calculated for each participant. A 1-minute rest period was given between each jump to reduce the effect of participant fatigue. After the participant completed the first testing brace condition, they were given the SAS-2 to complete under the verbal prompt "*How did you feel during that test condition*?". After a 5-minute rest period, the participant was assigned to the opposite test bracing condition and the same steps repeated. At this point, testing was then completed. The participant removed the ankle braces, any questions the participant had were answered, and they were thanked for their participation.

Figure 9.

Jump Testing Setup with Vertec™ and AMTI© Force Plate

Data Processing

The Vertec^{TM} data were collected after each jump trial by measuring height from the floor to the highest reached plastic vein and was inputted into Microsoft® Excel®. The distance of the participant's standing reach height was subtracted from their total reach height to calculate their total vertical displacement and normalize the vertical jump data.

The AMTI® force plate data were recorded using AMTI® NetForce, and processed using AMTI® BioAnalysis Software to examine force in the Z-plane during takeoff. Time to complete the Modified X Running Test was recorded using Brower® infrared timing gates, and these times were documented using Microsoft® Excel® after each trial. The self-report SAS-2 data were recorded via pen and paper hardcopy and were scored using the scoring key to measure each subscale.

The dependent variables were the performance factors including the swing block vertical jump height (cm), agility time to completion (s), GRFs (N), and scores for sport related anxiety. The two independent variables were brace condition (brace versus no brace) and sex (male versus female).

Data Analysis

For the purposes of data analysis, all AMTI® NetForce data were processed through AMTI® BioAnalysis to retrieve the raw data and then inputted into a Microsoft® Excel® spreadsheet to allow for the proper management of data.

Force Platform Data. Force platform data (N) from each of the five trials of the vertical jump test were averaged after checking for outliers that significantly affected the group mean and skewness of the data. In the case that these outliers were present or there was missing data, they were replaced with the mean of the remaining trials. The remaining data were then expressed as a factor of bodyweight (%BW) using the following equation: $\frac{Mean\ Peak\ Force(N)}{Bodyweight\ (N)}$.

Vertec™ Data. Vertec data (cm) from each of the five trials were averaged, then normalized to allow for comparison across participants using the following equation: (Mean Jump Touch Height – Reach Height). This processing allowed for the extraction of data for mean vertical displacement of each participant.

Modified X Running Test Data. Time to completion (s) of the test was averaged using each of the five trials for each participant. No further processing was necessary.

SAS-2 Data. Data from the SAS-2 questionnaire was recorded and coded via the scoring key provided. Values for the total score and total scores from each of the three domains (concentration disruption, somatic anxiety, and worry) that the questionnaire measures were calculated.

Statistical Analysis

Statistical analysis was conducted using IBM© SPSS 28. Each of the previously stated research questions were used to guide the statistical analysis. Descriptive statistics were conducted for the variables of interest.

To answer research question 1, a two-way mixed factorial analysis of variance (ANOVA) was used. This statistical test was conducted to determine the interaction effect of the independent variables brace condition (brace versus no brace) and sex (male versus female) on each of the dependent variables including maximum height acquired (cm), normalized GRF in the Z-plane during takeoff (N), and sport related anxiety during the swing block vertical jump test. For this statistical test, the alpha level was set at $p<.05$.

To answer research question 2, a two-way mixed factorial ANOVA was used. This statistical test was conducted to determine the interaction effect of the independent variables brace condition (brace versus no brace) and sex (male versus female) on each of the dependent variables including time (s) and sport related anxiety during the completion of the Modified X Running Test. For this statistical test, the alpha level was set at $p<.05$.

If statistical analysis revealed a statistically significant interaction effect between variables, post hoc testing was done to examine the simple main effects of each independent variable. To examine the simple main effects of sex, a *t*-test for independent measures was used to examine differences between males and females, for each ankle brace separately. To examine the simple main effects of ankle braces, a *t*-test for dependent measures was used to examine differences between brace and no brace, for each sex separately. If no statistically significant interaction was found, main effects of ankle bracing regardless of sex were analysed.

Chapter 3: Results

The results of this study provide insight into effect that softshell ankle braces may have on vertical jump height with a swing block approach, normalized GRF in the Z-plane during swing block vertical jump, time to complete the Modified X Running Test, and SAS-2 scores during each of these tasks.

Demographic Information

A total of 36 (24 male and 12 female) people participated in this study, with one participant not completing the vertical jump test due to withdrawing from the study. This participants agility test data was still included as they completed both test conditions prior to dropping out of the study. Demographic information for all participants is presented in Table 1 and Table 2.

Table 1. *Participant Demographic Information for Male Participants*

Number of Participants	24
Age (years)	20.58 +/- 2.87
Height (cm)	184.22 +/- 9.94
Weight (Kg)	78.46 +/- 8.30
Competition Level	2 high school, 20 club, 2 varsity
Foot Dominance	7 left, 17 right
Injury History*	14 none, 7 one, 3 more than one
Brace History**	13 never, 10 sometimes, 1 always

*Injury history was recorded based on self-report from each participant on the number of ankle injuries they have sustained
**Brace history was recorded based on self-report from each participant on the frequency to which they wear ankle braces.

Table 2. *Participant Demographic Information for Female Participants*

Number of Participants	12
Age (years)	21.42 +/- 2.11
Height (cm)	173.33 +/- 5.48
Weight (Kg)	70.69 +/- 7.89
Competition Level	3 high school, 4 club, 5 varsity
Foot Dominance	1 left, 11 right
Injury History*	6 none, 2 one, 4 more than one
Brace History**	7 never, 2 sometimes, 3 always

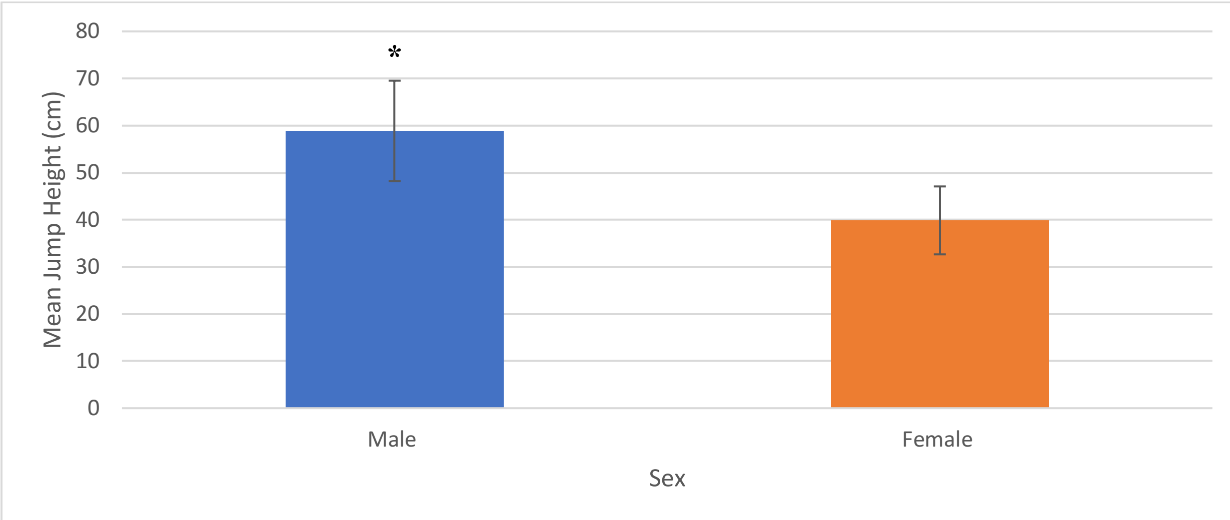
*Injury history was recorded based on self-report from each participant on the number of ankle injuries they have sustained
**Brace history was recorded based on self-report from each participant on the frequency to which they wear ankle braces.

