International Journal of
EXERCISE SCIENCE

Original Research

The Effect of Active Ankle T1™ Ankle Braces on the Timing of Muscular Activation in the Leg in Female Varsity Volleyball Players: A Pilot Study

HEATHER BROUSSEAU*[1], KYLEE KUCHTA*[1], SARA POTTER*[1], IAN NEWHOUSE‡[1]

[1]Department of Kinesiology, Lakehead University, Thunder Bay, ON, CANADA

*Denotes undergraduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 11(1): 1086-1095, 2018. The objective was to examine the effect of Active Ankle T1™ ankle braces on the timing of muscular activation of the upper leg in female volleyball athletes during a one-legged landing task. Fourteen healthy female varsity volleyball athletes participated in this study. Each signed a participant recruitment form, consent form, a Physical Activities Readiness Questionnaire (PAR-Q) and completed the injury screening form. A warm up was completed followed by two practice jumps. Each participant was randomly assigned and counterbalanced to a condition to begin with (no brace or brace). Once the warm up and practice trials, the participant applied the appropriate condition. A researcher applied Delsys™ electrodes to the participant's left leg on the vastus medialis and biceps femoris. The jumps consisted of a two foot approach, a two foot takeoff, and a landing on the left leg. The participants completed three trials in the first condition and then three in the opposite condition. A Vertec™ device was used to increase participant's motivation. The differences in timing of the muscular activation of the biceps femoris and vastus medialis were analyzed. A repeated measures t-test was used to analyze the data. There was no significant difference in timing of muscular activation of the biceps femoris and vastus medialis between the brace condition and no brace condition. The findings of this study show that the use of Active Ankle T1™ ankle braces do not increase the risk of injury to the anterior cruciate ligament in terms of timing of muscular activation.

KEY WORDS: Anterior cruciate ligament injuries, biceps femoris, vastus medialis, electromyography.

INTRODUCTION

Ankle injuries account for 10-30% of all injuries reported by athletes involved in sports that require explosive cutting, sidestepping, and agility type movements such as volleyball (23). The most common type of ankle injury is a lateral, or inversion ankle sprain (7). These sprains are typically induced by movements involving plantar flexion, supination, and inversion of the ankle (23). Although upwards of 23 000 ankle sprains have been estimated to occur every day in the United States, only a small percentage result in the ligament completely rupturing (10,23). Despite not resulting in a complete rupture, there is a 70% chance that the athlete will reinjure the ankle joint after rehabilitation, and 55-72% of patients report residual symptoms between six weeks and eighteen months post-injury (10). This has led to a great increase in research surrounding ankle injury and the application of a variety of different ankle taping and bracing techniques. As a result of this research, wearing bilateral ankle braces has become common practice for volleyball athletes, regardless of the athlete's history of injury, and current ankle strength (18).

Ankle injuries are not the only common injury seen in volleyball players. Noncontact anterior cruciate ligament (ACL) injuries are also very common, especially in the female population (1). When female volleyball players land from a hit, they often land on one leg (most commonly the left leg) (18). The load of landing on one leg often results in an exaggerated valgus force on the knee, which produces a high force loading on the ACL, increasing risk for injury or rupture (12,14). The high prevalence of ACL-related injuries is very concerning, especially given the relatively young age that the injury typically occurs at, and the chronic effects that they have on the individual (16). It is therefore crucial to understand the specific forces that put the ACL at a greater risk of injury.

Multiple studies have suggested the timing of muscular activation in the upper leg contribute to ACL injuries (2,3,11,13). A study done by Besier, Lloyd, and Ackland (2003) showed that when the hamstrings are activated first during dynamic landing tasks, the anterior translation of the tibia decreased with respect to the femur. In contrast, it has been shown that excessive quadriceps contractions during landing or cutting maneuvers can be harmful to the ACL (2,6). Because the insertion of the quadriceps is the tibial tuberosity, excessive contraction, or shortening, of the quadriceps muscles produces anterior translation of the knee joint which puts greater forces on the ACL and highly increases risks for injury (6). Therefore, the combination of excessive quadriceps contraction and ineffectively timed muscular activation of the hamstrings compresses the knee joint, translates the tibia anteriorly, and opens the medial joint resulting in direct forces to the ACL (11). When the muscles fire in inefficient patterns as explained above, more of the forces are directly applied to the ACL as opposed to the surround muscle tissues and tendons (11). The ACL ligamentous tissue is not designed to withstand such direct impact and the excessive forces compromise its stability and integrity; resulting in high incidence of injury (11).