Question 1: Is there an interaction effect between ankle brace condition (brace versus no brace) and sex (male versus female) when performing a vertical jump on measures of maximum height acquired, normalized GRF during takeoff, and sport related anxiety respectively for a swing block approach?

Swing Block Vertical Jump Maximum Height. A Levene's Test was conducted to assess the equality of variances in the data between the sex groups. It was determined that there was no violation in the equality of variance between the sex groups for the swing block jump height data with (F(1,33)=1.752, p=.195) or without (F(1,33)=0.356, p=.555) ankle braces.

A two-way mixed factorial ANOVA was conducted to compare the interaction effect between sex and ankle brace condition on maximum vertical jump height following the swing block approach. There was no statistically significant interaction effect between sex and brace condition on maximum vertical jump height (F(1,33)=.970, p=.332, η^2=.009). There was a statistically significant main effect of sex on maximum vertical jump height (F(1,33)=31.21, p=.001, η^2=.486) with a large effect size. Descriptive statistics showed that male participants jumped an average of 58.88 cm (SD=10.65 cm) and this was significantly higher than female participants, who jumped an average of 39.87 cm (SD=7.21 cm; see Figure 10).

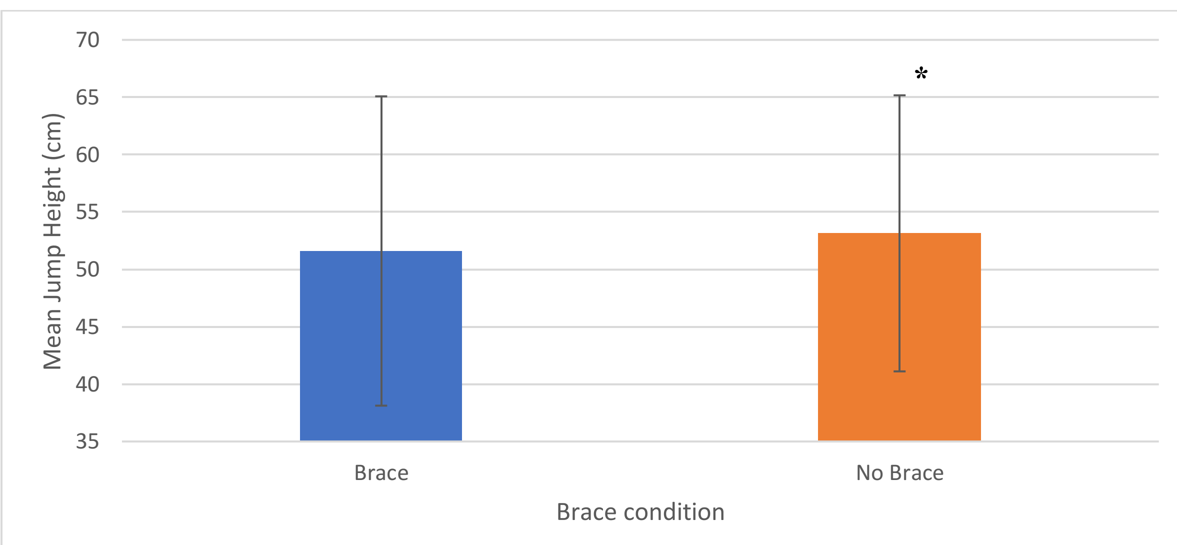
Figure 10. *Descriptive Statistics for Sex and Swing Block Jump Height*



* Denotes a statistically significant difference at $p<.05$

There was also a statistically significant main effect of brace condition on jump height ($F(1,33)=11.00$, $p=.002$, $\eta^2=.25$) with a large effect size. Participants jumped significantly higher without ankle braces (M=53.14 cm, SD=12.92) than they did with the ankle braces (M=51.60 cm, SD=11.11; see Figure 11).

Figure 11. *Descriptive Statistics for Brace Condition and Jump Height*



* Denotes a statistically significant difference at $p<.05$

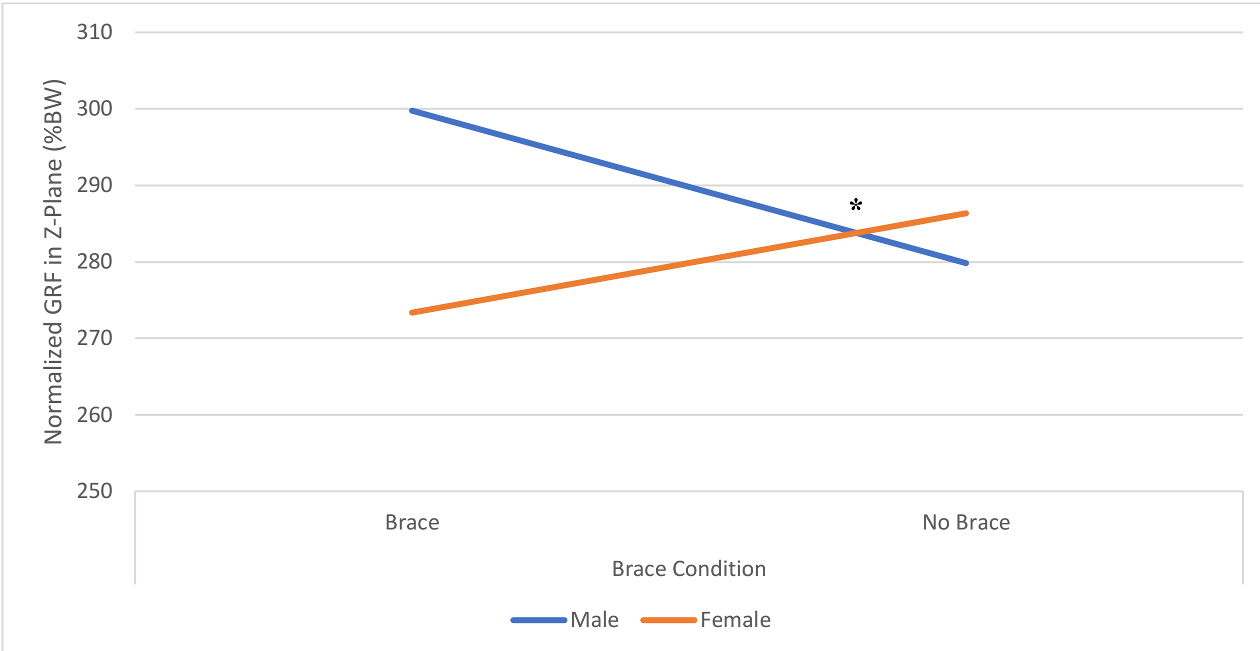
Normalized GRF in the Z-plane. A Levene's Test was conducted to assess the equality of variances in the data between the sex groups. It was determined that there was no violation in the equality of variance in the data between the sex groups for normalized GRF in the Z-plane with ($F(1,33)=2.891$, $p=.098$) or without ($F(1,33)=0.112$, $p=.704$) ankle braces.

A two-way mixed factorial ANOVA was conducted to compare the interaction effects between sex and ankle brace condition on peak normalized GRF in the Z-plane during takeoff of a vertical jump with swing block approach. There was a statistically significant interaction effect between sex and ankle brace condition on GRF in the Z-plane during takeoff ($F(1,33)=7.710$, $p=.009$, $\eta^2=.189$) with a large effect size, as shown in Figure 12.

When examining the interaction effects, the results of the simple main effects of sex via dependent measures t-test revealed no statistically significant differences between ankle brace condition for the female athletes, $t(11)=-1.821$, $p=0.096$, $d=.53$. CI:[-56.568, 5.351], as shown in Figure 13. The female athletes produced less force respective to bodyweight in the Z-plane while wearing ankle braces (M=273.26%BW, SD=36.79) than they did when not wearing ankle braces (M=298.87%BW, SD=37.71). The opposite is true of male athletes, who produced statistically significantly less force in the Z-plane respective to bodyweight, $t(22)=2.139$, $p=.044$, $d=.446$. CI:[0.602, 39.154] while not wearing ankle braces (M=279.83%BW, SD=38.48) compared to when they were wearing ankle braces (M=299.70%BW, SD=46.72), with a medium effect size, as shown in Figure 14.

When examining the interaction effect, the results of the simple main effects of brace condition via independent samples t-test revealed no statistically significant differences between males and females for the "with brace" condition, $t(33)=1.701$, $p=0.098$, $d=.61$. CI:[-5.189, 58.081], as shown in Figure 15. There was also no statistically significant differences between males and females for the "no brace" condition, $t(33)=-1.398$, $p=0.171$, $d=-.50$. CI:[-46.753, 8.672], as shown in Figure 16

Figure 12. *Results for Normalized GRF in Z-plane*



* Indicates statistically significant interaction

Figure 13. *Simple Main Effects of Females and Brace Condition on Normalized GRF in Z-plane*

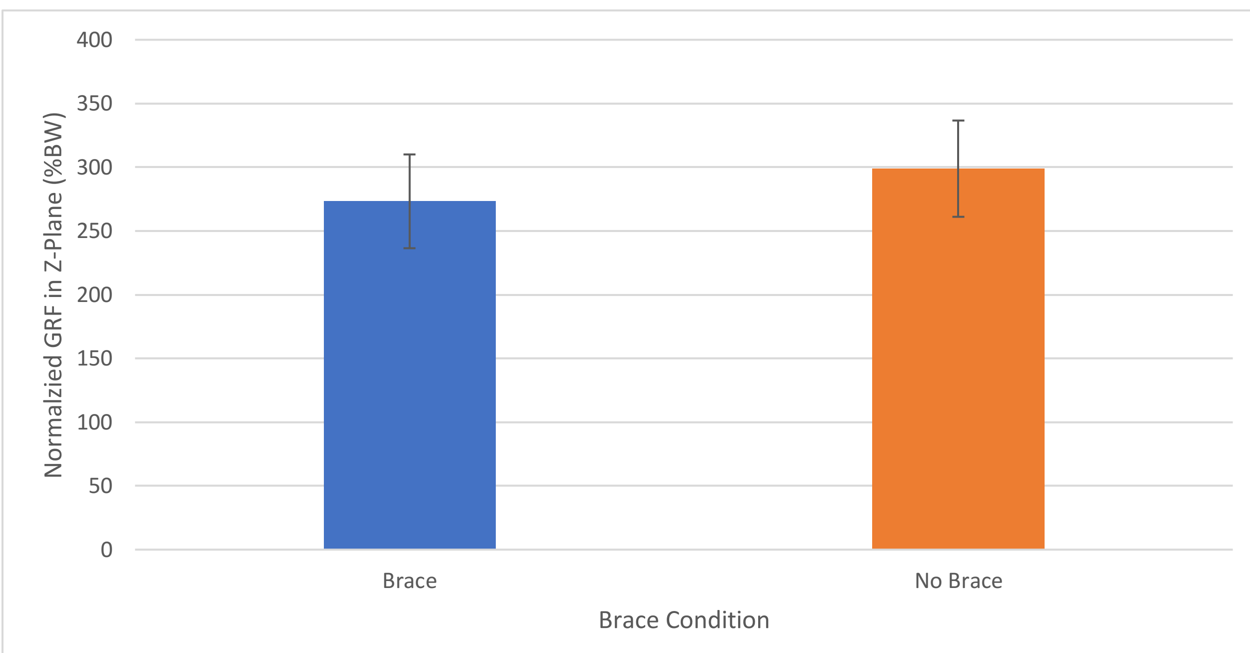
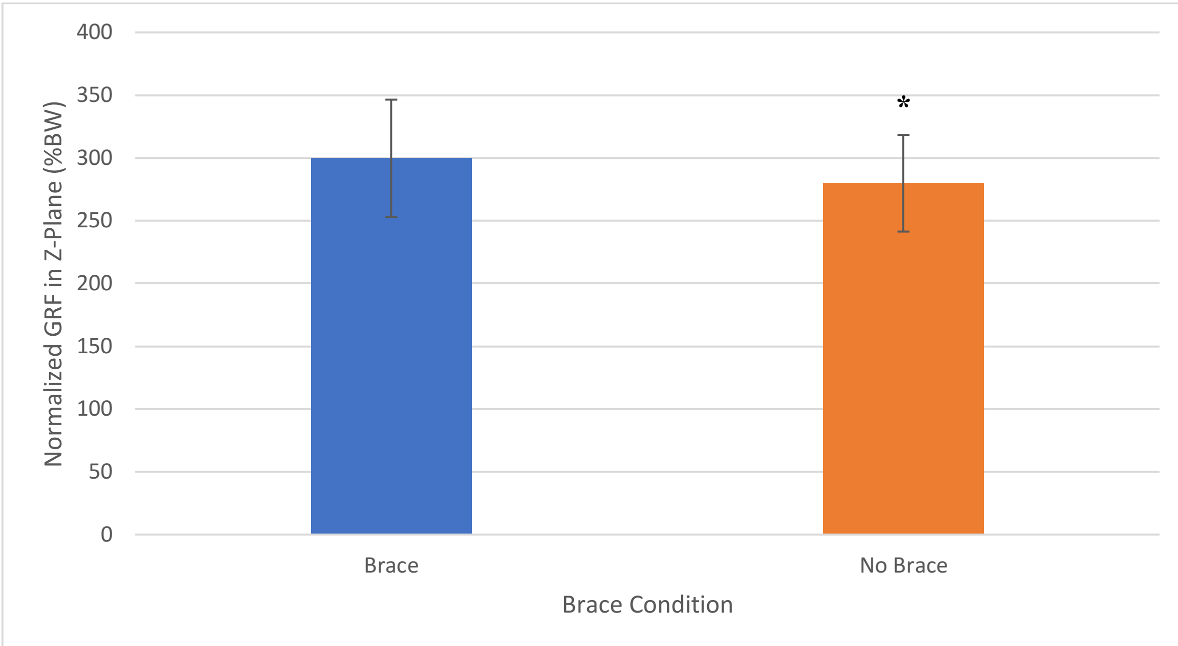


Figure 14. *Simple Main Effects of Males and Brace Condition on Normalized GRF in Z-plane*