This study will focus on a female population, as females have a high incidence of ACL injury in volleyball (7). One contributing factor to the prevalence of female ACL injuries is a heightened dependence on the quadriceps muscles to stabilize the knee during landing, or decelerating tasks (14). Hamstring muscle contraction is protective to the ACL while excessive quadriceps muscle contraction may be harmful (2). Therefore, the ratio and timing of quadriceps to hamstring muscle activation seems to be the most important relationship regarding serious knee injury (2,11,14,20). Since females tend to depend on excessive quadriceps contraction in addition to slow and decreased hamstring contraction during landing, the risk for ACL injuries is greatly heightened when compared to their male counterparts (2,11,14). As a result, both players and coaches are highly interested in prevention of ACL injuries specifically as it related to the female population (22). It is important to understand if the use of ankle braces is beneficial or detrimental to the risk of ACL injury of female volleyball players based off the timing of muscle activation between the hamstring and quadricep muscles alone.

As mentioned above many sports teams, and specifically volleyball teams, require their athletes to wear ankle braces to prevent injury to the ankle joint (18). However, few research studies have looked at the effects that wearing ankle braces has on muscular activation of the upper leg as it related to risk for ACL injury (5,17). A study by Romkes & Schweizer (2015) found that the use of external ankle support may influence lower body gait kinematics and temporal-spatial parameters. Their study found that external ankle support resulted in decreased hip extension, greater hip flexion and abduction in the terminal swing, and greater knee flexion (19). This change in joint kinematics suggests that muscle activation is significantly altered as a result of restricting range of motion. In addition, a study conducted in 2014 demonstrated overall decreased muscle activation during the ankle bracing trial, as compared to the non-bracing trial (8). In their study, they measured EMG activity of six lower extremity muscles during standard ankle rehabilitation exercises (8). They demonstrated decreases muscle activation during the bracing trials; especially that of the rectus femoris and gluteus medius during the star excursion balance task (8). In a similar study, ankle bracing resulted in decreased muscle activation of the peroneus longus, as well as decreased and slower muscle activation of the anterior tibialis, rectus femoris and gluteus medius during walking (4). Since a large majority of female volleyball players wear ankle braces on a daily basis, it is crucial to understand if and how the use of ankle braces alter muscular activation of the leg during landing tasks commonly seen in volleyball.

The purpose of this study is to determine if the use of Active Ankle T1™ ankle braces affects the timing of muscular activation of the upper leg, specifically the biceps femoris, and vastus medialis, in female varsity volleyball athletes during a landing task. The vastus medialis was selected for analysis because it is in full contraction when the knee is fully extended, and therefore has a more prominent role in knee extension torque relative to the other quadricep muscles (15). Aside from anterior shear forces, a combination of valgus force and internal rotation has been noted to put excessive loading on the ACL (21). The biceps femoris is in the lateral, posterior aspect of the thigh and in a study conducted by Fujii, Sato, and Takahira (2012) was noted to have lower activation levels at peak internal rotation. Because of it's ability to externally rotate the knee, as well as oppose anterior translation, it is one of the ACL's preventative muscles, and therefore an area of focus for the study at hand. Since some literature has suggested that wearing ankle braces alters the biomechanics and kinematics of the leg, we hypothesize that the use of these Active Ankle T1™ ankle braces will affect the timing of muscular activation of the upper leg. The results of this study could help coaches, athletic trainers, and players better understand the potential risks or further benefits of wearing ankle braces in regards to serious knee injuries.

METHODS

Participants

Once the Lakehead University School of Kinesiology Ethics Committee approved this study, 14 healthy female varsity volleyball players on the Lakehead Women's Volleyball team were recruited to participate in this study. These participants were between the ages of 18 and 22 years of age, with a mean height of 174.62cm and mean mass of 68.2Kg. They were recruited using convenience and purposive sampling. Given the limited time frame, the sample size was not determined based off a power analysis, but by recruiting as many eligible participants as possible in the allotted time. To participate in the study, each participant was required to be healthy and have no acute lower body injuries within the last 6 months. Participants were excluded from the study if they were currently not cleared to play by the team's physician. Previous injuries, and surgeries were not part of the exclusion criteria as long as the participant was considered fully healed by the team physician for a minimum of 6 months.