* Indicates statistical significance of main effect of sex at *p*<.05

Figure 15. *Simple Main Effects of Sex With Braces on Normalized GRF in Z-plane*

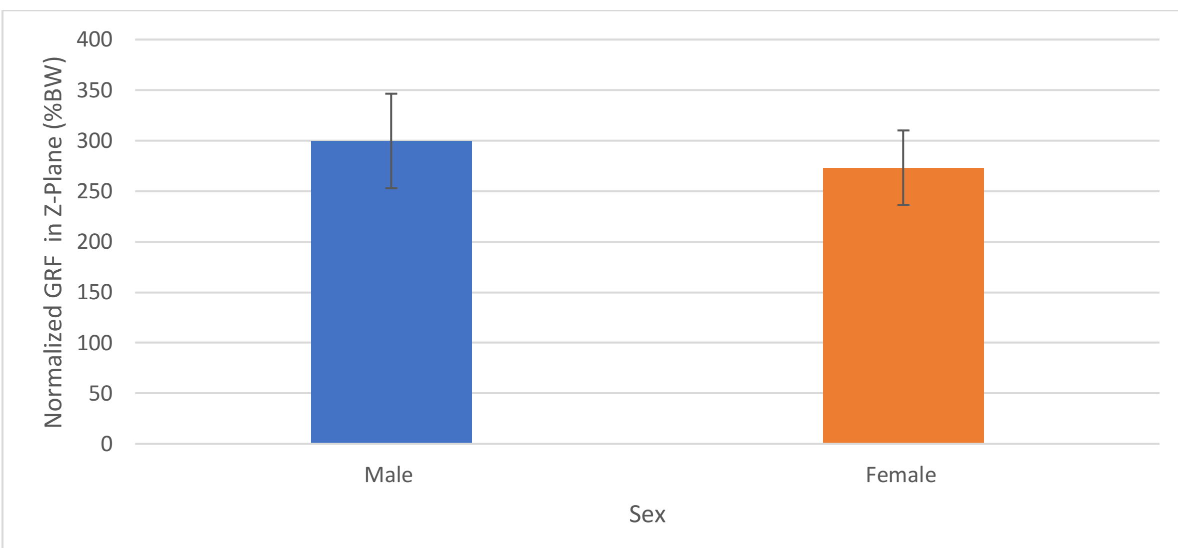
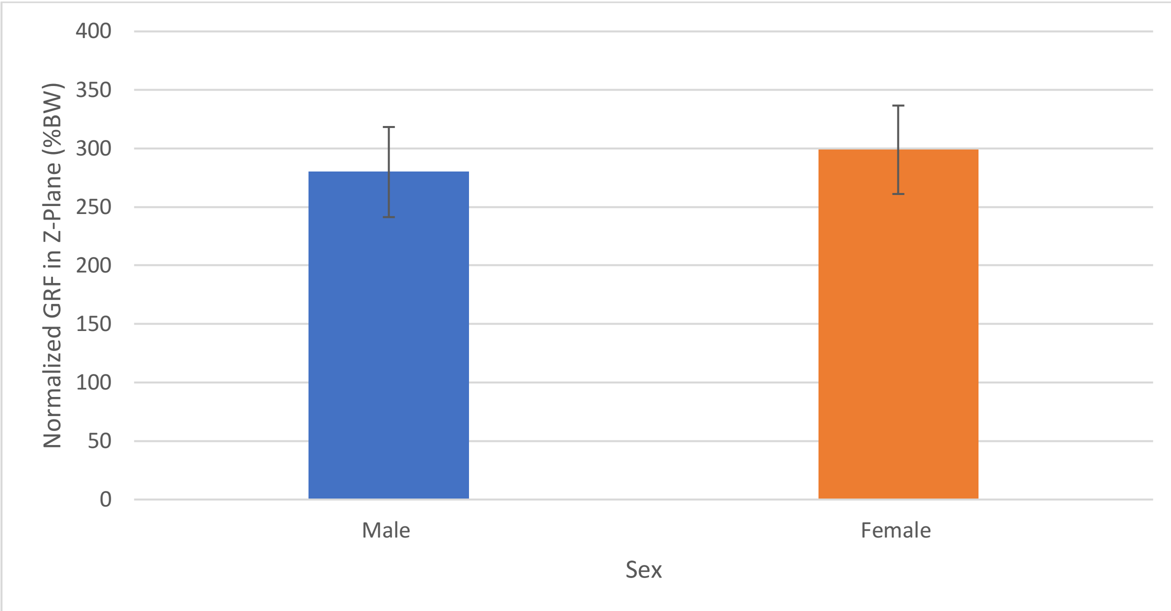


Figure 16. *Simple Main Effects of Sex Without Braces on Normalized GRF in Z-plane*



SAS-2 Questionnaire Scores during the Swing Block Vertical Jump. A Levene's Test was conducted to assess the equality of variances in the data between the sex groups. It was determined that there was no violation in the equality of variance in the data between sex groups for SAS-2 scores during the swing block vertical jump test with (F(1,33)=0.74, p=.787) or without (F(1,33)=0.186, p=.669) ankle braces.

A two-way mixed factorial ANOVA was conducted to compare the interaction effect between sex and ankle brace condition on total score of the SAS-2. There was no statistically significant interaction effect between brace condition and sex on total SAS-2 score (F(1,33) =0.305, p=.584, η^2 =.009).

There was no statistically significant main effects of brace condition on SAS-2 scores after completing the vertical jump test with (M=20.91, SD=5.72) or without (M=20.57, SD=6.10) ankle braces, (F(1,33)=.638, p=.807, η^2=.002). There was no statistically significant main effects of sex on the total score of the SAS-2 (F(1,33)=.228, p=.636, η_p^2 =.007), with males reporting a mean score of 21.06 (SD=6.31) and females reporting a mean score of 20.29 (SD=5.25).

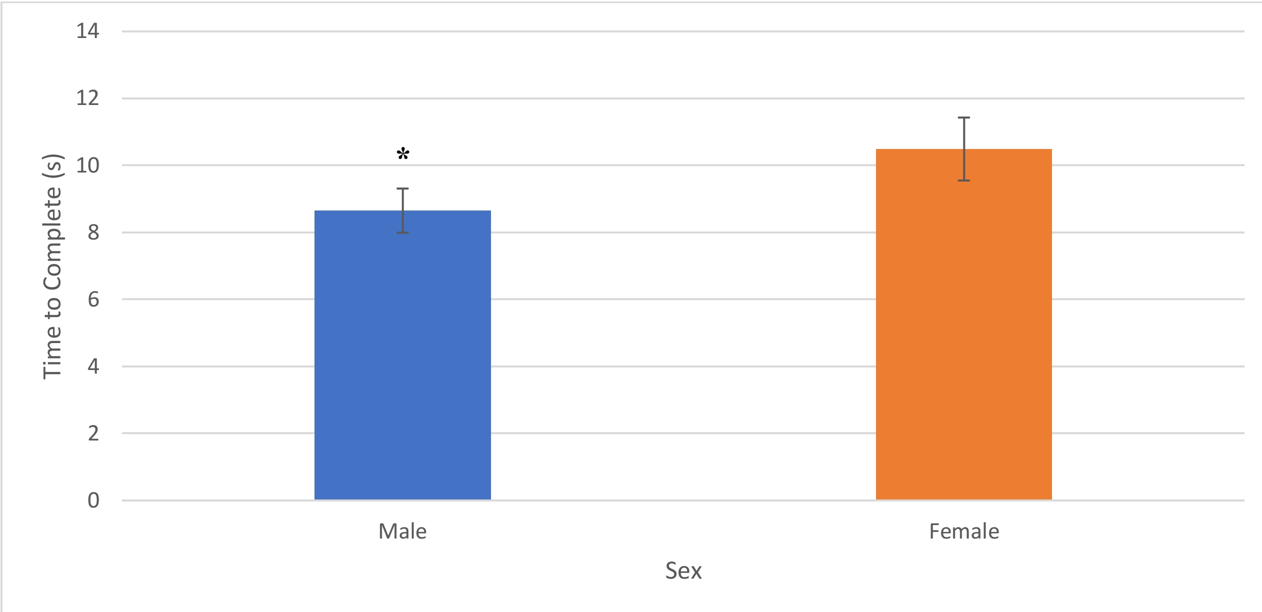
Question 2: Is there an interaction effect between ankle brace conditions (brace versus no brace) and sex (male versus female) on time and sport related anxiety, respectively, during the completion of the Modified X Running Test?

Modified X Running Test Time to Completion. A Levene's Test was conducted to assess the equality of variances in the data between the sex groups. It was determined that there was no violation in the equality of variance in the data between sex groups for time to complete the Modified X Running Test with (F(1,34)=0.328, p=.571) or without (F(1,34)=0.485, p=.491) ankle braces.

A two-way mixed factorial ANOVA was conducted to compare the interaction effect between sex and ankle brace condition on time to complete the Modified X Running Test. There was no statistically significant interaction effect between sex and ankle brace condition on time to complete the Modified X Running Test (F(1,34)=.442, p=.511, η^2 =.013).

There was a statistically significant main effect of sex on time to complete the Modified X Running Test (F(1,34)=47.437, p=.001, η^2 =.582) with a large effect size, as shown in figure 17. Male participants completed the Modified X Running Test quicker (M=8.64 s, SD=0.66 s) than the female participants (M=10.49 s, SD=0.94 s). There was no statistically significant main effect of ankle brace condition for measures of time to complete the Modified X Running Test with (M=9.24 s, SD=1.16) or without (M=9.28 s, SD=1.15) ankle braces, (F(1,34)=1.364, p=.251, η^2 =.039).

Figure 17. *Sex Differences for Modified X Running Test*



* Indicates statistical significance of main effect of sex at $p<.05$

SAS-2 Questionnaire during Modified X Running Test. A Levene's Test was conducted to assess the equality of variances in the data between sex groups. It was determined that there was no violation in the equality of variance in the data between sex groups for total SAS-2 questionnaire scores during the Modified X Running Test with ($F(1,34)=0.597$, $p=.445$) or without ($F(1,34)=0.607$, $p=.441$) ankle braces.

A two-way mixed factorial ANOVA was conducted to compare the interaction effect between sex and ankle brace condition on total score for the SAS-2 questionnaire. There was no statistically significant interaction effect between brace condition and sex on total SAS-2 questionnaire score ($F(1,34)=2.035$, $p=.163$, $\eta_p^2=.056$).

There was no statistically significant main effect of sex on the total score of the SAS-2 questionnaire ($F(1,34)=2.301$, $p=.139$, $\eta_p^2=.063$). There was also no statistically significant main effect of brace condition on the total score of the SAS-2 questionnaire ($F(1,34)=.297$, $p=.590$, $\eta_p^2=.009$).

There were no statistically significant differences between SAS-2 questionnaire scores after completing the Modified X Running Test with (M=20.83, SD=5.11) or without (M=20.88, SD=6.96) ankle braces.

Chapter 4: Discussion

The purpose of this study was to examine the effects that ankle bracing and sex have on maximum vertical jump height with a swing block approach, normalized GRF in the Z-plane, agility, and sport related anxiety. Previous literature examining the effects of ankle bracing on athletic performance is inconclusive, with some studies reporting a decrease in performance (Boulanger, 2022; Henderson et al., 2018; You et al., 2020), and others reporting no difference (Gross et al.,1994; Macpherson et al.,1995; Pienkowski et al.,1995). The results of this study are also mixed, with results revealing that there are no differences for some variables, but a decrease in performance for others. Additionally, this study contributed to the literature surrounding the psychological effects of ankle bracing during sport participation. The following section will discuss the results and implications of this study in greater detail.

Swing Block Vertical Jump Maximum Height

Results of this analysis revealed no statistically significant interaction effect between sex and brace condition on maximum jump height during the completion of a swing block vertical jump test. There was, however, a statistically significant main effect of brace condition on swing block vertical jump height; when compared to not wearing the soft-shell ankle brace, all participants produced a statistically significant decrease of 1.54 cm in swing block vertical jump height. When stratified by sex, male participants had a decrease of 1.19 cm and female participants had a decrease of 2.2 cm.

The reported sex differences in jump height during this study are consistent with existing literature, and as such, it was expected to see sex differences in performance. McMahon et al. (2017) discussed the differences in jump kinematics that allow males to produce higher vertical jumps. These differences include males producing larger peak concentric force relative to body mass and greater absolute rate of force development. They continued to explain that although relative force-time curves were similar between sexes, males produced greater power-, velocity-, and displacement-time curves (McMahon et al., 2017). This suggests that male athletes are capable of producing power at a quicker rate than female athletes, allowing the males to jump higher. These sex differences were explained by Esteban et al. (2017), who stated that males had greater muscle activation in the vastus lateralis and gastrocnemius muscles than females while completing the same style vertical jump. The greater muscle activation may have contributed and allowed male athletes to produce more force, therefore, jumping higher.

The results in the current study of brace condition on maximum swing block jump height are comparable to those from Henderson et al. (2018), You et al. (2020), and Boulanger (2022) who each had a reported decrease in vertical jump height by 2.1 cm, 2.3 cm, and 1.8 cm, respectively, while wearing soft-shell ankle braces. While the differences between brace condition in this study were statistically significant, looking at the entire population that participated produced a decrease in performance that was smaller than was seen in the aforementioned studies. This current study utilized a swing block jump approach, while You et al. (2020) used a 3-step spike approach, and Boulanger (2022) and Henderson et al. (2018) used a countermovement vertical jump. The differences in jumping style may explain the similar yet varying results found between these four recent studies. Future investigation regarding the interaction between jump type and brace conditions may provide more information on the impact that ankle bracing has on athletic performance, specifically, the vertical jump. Previous literature by Gross et al. (1994), Macpherson et al. (1995), and Pienkowski et al. (1995) all suggested that there were no statistically significant differences in jump height when wearing ankle braces, however, their conclusions were based on methodologies that employed a field test.

A field test, defined by Klavora (2000), is a test that can be done in a variety of different settings, but at the cost of accuracy. Laboratory tests that use force plates or similar devices such as contact mats are more accurate in recording jump height than field tests, however, come at a higher cost and are less portable (Klavora, 2000). The studies by Gross et al. (1994), Macpherson et al. (1995), and Pienkowski et al. (1995) utilized tape or ink on the ends of their participants fingers and relied on the participant jumping and touching the wall at the peak of their jump. While this is considered a valid and reliable method of measuring jump height (Whitmer et al., 2015), newer studies have revealed a difference of mere cm between trials, thus, human error may have played a role in the lack of difference the older studies reported that employed a different method of measuring vertical jump height.