Protocol

A Delsys™ Bagnoli-2 Electromyography (EMG) System was used to collect and analyze data. Two Delsys™ electrode sensors were applied to the left leg and used to obtain EMG activity and timing of the vastus medialis and the biceps femoris muscles during a one-legged landing task. The raw EMG data was first rectified and then filtered using a lowpass filter at 10Hz. Jump height was measured using a Vertec™ device to motivate participants to jump higher. Because the Vertec™ provides a visual and numerical representation of jump height, the first jump served as a rough benchmark for that participant's maximum vertical jump height. The participant then intuitively strived to meet, or surpass, that benchmark and therefore continued to exert maximal effort.

Each participant read and signed various forms including the participant recruitment letter, informed consent form, Physical Activities Readiness Questionnaire (PAR-Q), and an acute injury screening questionnaire. Once the methodology and purpose was fully explained to the participant, they randomly selected which condition (brace or no brace) they would complete first by selecting one of two playing cards. If they selected a black card, they were placed in the bracing condition; a red card indicated the non-bracing condition. This random selection process was counterbalanced to ensure there was an equal number of participants starting in each condition. If the participant selected the bracing condition as the first condition, they were instructed to apply the ankle brace to their left ankle as per the manufacturer's instructions. A researcher ensured that the ankle brace was correctly applied. As mentioned above, data was collected on the left leg only, as all of the participants use their right hand to hit, and as such typically land on their left leg.

After the condition (brace or no brace) had been assigned and correctly applied, a warm up was conducted. The warm up was run by a researcher and included a cardiovascular component, as well as dynamic stretching of the lower and upper extremity. The warm up began with a cardiovascular component performed on the Monark™ Ergomedic 828 E bike. Each athlete was required to bike for five minutes at a resistance of approximately two percent of their body weight. Once the five-minute cardiovascular component was completed, a dynamic stretch was led by one of the researchers. Each stretch was to be performed over a 20m distance. The stretches included the following: side shuffles, karaoke, skips, high knees, butt kicks, hip flexor rotations, lunges, and side lunges. All the movements were familiar to the participants as they are also incorporated into their daily practice routine.

Once the warm up was complete, a researcher verbally explained the procedure and provided a visual demonstration for the participant, emphasizing that a two-step approach was to be used to initiate the vertical jump. Knowing this, the participant determined an appropriate starting distance from the Vertec™ device. Once the starting position was established, the participant was instructed to take a step with their right foot and another step with their left foot, followed by a two foot take off into a vertical jump. Researchers emphasized a single-legged landing on the left foot. Although a three-step approach is typically used in volleyball, a two-step approach was used for the purpose of this study in order to account for the condensed lab space available. Once the participant was aware of the procedure, they performed a task-specific warm-up (pre-test). During this pre-test, the participant familiarized themselves with the procedure. The participant was allotted two to four pre-test trials to ensure they were comfortable and familiar with what was being asked of them. After the pre-test trials, participants rested for five minutes during which the Delsys™ electrodes which were attached to five-foot-long cords that were applied to their left leg on their vastus medialis and biceps femoris. Throughout the duration of the jump the cords were held loosely by one of the researchers to prevent tripping. As the athlete moved forward, the researcher also moved forward; conscious of keeping the wires out of the athlete's way, and keeping the wire slack, so not to rip the electrode off.

The participants were asked to lie prone on a table to allow a researcher to apply the Delsys™ electrode to their biceps femoris muscle. Rubbing alcohol was used to clean the areas in which the electrodes were placed. The electrode on the biceps femoris was placed on the center of the posterior thigh while the participant flexed their knee to approximately 45 degrees. The participants were then asked to turn onto their backs and sit at the edge of the mat. The Delsys™ electrode on the vastus medialis was placed on the distal muscle belly approximately 5cm from the patella while the participant extended their knee. Refer to Figure 2 for placement.

Once the Delsys™ electrodes were applied, the participant was asked to perform three trials in the first condition. Timing of the vastus medialis and biceps femoris muscle activation was measured and recorded using LabChart™ software while the participant followed the same procedure used during the pretest. Three trials were completed, with 30 seconds of rest between each trial. During the rest period, the Vertec™ was reset and jump height was recorded. Five minutes of rest was allowed between conditions. During this time, the condition was changed. If the bracing condition was completed first, the brace was removed. If the non-bracing condition was completed first, the brace was then applied. Once the new condition was correctly applied, the participants completed three trials following the same procedure as the first condition.