In addition, the differences in methodology between the studies that used a dynamic approach (i.e., swing block or spike approach) versus a static approach (i.e., countermovement or squat jump) may explain the disagreement between the results. This current study and You et al. (2020) used the dynamic approaches while the static approaches were used by Gross et al. (1994), Macpherson et al. (1995), and Pienkowski et al. (1995). The utilization of a momentum-based jump may also explain the differences found as the momentum-based jumps could allow for greater amounts of force production to be applied via the SSC. This is a topic that was discussed by Yamauchi and Koyama (2021), who hypothesized that ankle braces reduce the range of motion of the ankle lessening the effect of the SSC. The SSC relies on a combination of eccentric and concentric contractions to create additional force in the muscle (Komi, 2000). When compared to purely concentric actions, the SSC combines eccentric contractions, concentric contractions, and elasticity in the tendons to enhance athletic performance and create more force (Komi, 2000). With a reduction in range of motion in the ankle, the SSC of the lower leg muscles is less effective, thus, hindering force production. Since the comparisons that Yamauchi and Koyama examined were between a countermovement vertical jump and a squat jump, the difference in effectiveness of the SSC between a squat jump and an approach-based jump are yet to be examined.

As discussed above, it was identified that a large effect size ($\eta^2 = .25$) was present between brace conditions and their effect on maximum jump height with a swing block approach. This suggests that there may be great practical significance to these findings (Kalinowski & Fidler, 2010). Although the difference between treatment groups was only 2.2 cm for females and 1.19 cm for males, in the context of volleyball, this difference could make or break a player's performance. Empirically, when attempting to block an opponent's ball, a difference of 1 cm may be the distinguishing factor between a straight down block, or a block that goes off the defenders' hands and out of play. This may also translate into the success for that point and possibly the outcome of the match.

Normalized GRF in the Z-plane

Results of the statistical analysis indicated a significant interaction effect between sex and brace condition on the amount of force produced by each participant in the Z-plane. Further examination of the simple main effects revealed that male athletes produced statistically significant less normalized GRF in the Z-plane during the braced condition than they did in the unbraced condition. These results show that in proportion to bodyweight, male athletes were producing less peak force when wearing ankle braces than when not wearing ankle braces. There were no other significant simple main effects between sex and brace condition. The normalized GRF data is aligned with the vertical jump height data, with lower values of normalized peak force (N) and maximum jump height (cm) being recorded during the with brace condition. This suggests that ankle bracing had a negative impact on the force production in the lower body which then results in a reduced vertical jump height in the male athletes. To further explain these findings, one may look to the kinematic impact of ankle bracing as described in previous studies. Henderson et al. (2018) and Smith et al. (2016) both observed a reduction in EMG activity in the gastrocnemius, which is a biarticular muscle that acts on both the ankle and knee (Smith et al, 2016). The gastrocnemius has two major actions including knee flexion and ankle plantarflexion, the latter of which is part of the chain of muscles responsible for jumping. Reduced EMG in the gastrocnemius muscle means that there is less muscle activity, resulting in the recruitment of less motor fibers and a lessened ability to produce force. Smith et al. (2016) also observed significantly reduced hip and ankle plantarflexion angles and increased knee flexion angles during the loading phase of a vertical jump while wearing ankle braces. Due to the changes in joint angles, specifically increased knee flexion, Smith et al. (2016) suggested that the ability of the gastrocnemius muscle to produce force during the loading phase of the vertical jump may be reduced, therefore, reducing overall max jump height. This is in line with the findings of the current study where normalized GRF was reduced in male athletes while wearing ankle braces. It was expected to see similar results across sex for the GRF data due to the results of the swing block jump test. Male participants jumped lower with the ankle braces by a mean difference of 1.19 cm and saw a statistically significant decrease in GRF in the Z-plane. Similarly, female participants jumped significantly lower with the ankle braces by a mean score of 2.2 cm but saw no significant difference in GRF. As there was no significant difference seen in GRF in the Z-plane for females between brace conditions, the question of why there are differences between sexes emerges. Adopting the previous discussion of why the men produced a significantly lower GRF in the Z-plane, it is possible that in the jumping mechanics of female athletes, there is less involvement of the gastrocnemius muscle. If female athletes do not rely as much on the gastrocnemius muscle to produce force, the effect of ankle bracing on the gastrocnemius muscle as previously discussed is negligible. Further EMG, kinetic, and kinematic analysis is needed to report on the sex differences of force producing muscles during takeoff of a swing block vertical jump. Alternatively, the differences in results of GRF in the Z-plane between sexes in this study may be attributed to sample size with less female (n=12) than male (n=24) participants, resulting in a type II error, a false negative due to under power. The GRF findings are essential for coaches, trainers, and athletes when considering bracing approaches, especially for those whose performance relies heavily on force production in the Z-plane, such as in volleyball. With the possibility that there are sex differences for force production between ankle brace conditions, further research is needed to fully understand the impact that ankle bracing has on GRF in the Z-plane. Once this impact of ankle bracing is more thoroughly understood, coaches, athletes, and trainers can make a better-informed decision on the use of ankle braces in volleyball.

Agility Time in the Modified X Running Test

Results of the statistical analysis indicated no interaction effect between sex and brace condition on the time to complete the Modified X Running Test. Furthermore, there was a statistically significant difference between sex and time to complete the Modified X Running Test, with male participants completing the test an average of 1.85 s quicker than female participants. There were no statistically significant differences between brace conditions on time to complete the Modified X Running Tests. This is contrary to the results of both Boulanger (2022) and Henderson et al. (2018) who reported significant increases in time to complete varying agility tasks while wearing ankle braces. The methodologies of these two studies were similar to each other when looking at the requirements of the agility task. Boulanger (2022), who used a T-test agility task that required participants to complete a full sprint for 9.14 m before coming to a halt; side shuffling 4.57 m to the left, then 9.14 m to the right, then 4.57 m returning back to the centre before back pedaling 9.14 m to the finish line. Henderson et al. (2018) developed a cutting task unique to their research project that was a modified version of the T-test. Henderson et al. (2018) required participants to sprint forward 5 m, side shuffle to the left 3 m, side shuffle to the right 3 m, and back pedal 5 m to the finish line. Both tests incorporated a full sprint in the antero-posterior plane followed by a side shuffle in the sagittal plane. As the there was no significant difference in the agility time between brace conditions for the Modified X Running Test, a test that focuses on a diagonal movement, this suggests that time lost may be at the intersection of perpendicular directional change. With regard to volleyball, there are very few instances where this type of movement is needed. This sport demands more lateral or diagonal movement, and almost no demand for full sprints followed by quick cutting movements.

The findings of the current study were similar to those of three previous studies (Gross et al., 1994; Macpherson et al., 1994; Pienkowski et al., 1995), and although each study utilized a different methodology, all reported no significant differences in the time to complete an agility task while wearing ankle braces. With respect to this study, infrared sensors were used to measure time to completion with extreme accuracy while the older studies by Gross et al. (1994), Macpherson et al. (1995), and Pienkowski et al. (1995) all used handheld stopwatches, which introduces the possibility of human error. Based on the results of the current study, sex differences were observed during the Modified X Running Test. Male participants completed the agility test faster than female participants, however, this was expected and supported by current literature. As explained by McMahon et al. (2017), males were capable of producing greater force at a quicker rate than females due to differences in musculature and males having higher values of muscle activation. This means that the male athletes may be able to complete the quick directional changes required in the Modified X Running Test faster than the female athletes.

With no significant differences between brace conditions during the Modified X Running Test, it can be recommended for volleyball players to utilize ankle braces prophylactically and as treatment for ankle injuries without fear of reduced agility performance.

SAS-2 Questionnaire

Through analysis of the results for both the Modified X Running Test and Swing Block Vertical Jump Test, it was identified that there were no significant differences in scores of the SAS-2 during either task when examining brace condition or sex. Further analysis was conducted on the effect of injury history on SAS-2 scores also revealed no difference in either sex or brace condition.

The existing literature discusses that athletes who have previously sustained an injury experience higher levels of anxiety than their uninjured counterparts (Hunt & Short, 2006). Furthermore, Dias et al. (2010) and Tomczak et al. (2022) reported that females have higher levels of general anxiety, with Tomczak et al. (2022) reporting higher levels of anxiety in female athletes as measured by the SAS-2. It was hypothesized and expected to see results that support that of Hunt and Short (2006), who suggested that athletes who typically use supportive devices on their ankles experience heightened anxiety levels when these supportive devices are removed. This is based on pilot work completed by the student researcher that found statistically significant differences on how an athlete predicted they would feel should their supportive device be removed, with reports of increased expected anxiety. Hunt and Short (2006) further explained differences in anxiety caused by the psychological comfort the device provided the athlete, knowing that they had extra support for their injured limb. The current study identified no differences in anxiety levels as measured by the SAS-2. This could be due to a number of factors including the participants familiarity with the student researcher, the sensitivity of the measurement device, or the tasks required for the athletes. Due to the close timing of the test conditions, participants may have remembered the answers they previously recorded and attempted to recreate those, as opposed to completing the questionnaire with an entirely open mind. Additionally, the required tasks in this study may not have accurately simulated the environment that an athlete typically encounters during sport participation. During the study, participants were required to complete the jumping and agility tasks in discrete movements; one trial at a time. In actual sport participation, the anxiety one experiences may be caused by the continuous arousal over the course of a game and not knowing the specific direction or sport specific requirement during each point.

As purposive and convenience sampling was used, every participant had a pre-existing relationship with the student researcher, as such they may have felt more comfortable during the data collection sessions than they would have during a game or practice situation. Furthermore, it is possible that the psychological demands of the data collection were not similar to those required for actual sport participation, which includes other nuances such as the desire to win, the pressure of team-mates, fans, or the game situation. Further examination of the effects of ankle bracing on sport related anxiety is needed to fully discover any relationships that may exist.

Limitations

As with many research studies, sample size is one aspect of the project that can be improved, and that is no different for this current study. Although statistical significance was obtained, a larger sample size allows for greater statistical power and the ability to further stratify the data into smaller populations (skill level, injury history, brace history) without sacrificing statistical significance. This study also saw an unequal distribution of male to female participants which may have impacted results of the inferential statistics by reducing overall power and may contribute to type I error (Rusticus & Lovato, 2014).

As mentioned previously, the student researcher was known to all the participants. This may have given prejudice to some of the data, specifically socially sensitive data, such as that which relates to mental health. Due to confidentiality, it was the assumption of the student researcher that all participants would answer the SAS-2 questionnaire fully and truthfully, however, there is no guarantee that this is the case for fear of judgement. Due to a fear of judgement, participants may have answered questions regarding sport related anxiety with a lower score than how they truthfully feel.

Lastly, this research project took place in a controlled environment. With a defined setting such as the multipurpose laboratory or a section of court that was closed to the public, there was little external distraction for the participants. This is not the case during a practice or game of volleyball, where there are external stimuli such as teammates, fans, or professional scouts. For a research measure as nuanced as anxiety, the environment has a large impact on how an individual performs.

Delimitations

Delimitations must also be considered with respect to this study. This study used a homogenous population of athletes who have experience playing volleyball, therefore, it can be assumed that these results are volleyball specific and can be applied to current and future volleyball players.

The methodology of this study used a Latin square method to randomize each participant's condition order, thereby eliminating the effect that fatigue may have had on the results. This, combined with adequate rest periods between each trial gives a strong notion to any differences between condition to be caused by the treatment, and treatment alone. Additionally, 5 trials were taken for each test under each condition with any statistically identified outliers being removed, strengthening the mean values, and reducing variability in the data.

Future Directions

This study was one that tested the psychological and physical effects of ankle bracing in a way that has yet to be examined thoroughly. Additionally, this study aimed to expand the knowledge of sex differences in athletic performance and the sport related anxiety. Further research is required to fully understand any effects that ankle bracing has on anxiety and athletic performance. Future research should simulate a game-like environment to try to recreate all external stimuli that may have an impact on sport performance as this may allow for more accurate SAS-2 data collection. Furthermore, a game-like environment allows for one to examine effects of ankle bracing throughout a whole game, including how fatigue interacts with ankle bracing and overall performance. Lastly, the incorporation of combined analysis techniques such as including EMG, kinetic, or kinematic analysis simultaneously would allow for a deeper exploration of the effects that ankle bracing has on physical performance in volleyball.

Chapter 5: Conclusions

The purpose of this study was to examine the effects that ankle bracing and sex had on maximum vertical jump height with a swing block approach, normalized GRF in the Z-plane, agility, and sport related anxiety. Previous literature provided mixed results on the effect of ankle bracing on athletic performance, and this study showed similar results. Significant decreases were found in maximum jump height with swing block approach while wearing ankle braces, and in GRF in the Z-plane for male athletes. Sex differences were identified in performance factors such as maximum jump height with a swing block approach, GRF in the Z-plane, and time to complete the modified X running test, but not in the reports of sport related anxiety as measured by the SAS-2. Because this study revealed no significant differences in agility time between ankle brace conditions, it is recommended for volleyball athletes who do not need to focus on vertical jump, such as defensive specialists, to continuously wear ankle braces to prevent the likelihood of sustaining injury. For other volleyball positions that require maximal vertical jumping, individuals must weigh the benefits that the ankle braces have, such as reduced likelihood of injury, against the potential draw backs, such as reduced vertical jump height, to make their decision on their own use. Unless an individual has a personal aversion to the feeling of wearing ankle braces, they may choose to wear ankle braces to reduce the likelihood of ankle injuries, regardless of sex. The effects of ankle bracing on performance may be minimal but in specific situations or positions on the court, the slight reduction in vertical jump height may have an impact on the overall outcomes. In summary, the negative impact of ankle bracing on vertical jump performance, while not affecting agility speed or sport related anxiety, can require adjustments in training, game strategy, and athlete confidence. It is essential to strike a balance between injury prevention and performance optimization while considering the specific needs and goals of the athlete and the demands of their sport as well as the psychological effects and these must all be considered how they differ across the sexes.

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Appendices

Appendix 1

Sport Anxiety Scale-2

REACTIONS TO PLAYING SPORTS

Many athletes get tense or nervous before or during games, meets or matches. This happens even to pro athletes. Please read each question. Then, circle the number that says how you USUALLY feel before or while you compete in sports. There are no right or wrong answers. Please be as truthful as you can.