Statistical Analysis

The difference in timing of the muscular activation was calculated for each trial by taking the time in which the biceps femoris activated and subtracting it from the time in which the vastus medialis activated. A positive result meant the hamstring muscle activated, first which is protective of the ACL. A negative result meant the quadriceps muscle activated first, which can be harmful to the ACL. The mean difference in timing of the muscular activation of the biceps femoris and vastus medialis muscles were calculated for both conditions for each participant. Using these findings, a repeated measures t-test was used to determine if there was a significant difference between the timing in the braced condition and the non-braced condition. The independent variable was the condition: brace or no brace. The dependent variable was the difference in timing in muscular activation of the vastus medialis and the biceps femoris. The rejection criteria was set with an alpha level > 0.05.

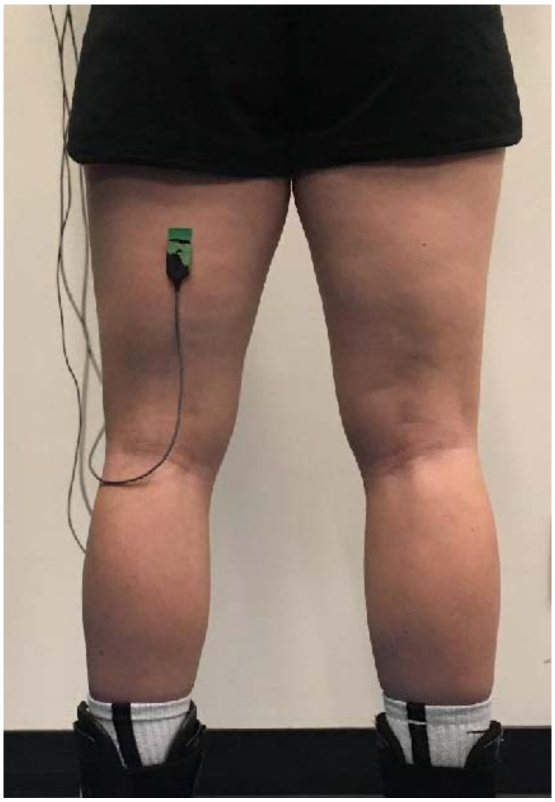

Figure 1. EMG placement for Biceps Femoris

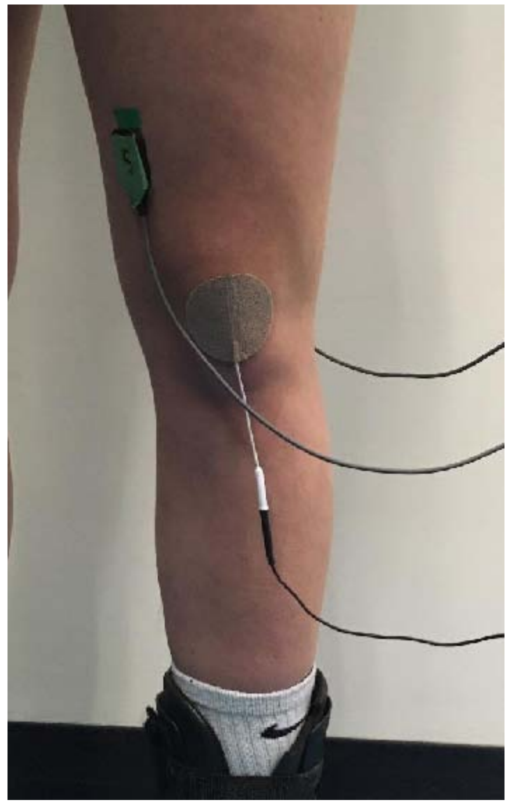

Figure 2. EMG placement for Vastus Medialis

RESULTS

The repeated measures t-test showed that there were no significant differences (p=0.615) in the timing of muscular activation between the braced trials and non-braced trials. The one-way ANOVA also showed there was no significant differences (p=0.664) in timing of muscular activation between the braced trials and non-braced trials. A power analysis (mean brace=.026643, mean no-brace=.037810) revealed a power of 0.30. Therefore, because the power was less than 0.80 it is not surprising that no significant difference was demonstrated by these psychometric measures. Jump height was recorded using a Vertec™ device. There was almost no difference in jump height between the two conditions. Overall, when participants wore the brace, they jumped an average of 0.012in higher than when they were not wearing the brace. Note that all trials were completed with a single leg landing on the left leg. Table 1 (below) displays the mean differences and standard deviation for each condition for each of the 3 trials of all 14 participants (totally of 42 trials). Figure 3 illustrates the mean differences in timing of muscular activation for each participant in the brace condition and non-braced condition. Any positive numbers represent the biceps femoris activating first while any negative numbers represent the vastus medialis activating first.

Table 1. Group mean and standard deviation between brace and no brace conditions for all 42 trials.

Group Mean - No Brace Condition	Group Mean - Brace Condition	Standard Deviation - No Brace Condition	Standard Deviation - Brace Condition
0.026642857	0.0388095	0.0562	0.0767

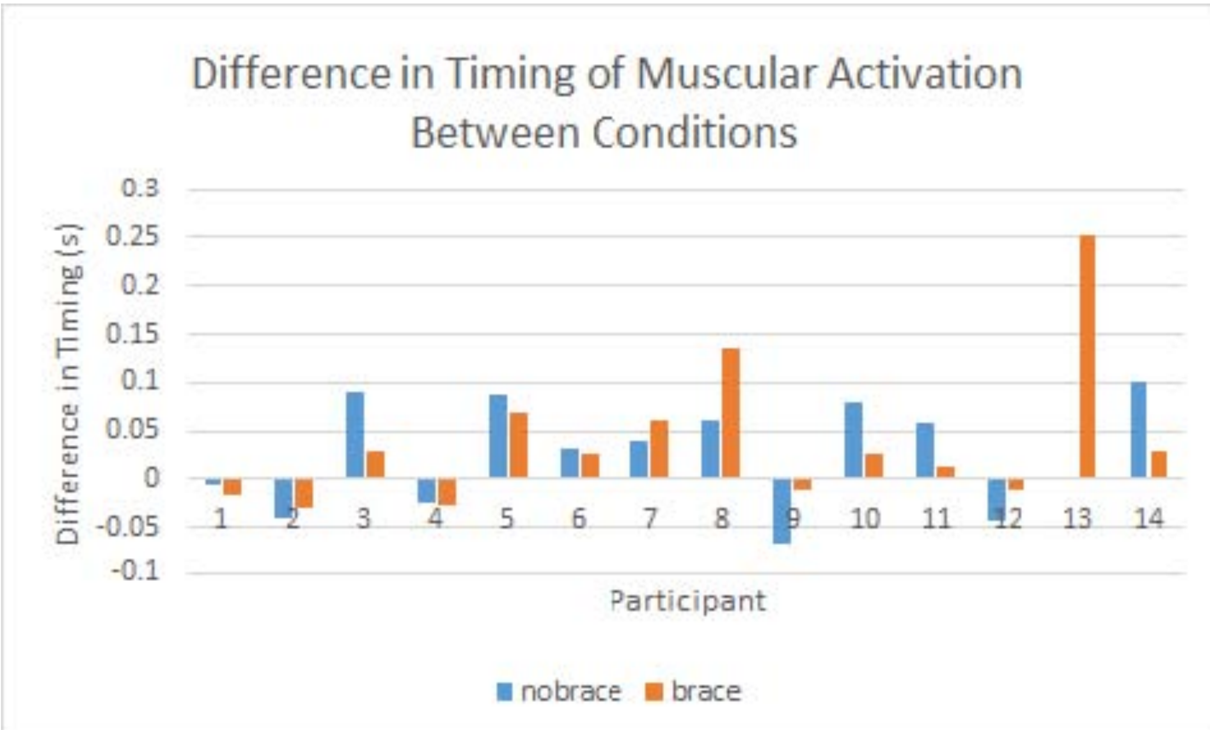

Figure 3. Difference in Timing of Muscular Activation between Brace and No Brace Condition.

DISCUSSION

This study examined the effect of Active Ankle T1™ ankle braces on the timing of muscular activation of the upper leg in female volleyball athletes during a one-legged landing task. The results showed there was no significant difference in the timing of muscular activation in the upper leg between braced trials and non-braced trials.

Few research studies have looked at the effect that wearing ankle braces has on the timing of muscular activation of the leg in terms of risk for ACL injury. Timing of muscular activation in the upper leg has been strongly associated with risk for developing an ACL related injury. As discussed above, many studies have concluded that early hamstring activation is protective to the ACL as it decreases anterior translation of the tibia and, as a result, protects the ACL from excessive tension (2,6,14, 20). It is interesting however, how the majority (64%) of participants activated their biceps femoris prior to the vastus medialis regardless of the bracing condition. Based on the literature review, early quadriceps activation was expected (14). One speculation as to why this was not true for this population is that they all perform an extensive warm up that is targeted toward ACL injury prevention every day at their volleyball practice. The warm up focuses on strengthening the posterior compartments of the thigh and it is possible that the overall early hamstring activation in this study is a result of this training regime.

The use of external ankle support has been shown to alter baseline gait kinematic and muscle activation patterns in some studies (8,19). One reason for the current study was to examine whether these changes effect the timing of muscular activation in the upper leg and discuss this in relation to risk of ACL injury. The results indicate that wearing Active Ankle T1 ™ brace does not appear to influence the timing of muscular activation in the upper leg. This would infer that wearing these braces should not increase the risk of an ACL related injury based solely on the timing of muscular activation. However, there are many factors that may influence risk of ACL injury such as range of motion, forces, sport-specific movements ect. These factors were not examined in the current study, therefore risk of ACL injury due to any factor other than muscular activation can not be speculated based on the results.

Nevertheless, the results of this study are important to athletes, coaches, and athletic trainers alike. Knowing that wearing an Active Ankle T1 ™ brace does not appear to affect the timing of muscular activation of the upper leg may encourage more athletes to wear the brace to prevent ankle injuries. Furthermore, the findings suggest that athletes wearing the brace do not appear to be at an increased risk for ACL injury due to timing of muscular activation. This may encourage coaches and trainers to advise their athletes to wear the Active Ankle T1™ braces with greater confidence. However, due to the small power and non-significant results found, the primary application of this paper is not to provide direct clinical applications. Rather, to our knowledge, this is the first study conducted looking at how external ankle bracing may affect risk of serious knee injury based upon timing of muscular activation, and it can be used to build upon by future researchers and larger sample sizes.

Limitations: the current study include the different types of ankle braces that the participants are accustomed to wearing. Although all participants wear an ankle brace during their daily volleyball training, not everyone is used to wearing the Active Ankle T1™ brace. It is possible that the participants that are accustomed to the Active Ankle T1™ would have reacted differently than those who are accustomed to wearing a different type of brace such as a soft prophylactic ankle brace. Individual styles of approaching a vertical jump also differed among the participants. Practice trials were required in order to try to control for this, however, three practice trials do not counter the well-developed habits of the participants. As a result, some found the task easier than others, potentially altering the data.

The lab and equipment used also had limitations. Throughout our data collection we shared the lab with a group who was doing concussion testing. The environment was occasionally quite loud, potentially adding noise and interference to the EMG signals. Wired EMG electrodes meant that the participants had to be conscious of where the wires were while performing the jump, potentially altering their concentration and technique. Lastly, the relatively small sample size used increases the risk of type II errors, and future research should include a larger recruitment group.

In our study of healthy, female volleyball players the timing of muscular activation between the biceps femoris and the vastus medialis was not significantly affected by the use of an Active Ankle T1™ brace. Our findings suggest that athletes who use the Active Ankle T1™ brace do not appear to be at an increased risk for ACL injury. This is important for coaches, athletic trainers, and athletes who wear ankle braces, specifically female volleyball players.

ACKNOWLEDGEMENTS

We would like to thank Dr. Carlos Zerpa and Zachariah Henderson for their knowledge, time, and resources throughout this research process.

REFERENCES

1. Agel J, Rockwood T, Klossner D. Collegiate ACL injury rates across 15 sports: National collegiate athletic association injury surveillance system data update (2004-2005 through 2012-2013). Clin J Sport Med, 26(6): 518-523, 2016.

2. Ambegaonkar JP, Shultz SJ, Perrin DH, Schmitz RJ, Ackerman TA, Schulz MR. Lower body stiffness and muscle activity differences between female dancers and basketball players during drop jumps. Sports Health: A Multidisciplinary Approach 3(1): 89-96, 2011.

3. Baratta R, Solomonow M, Zhou B, Leston D, Chuinard R, D'Amrosia R. Muscular coactivation: The role of the antagonist musculature in maintaining knee stability. Am J Sports Med, 16(2): 113-122, 1988.

4. Barlow G, Donovan L, Hart JM, Hertel, J. Effect of lace-up ankle braces on electromyography measures during walking in adults with chronic ankle instability. Phys Ther Sport, 16(1): 16-21, 2015.

5. Cordova M, Cardona C, Ingersoll C, Sandrey M. Long-term ankle brace use does not affect peroneus longus muscle latency during sudden inversion in normal subjects. J Athl Train, 35(4): 407–411, 2000.

6. DeMorat G, Weinhold P, Blackburn T, Chudik S, Garrett W. Aggressive quadriceps loading can induce noncontact anterior cruciate ligament injury. Med Sci Sports Exerc, 32(2): 477-783, 2004.

7. Doherty C, Delahaunt E, Caulfield B, Hertel J, Ryan J, Bleakley C. The incidence and prevalence of ankle sprain injury: A systemic review and meta analysis of prospective epidemiological studies. Sports Med, 44(1): 123-40, 2014.

8. Feger MA, Donovan L, Hart JM, Hertel J. Effect of ankle bracing on lower extremity muscle activation during functional exercises in participants with chronic ankle instability. Int J Sports Phys Ther, 9(4): 476-487, 2014.

9. Fujii M, Sato H, Takahira N. Muscle activity response to external moment during single-leg drop landing in young basketball players: The importance of biceps femoris in reducing internal rotation of knee during landing. J Sports Sci Med, 11(2): 255-259, 2012.

10. Hertel J. Functional anatomy, pathomechanics, and pathophysiology of lateral ankle instability. J Athl Train, 37(4): 364–375, 2002.

11. Hewett TE, Zazulak BT, Myer GD, Ford KR. A review of electromyographic activation levels, timing differences, and increased anterior cruciate ligament injury incidence in female athletes. Br J Sports Med, 39(6): 347-350, 2005.

12. Kewwan K, Kyoungkyu J. Comparison of knee and ankle joint angles and ground reaction force according to functional differences during single-leg drop landing. J Phys Ther Sci, 28(4): 1150-1154, 2016.

13. Li G, Rudy T, Sakane M, Kanamori A, Ma C, Woo S. The importance of quadriceps and hamstring muscle loading on knee kinematics and in-situ forces in the ACL. J Biomech, 32(4): 395-400, 1999.

14. Lim B, Lee Y, Kim J, An K, Yoo J, Kwon Y. Effects of sports injury prevention training on the biomechanical risk factors of anterior cruciate ligament injury in highs school female basketball players. Am J Sports Med, 37(9): 1728-1734, 2009.

15. Marcon M, Ciritsis B, Laux C, Nanz D, Fischer MA, Andreisek G, Ulbrich EJ. Quantitative and qualitative MR□imaging assessment of vastus medialis muscle volume loss in asymptomatic patients after anterior cruciate ligament reconstruction. J Magn Reson Imaging, 42(2): 515-525, 2015.

16. Oliphant JG, Drawbert JP. Gender differences in anterior cruciate ligament injury rates in Wisconsin intercollegiate basketball. J Athl Train, 31(3): 245-247, 1996.

17. Ota S, Ueda M, Aimoto K, Suzuki Y, Sigward S. Acute influence of restricted ankle dorsiflexion angle on knee joint mechanics during gait. The Knee, 21669-675, 2014.

18. Reeser J, Bahr R. Principles of prevention and treatment of common volleyball injuries. FIVB Medical Commission, 2011.

19. Romkes J, Schweizer K. Full length article: Immediate effects of unilateral restricted ankle motion on gait kinematics in healthy subject. Gait Posture, 41835-840, 2015.

20. Serpell B, Scarvell J, Pickering M, Ball N, Newman P, Perriman D, Smith P. Medial and lateral hamstrings and quadriceps co-activation affects knee joint kinematics and ACL elongation: A pilot study. BMC Musculoskelet Disord, (16): 1-11, 2015.

21. Shimokochi Y, Shultz SJ. Mechanisms of noncontact anterior cruciate ligament injury. J Athl Train, 43(4): 396–408, 2008.

22. Wakeham TT. Knee injuries: The major problem of female athletes and how to prevent them. Coach & Athletic Director, 73(7): 64-66;70, 2004.

23. Zoch C, Fialka-Moser V, Quittan M. Rehabilitation of ligamentous ankle injuries: A review of recent studies. Br J Sports Med, 37(4): 291–295, 2003.