	Before or while I compete in sports:	Not At All	A Little Bit	Pretty Much	Very Much
1.	It is hard to concentrate on the game.	1	2	3	4
2.	My body feels tense.	1	2	3	4
3.	I worry that I will not play well.	1	2	3	4
4.	It is hard for me to focus on what I am supposed to do.	1	2	3	4
5.	I worry that I will let others down.	1	2	3	4

	Before or while I compete in sports:	Not At All	A Little Bit	Pretty Much	Very Much
6.	I feel tense in my stomach.	1	2	3	4
7.	I lose focus on the game.	1	2	3	4
8.	I worry that I will not play my best.	1	2	3	4
9.	I worry that I will play badly.	1	2	3	4
10.	My muscles feel shaky.	1	2	3	4

	Before or while I compete in sports:	Not At All	A Little Bit	Pretty Much	Very Much
11.	I worry that I will mess up during the game.	1	2	3	4
12.	My stomach feels upset.	1	2	3	4
13.	I cannot think clearly during the game.	1	2	3	4
14.	My muscles feel tight because I am nervous.	1	2	3	4
15.	I have a hard time focusing on what my coach tells me to do.	1	2	3	4

Scoring Key. Somatic: Items 2, 6, 10, 12, 14; Worry: Items 3, 5, 8, 9, 11; Concentration Disruption: Items 1, 4, 7, 13, 15.

Appendix 2

Par-Q+

2021 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	**YES**	**NO**
1) Has your doctor ever said that you have a heart condition ☐ **OR** high blood pressure ☐?	☐	☐
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?	☐	☐
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:** ______	☐	☐
5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:** ______	☐	☐
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past, but it **does not limit your current ability** to be physically active. **PLEASE LIST CONDITION(S) HERE:** ______	☐	☐
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.
Please sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow Global Physical Activity Guidelines for your age (https://www.who.int/publications/i/item/9789240015128).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and NOT accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

PARTICIPANT DECLARATION
If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for its records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAMF ______________________ DATE ______________

SIGNATURE ______________________ WITNESS ______________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ______________________

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at www.eparmedx.com before becoming more physically active.
- Your health changes - answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

2021 PAR-Q+

FOLLOW-UP QUESTIONS ABOUT YOUR MEDICAL CONDITION(S)

1. Do you have Arthritis, Osteoporosis, or Back Problems?

If the above condition(s) is/are present, answer questions 1a-1c — If **NO** ☐ go to question 2

1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	YES ☐ NO ☐
1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	YES ☐ NO ☐

2. Do you currently have Cancer of any kind?

If the above condition(s) is/are present, answer questions 2a-2b — If **NO** ☐ go to question 3

2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and/or neck?	YES ☐ NO ☐
2b.	Are you currently receiving cancer therapy (such as chemotheraphy or radiotherapy)?	YES ☐ NO ☐

3. Do you have a Heart or Cardiovascular Condition? This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm

If the above condition(s) is/are present, answer questions 3a-3d — If **NO** ☐ go to question 4

3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
3b.	Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction)	YES ☐ NO ☐
3c.	Do you have chronic heart failure?	YES ☐ NO ☐
3d.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	YES ☐ NO ☐

4. Do you currently have High Blood Pressure?

If the above condition(s) is/are present, answer questions 4a-4b — If **NO** ☐ go to question 5

4a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
4b.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer **YES** if you do not know your resting blood pressure)	YES ☐ NO ☐

5. Do you have any Metabolic Conditions? This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes

If the above condition(s) is/are present, answer questions 5a-5e — If **NO** ☐ go to question 6

5a.	Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician-prescribed therapies?	YES ☐ NO ☐
5b.	Do you often suffer from signs and symptoms of low blood sugar (hypoglycemia) following exercise and/or during activities of daily living? Signs of hypoglycemia may include shakiness, nervousness, unusual irritability, abnormal sweating, dizziness or light-headedness, mental confusion, difficulty speaking, weakness, or sleepiness.	YES ☐ NO ☐
5c.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, **OR** the sensation in your toes and feet?	YES ☐ NO ☐
5d.	Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)?	YES ☐ NO ☐
5e.	Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future?	YES ☐ NO ☐

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6.	**Do you have any Mental Health Problems or Learning Difficulties?** This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome If the above condition(s) is/are present, answer questions 6a-6b — If **NO** ☐ go to question 7	
6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
6b.	Do you have Down Syndrome **AND** back problems affecting nerves or muscles?	YES ☐ NO ☐
7.	**Do you have a Respiratory Disease?** *This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure* If the above condition(s) is/are present, answer questions 7a-7d — If **NO** ☐ go to question 8	
7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
7b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	YES ☐ NO ☐
7c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	YES ☐ NO ☐
7d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	YES ☐ NO ☐
8.	**Do you have a Spinal Cord Injury?** *This includes Tetraplegia and Paraplegia* If the above condition(s) is/are present, answer questions 8a-8c — If **NO** ☐ go to question 9	
8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
8b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	YES ☐ NO ☐
8c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	YES ☐ NO ☐
9.	**Have you had a Stroke?** *This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event* If the above condition(s) is/are present, answer questions 9a-9c — If **NO** ☐ go to question 10	
9a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
9b.	Do you have any impairment in walking or mobility?	YES ☐ NO ☐
9c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	YES ☐ NO ☐
10.	**Do you have any other medical condition not listed above or do you have two or more medical conditions?** If you have other medical conditions, answer questions 10a-10c — If **NO** ☐ read the Page 4 recommendations	
10a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months **OR** have you had a diagnosed concussion within the last 12 months?	YES ☐ NO ☐
10b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	YES ☐ NO ☐
10c.	Do you currently live with two or more medical conditions?	YES ☐ NO ☐

PLEASE LIST YOUR MEDICAL CONDITION(S) AND ANY RELATED MEDICATIONS HERE: ______________________________

____

GO to Page 4 for recommendations about your current medical condition(s) and sign the PARTICIPANT DECLARATION.

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If you answered NO to all of the FOLLOW-UP questions (pgs. 2-3) about your medical condition, you are ready to become more physically active - sign the PARTICIPANT DECLARATION below:

- It is advised that you consult a qualified exercise professional to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually - 20 to 60 minutes of low to moderate intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.

If you answered **YES** to **one or more of the follow-up questions** about your medical condition:
You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program - the **ePARmed-X+ at www.eparmedx.com** and/or visit a qualified exercise professional to work through the ePARmed-X+ and for further information.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ **at www.eparmedx.com** before becoming more physically active.
- Your health changes - talk to your doctor or qualified exercise professional before continuing with any physical activity program.

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The authors, the PAR-Q+ Collaboration, partner organizations, and their agents assume no liability for persons who undertake physical activity and/or make use of the PAR-Q+ or ePARmed-X+. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.

PARTICIPANT DECLARATION

- All persons who have completed the PAR-Q+ please read and sign the declaration below.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME ______________________________ DATE ______________________________

SIGNATURE ______________________________ WITNESS ______________________________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ______________________________

For more information, please contact
www.eparmedx.com
Email: eparmedx@gmail.com

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Key References

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Appendix 3

Demographic Information Collection Sheet

Lakehead UNIVERSITY

Demographic Information

Age:

Height (cm):

Body Weight (N):

Foot Dominance: L **or** R

Injury History:

History with Ankle Braces:

Appendix 4

Borg Scale of Perceived Exertion

Rating	Perceived Exertion
6	No exertion
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion