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Prevention of Ankle Sprains

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Statement of the Problem

According to the National Collegiate Athletic Association (NCAA), more than 460,000 college athletes play a total of 24 sports. Results from Indiana University showed that 67% of former players claim they suffered a major injury while competing on the collegiate level (Simon & Docherty, 2014, p. 427). Half of college athletes said they had chronic injuries throughout college while 40% said they were diagnosed with osteoarthritis after their career (Simon & Docherty, 2014, p. 426-427). Of these total injuries, ankle injuries are the most common injury in sports, whether that be a sprain or a fracture (Kaminski et al., 2013; McCriskin, Cameron, Orr, & Waterman, 2015; Osborne & Rizzo, 2003; McNerney, 2015; Wester, Jespersen, Nielsen, & Neumann, 1996; Janssen, Mechelen, & Verhagen, 2011; Hupperets, Verhagen, & Mechelen, 2008; Os et al, 2005; Dolan, 2009). Data from the National Electronic Injury Surveillance System for all ankle sprains showed that over a five year period, 49.3% of ankle sprains were caused by sports (McCriskin et al, 2015, p. 164). Of these ankle sprains, basketball was responsible for the most with 41.1%, followed by football with 9.3% and soccer with 7.9% (McCriskin et al, 2015, p. 164). After sustaining an initial injury, the reinjury rate of a lateral ankle sprain can be as high as 80% in athletes (Denegar & Miller, 2002, p. 430). The more injuries one has to the same ankle results in the increased likelihood of chronic conditions such as osteoarthritis. With multiple injuries, athletes begin to develop what is known as ankle instability.

Ankle instability is weakness of the ankles due to previous injuries. Injuries are classified into three categories; lateral, medial, and syndesmotic, in which lateral ankle sprains account for 85% of all ankle sprains (McCriskin et al, 2015, p. 162). The three affected areas are the anterior talofibular ligament, the calcaneofibular ligament, and the posterior talofibular

ligament (McCriskin et al, 2015, p. 162). Sprains are classified into three degrees with 1st degree being the less severe and 3rd degree being the most severe.

Ankle injuries can greatly affect the outcome of the season if players do not take the correct preventive measures to reduce the risk of injury. The result of missed or undertreated ankle instability is documented with chronic instability resulting in as many as 60% of patients (McCriskin et al, 2015, p. 164). The exact timeline for recovery differs from person to person. Mechanical stability may not be present until 6-12 weeks after an injury whereas subjective ankle instability was present for even longer and could last up to a year after the injury (Hubbard & Hicks-Little, 2008, p. 528). Once the ankle is initially injured, it is very crucial to take preventive measures to decrease the risk of multiple injuries.

The problem of ankle sprains is relevant to the researcher because of his occupation as a basketball coach at the collegiate level. In order to be a successful coach, one must have skilled, healthy players. These lateral injuries to the ankle are common in the sport of basketball. This systematic review is designed to investigate the most effective preventive technique between a combination of resistance training and balance/coordination training compared/coupled with bracing/taping of the ankles to prevent recurrent ankle sprains in athletes. The approach of a systematic review is relevant because of the overwhelming techniques and training programs that are utilized. There is extensive research that has been conducted on these topics but has been limited in reviewing it in a holistic perspective.

Research on the most effective preventive techniques were searched using multiple databases and many search terms. Articles were then reviewed to determine what the literature had so say about the various topics and common practices. This information is presented in the next section, and discusses training programs and the use of ankle supports as the most effective

techniques. Since the search showed the variety and diversity in preventive techniques, this sparked the need for a more specific search in order to determine what could be best practice. PubMed was used to acquire articles from one specific database. These articles were reviewed in whole with the results of the articles summarized. Following that is a detailed summary, tying all of the articles together, followed by a practical application of the research.

Review of Literature

The competing areas are resistance and balance/coordination training as well as the use of ankle supports such as bracing and taping. Each one will be discussed in specific to allow the reader to understand how/why the systematic review was conducted.

Resistance and Balance/Coordination Training

Training programs have been shown to greatly decrease the risk of sustaining an ankle injury. Strength deficits of leg muscles and hip extensors and abductors are present in patients with ankle instability (Kaminski et al., 2013). Therefore, it has been shown that neuromuscular training programs reduce the risk of ankle sprains (Kaminski et al., 2013). These multi-intervention injury prevention programs should last at least three months and focus on balance and neuromuscular control (Kaminski et al, 2013, p. 530). Studies have also found that balance control training resulted in a 20%-60% risk reduction for lateral ankle sprains (McCriskin et al, 2015, p. 168; McKeon & Hertel, 2008, p. 306). Some training programs use platforms such as an ankle disk. In a study involving a control group and a group engaging in coordination training with an ankle disk, 17% of players in the control group suffered an ankle injury whereas only 5% suffered an injury after completing the coordination program (Troop, Askling, & Gillquist, 1985, p. 260-261). For optimal results, it's suggested that athletes would perform these exercises at least three times per week throughout a competitive season (McKeon & Hertel, 2008). Their

results however, only showed that this program provided preventive effects in athletes with a history of ankle sprains (McKeon & Hertel, 2008, p. 306). There is a multitude of research on resistance and balance/coordination training. These topics are broad and diverse but similar in many aspects. The following paragraphs will help simplify/inform the reader on each topic.

Resistance training is a technique athletes use to gain strength in various areas. Most resistance training programs for athletes involve weight training in order to gain muscle mass. As a whole, this type of resistance training will not greatly affect the muscles used to prevent ankle injuries. However, there are a few muscles that resistance training can strengthen to aid in the decreased risk of sustaining ankle injuries. The most common muscles in the ankle that affect its strength are the evertor muscles (Holmes & Delahunt, 2009; Han & Ricard, 2011). The 3 muscles that evert the ankle are the peroneus longus, brevis, and tertius. The peroneus longus and brevis assist in plantar flexion while the peroneus tertius assists in dorsiflexion. A major muscle outside of the ankle that affects lower extremities are the hip muscles (Snyder et al, 2009). Hip stability and strength aid in proper running mechanics (Friel et al, 2006). In turn, poor mechanics can increase the risk of occurring an ankle sprain (Friel et al, 2006). Also, hip range of motion directly affects plantar function which in turn affects the evertor muscles (Friel et al, 2006).

Resistance training in this systematic review is going to refer to any type of exercise that adds the factor of resistance in it. Types of resistance are, but not limited to, elastic/resistant tubing (Holmes & Delahunt, 2009; Han & Ricard, 2011; Borreani et al, 2014), cable column system (Snyder et al, 2009), or free weights (Osborne & Rizzo, 2003). To clarify resistance training from balance training and coordination training, an exercises may be considered

balance/coordination training but when one adds in the factor of resistance, it become a resistance training exercise.

The literature did not have a clear consensus on the effectiveness of resistance training to directly prevent ankle injuries. There are many factors that are involved in resistance training as well as different beneficial outcomes. The two beneficial outcomes are muscle control/activation and muscle strength. Three common muscles that help control movement of the ankle are the peroneus longus (evertor muscles), tibialis anterior, and soleus. In a study comparing the use of elastic tubing versus no tubing, the highest activation group occurred when the subjects used elastic tubing (Borreani et al, 2014, p. 407). This is able to show that resistance was beneficial when compared to subjects completing the same exercises without resistance. Likewise, it was reported that significant improvements in postural balance/control of the ankle occurred after completing four weeks of exercises using elastic or resistant tubing (Han & Ricard, 2011, p. 158). The research thus far has shown the effectiveness of resistance training on muscle control.

Research on effectiveness of resistance training to increase muscle strength was not as significant. There has been significant evidence showing the effectiveness of resistance training on strengthening the hip. By means of a cable column system, it was conclude that this type of exercise strengthens the hip abductors and external rotators (Snyder et al, 2009). These exercises can be productive in the prevention of lower extremity injuries. However, the study does not explicitly state what lower extremities it could benefit, therefore not being able to conclude its significance in preventing ankle injuries.

In terms of ankle muscle strength, strength deficits have been thought of as predictors of ankle injuries. Han and Ricard (2011) conducted a study where they wanted to determine the effectiveness of an elastic-tubing exercise program on ankle-evertor strength. They looked at

subjects with and without a history of ankle sprains. Their results showed that after the four week training period, elastic tubing exercises did not change the subject's one rep max in ankle-evertor strength (Han & Richard, 2011, p. 170). However, they stated that there were findings that it lead to improved muscle control.

The other two training programs that were found were balance training and coordination training. These two programs are not the same but can be very similar. Balance training involves exercises that will help athletes distribute weight evenly and therefore reduce the risk of falling by means of "rolling" the ankles. Coordination training is a little broader and involves exercises that improve balance, the ability to move body parts together, and timing. Due to this overlap, the author will not distinguish between the two when researching different exercises and techniques. Also, the author will use the terms balance and coordination interchangeably when referring to the training. Studies have shown that coordination training has no effect on the prevention of first time ankle sprains (Kerkhoffs et al, 2012, p. 858; Janssen et al, 2011, p. 2; McKeon & Hertel, 2008, p. 308; Hupperets et al, 2008, p. 2). However, it does prevent the recurrence of ankle injuries in athletes post injury (Kerkhoffs et al, 2012, p. 858; Ross et al, 2007, p. 2; McKeon & Hertel, 2008, p. 308). The length of the program can have an effect on the outcome of success. There was a 49% reduction in the risk of ankle sprains in volleyball players during their second year of coordination training compared to a 21% reduction in the first year (McKeon & Hertel, 2008, p. 312). However, clinically it is proven that six to eight weeks of coordination training reduces the risk of recurrent ankle injuries (McKeon & Hertel, 2008, p. 314; Hupperets et al, 2008, p. 5).

After an athlete suffers an ankle sprain, some of their balance and coordination is lost due to the weakening ankle. There is a specific process that starts with examination of the injured

ankle and leads all the way up to continuing normal exercise functions. To determine the amount of balance that is lost, athletes will complete various tests such as a plate balance test (Osborne & Rizzo, 2003, p. 1147), Romberg's balance test (McNerney, 2015, p. 138), and others. The first stage after diagnosis is rehab to strengthen back the injured ankle. This can often times include resistance training exercises. After the ankle is strengthened, the athlete can move into coordination training. First, the athlete should perform proprioceptive exercises (Osborne & Rizzo, 2003; Miller & Raikin, 2014; McNerney, 2015). Among 65 male soccer players with previous ankle sprains, there was an 80% decrease in ankle sprains over a six month period compared to a control group (Osborne & Rizzo, 2003, p. 1147). The goal of proprioceptive exercises is to restore dynamic ankle balance and stability. There are many apparatuses used such as an ankle disk/wobble board, a single leg stance on uneven surfaces such as a BOSU (Both Sides Up) ball, and others. It has been shown that eight weeks of ankle disk training will alter ankle muscle onset latencies that may act to improve dynamic ankle stability (Osborne & Rizzo, 2003, p. 1148). Also, it was concluded that wobble board training was effective in reducing the number of recurrent injuries (Wester et al, 1996, p. 334).

The next and final phase of the ankle prevention consists of functional exercises and sport-specific drills (Osborne & Rizzo, 2003; Miller & Raikin, 2014; McNerney, 2015). The goal here is to continue restoring balance as well as dynamic strength and power. Some common methods of this are jogging, running, double-leg jumping, single-leg hopping, jumping rope, and lateral cutting drills. These should not occur until the athlete has no pain, full range of motion, and around 80% strength back in the injured ankle (Osborne & Rizzo, 2003, p. 1148). Athletes should start with low-level intensity and difficulty and progress if they are pain free and without swelling (Osborne & Rizzo, 2003, p. 1148).

Ankle Supports (Bracing/Taping)

Bracing or taping to prevent ankle injuries is also a very common technique used by athletes. Studies have demonstrated that the use of braces and tape have reduced the risk of recurrent ankle injuries in those active in sports (Kerkhoffs et al, 2012, p. 858; Osborne & Rizzo, 2003, p. 1146). It is important to note that their findings only suggested a reduction in risk of athletes with a history of ankle sprains. Both taping and bracing should only be used as means of prevention from multiple ankle sprains for at least six months post injury (Osborne & Rizzo, 2003, p. 1146). Bracing was found to be more effective in limiting ankle motion compared to taping. Taping was shown to loosen and lose most of its restrictive support 20 minutes after beginning exercise (Osborne & Rizzo, 2003, p. 1146). It is recommended that athletes with a history of previous ankles sprains should wear ankle supports for all practices and games (Kaminski et al., 2013, p. 530). However, it is important to keep in mind that ankle supports were not found to improve athletic performance and in some situations were found to impair athletic performance (Osborne & Rizzo, 2003, p. 1146).

Bracing and taping attempt to accomplish the same task but they are different in some ways. They both warrant some positive and negative outcomes. The use of taping has shown to have no effect on jumping movements or balance in athletes (Evans & Clough, 2012). It was actually shown that taping the ankles increased the loading rate, which in turn can cause more injuries (Evans & Clough, 2012). Due to that, it is suggested that proper landing technique should be taught to athletes who tape their ankles. However, studies have shown that taping improves the stability of the ankle joint in both planned and unplanned movements (Evans & Clough, 2012, p. 157). One study comparing taping and bracing, showed that neither method had more effect than the other (Evans & Clough, 2012, p. 157). Other research has shown that

those athletes with previous ankle sprains are three times more likely to suffer another ankle injury by not wearing ankle brace (Janssen, Mechelen, & Verhagen, 2014, p. 1238). However, it was noted that although it can reduce injury, bracing can have negative effects on the knees (Feger et al, 2014). In comparing the two, there was no distinction between one being more beneficial than the other on reducing ankle injuries. However, when one is performing resistance/balance/coordination training exercises, wearing ankle supports was shown to be counterproductive to the benefits of these exercises (Feger et al, 2014, p. 484).

Research Methodology

Articles were found through the use of the web based system PubMed. The base search was “prevention of ankle injuries”. Secondary search terms that were used were: “balance training”, “coordination training”, “neuromuscular training”, “ankle bracing”, and “ankle taping”. One tertiary search term that was used with “neuromuscular training” was “sports”. The articles pooled were all within ten years old with the subjects as humans. All of the articles were reviewed by the author by means of reading the abstract. After the review process, 31 articles were deemed relevant for this particular study. These 31 articles were reviewed in their entirety before any results were recorded or analysis made. After this reviewing process, the author concluded that 14 articles were relevant to this study. Of the 14 articles, seven were used in the training section as well as seven used under the ankle support section. The author then went back through the articles and recorded the results. A brief synopsis of the procedure of each article was included for all articles to give the reader a sense of the articles that were reviewed for the study. No statistical tool was used since this was a written systematic review.

This study only summarizes the article and does not collect data based on the articles. This is the main limitation to this study. Conducting this study in a way that would give

statistical data to compare would have enhanced the study. Also, the study could have reviewed articles from many databases if there were more authors involved in the study. This in turn would have given the study a larger sample size and therefore more reliability.

Results/Findings

Below are the findings from the articles reviewed. They are sectioned between articles consisting of a training program and articles consisting of ankle supports, whether that be bracing or taping. There are a few articles that discussed both and compared training to ankle supports or included aspects of both within them. Also, these two groups, training and ankle support, are the main techniques but there are other additional techniques that these articles may use.

Resistance and Balance/Coordination Training

The first study examined the effect of coordination training as well as stochastic resonance (SR) on static postural stability with subjects suffering from FAI. The subjects were broken into three different groups. The three groups were the conventional coordination group, the SR stimulation coordination group, and the control group. Each group was comprised of ten subjects. The training groups performed coordination training five times per week for six weeks on their leg with FAI. The single leg tested was used as the measurement tool. The subjects were instructed to stand as motionless as possible for twenty seconds. Each participant performed one practice trial and three test trials. The mean of the three trials was used for the pre and post-test data. The results showed that the most effective technique to enhance postural stability was coordination training coupled with SR stimulation. This proved to be clinically

significant. In terms of comparing the control group with the coordination training group, there was no difference between the two in regards to postural stability (Ross et al, 2007).

The second study used an intervention of a single leg balanced training program on a foam stability pad. This treatment was applied to high school football players. The training program was used on football players who were labeled at risk. To be labeled at risk, that meant they had a high BMI (the study determined what high was) and/or had a history of ankle injuries. Four categories were used. The first was minimal risk, those with no previous ankle sprain and normal weight. The second was low risk, no previous ankle sprain with at risk for overweight OR previous ankle sprain and normal weight. The third group was moderate risk, no previous sprain plus being overweight OR previous ankle sprain plus being at risk for overweight. The fourth and last group, the high risk group, consisted of those with a previous sprain and were overweight. The participants performed balance training for five minutes on each leg, five days a week for four weeks in preseason and twice per week for nine weeks during the season. All subjects performed training on both legs. An ankle sprain was defined as an ankle injury requiring the player to miss at least one game or practice. Also, the researchers only examined non-contact ankle injuries, making the results more generalizable. There was one injury (3% prevalence) in the minimal risk group while a total of twelve (18% prevalence) ankle injuries in the low, moderate, and high risk groups (McHugh et al, 2007, p. 1291). In the post intervention groups, there was three ankle injuries in the minimal risk group (7%) relevance, and five injuries in the low, moderate, and high risk group (4% prevalence) (McHugh et al, 2007, p. 1291). From pre-intervention to post intervention, injuries per 1000 exposures for minimal, low, moderate, and high risk were 0.4 to 0.8, 1.2 to 0.8, 1.9 to 0.6, and 5.7 to 1.4 respectively. Overall, these ankle sprains were reduced by 77% (McHugh et al, 2007, p. 1291).

The third study determined the effectiveness of a balance training program using a wobble board. The participants were high school basketball players from 25 schools and were divided between the control and training group. Each subject completed a timed, dynamic, eyes-closed, unipedal balance test on an Airex Balance Pad, taking the maximum score of the three trials. The baseline assessment also consisted of a twenty meter shuttle run and a vertical jump test. The study period was one year and the basketball season was eighteen weeks long. The subjects completed the exercise program on a wobble board, roughly five times per week for twenty minutes before practice. The results showed a reduction in all injury, lower extremity injury and ankle sprain injuries. Further, they showed an injury incidence rate of 33.1 injuries per 100 (141 total injuries with 426 subjects) in the control group and 26.32 injuries per 100 (130 total injuries with 494) in the training group (Emery et al, 2007, p. 19). Of these injuries, the ankle sprain was the most common at 53.9% of the control group (76 injuries) and 47.7% of the training group (62 injuries) (Emery et al, 2007, p. 21). In terms of just ankle injuries, there was 17.8 injuries per 100 for the control group versus 12.6 injuries per 100 for the training group (Emery et al, 2007, p. 21).

The fourth study examined patients with FAI. The purpose was to see if a twelve week biomechanical ankle platform system (BAPS) training program was effective on improving postural stability and ankle stability in subjects with unilateral FAI. To test postural stability, subjects stood barefoot in a comfortable upright posture on a force platform. Their displacement was recorded and used to determine postural stability. To test ankle proprioception, subjects placed their barefoot into the Biodex ankle inversion/eversion apparatus. The apparatus then gave the numerical data for ankle proprioception. The training program was then conducted on the BAPS and lasted for roughly twenty minutes per segment. Subjects started on the lowest of

the five levels and progressed to the top accordingly. The results showed that 12-week BAPS training program produced significant improvements in ankle proprioception and postural stability (Lee & Lin, 2008).

The fifth article compared the effectiveness between a multiaxial (Dynadisc) and uniaxial (rocker board) unstable surfaces on affecting balance. Studies have shown that both are effective but no study has compared the two. The multiaxial Dynadisc is a flexible plastic pillow filled with air that allows for multiaxial ankle movement in all axes of the ankle. Muscles that stabilize the ankle to prevent any unwanted motion are the invertors, evertors, plantarflexors, and dorsiflexors. Examples of invertors and evertors are the tibialis posterior and the peroneal muscles. Examples of plantarflexors and dorsiflexors are the gastrocnemius and the tibialis anterior. The uniaxial rocker board is a flat wooden surface placed on a half cylinder or a dowel to allow uniaxial movement along 1 axis of the ankle. Therefore, the direction of training can be chosen by how one positions the foot. Subjects were split into three groups, control, rocker board, and Dynadisc group. Balance training occurred three times per week for four weeks. The Star Excursion Balance Test was used to test balance before, during, and after training. The results of the study showed that one form a training, multiaxial versus uniaxial, is not better than the other. Each improved balance and therefore will prevent ankle injuries, but one method was not shown to be superior to the other (Eisen et al, 2010).

The purpose of the sixth study was to determine the amount of muscle activity in a series of balance exercises with differing levels of stability and additional resistance to establish a progression based on the amount of muscle activation. Subjects took part in two sessions, familiarization and the data collection. The different exercises were performed on stable or unstable surfaces. The Exercise Station was the stable platform, the Rocker Board was unstable

in the anteroposterior direction, and the Exercise Ball and Soft Stability Trainer were unstable in a multiaxial direction. In addition to a variation of surfaces, exercises were performed with and without external resistance (Elastic Tubing). Each subject performed all twelve exercises and data was collected during the exercise. The greatest ankle muscle activation was achieved with exercises involving a unipedal stance. The results also showed that narrowing the base of the support produces greater activation in order to stabilize the body. In terms of resistance versus no resistance, the data is split. There was no significant difference in peroneus longus or tibialis anterior activation. However, there was significant difference in soleus activation (Borreani et al, 2014).

Study seven took German basketball players that played in the top seven basketball leagues in Germany. The aim of the study was to evaluate the effectiveness of a multistation proprioceptive exercise program for the prevention of ankle injuries. Subjects were divided into two groups, control and training, using a stratified randomization design defined by performance and sex. The control group did not complete any testing exercises but still continued with their normal workout routines (all subjects currently performing exercises similar to those in the experiment were excluded from the study). The training group performed the multistation proprioceptive program while still completing their normal training routines. A subgroup of both the control and training group was used to determine the effectiveness of the program on neuromuscular performance. A pressure distribution platform (Emed ST4) was used to measure postural sway in a single-limb stance. There was 21 injuries in the control group compared to only 7 injuries in the training group (Eils et al, 2010, p. 2102). Also shown in the results was subjects in the training group showed to have significantly more stable single limb stance, as well as specific changes in neuromuscular performance, specifically in proprioception and

postural sway. Overall, the study yielded a 35.5% reduction in ankle injuries (Eils et al, 2010, p. 2103).

Ankle Bracing/Taping

In the first study reviewed, the authors used volleyball players and compared bracing versus non bracing. The brace used in this study was the active ankle brace. The comparison group was taken from the NCAA's Injury Surveillance System (ISS). The NCAA ISS is a database that provides current and reliable data on injury trends in college athletes. They gather the injury data and this is made public on the internet. During a seven year observation within the collegiate team, a total of 43 athletes were included in the study, totaling an approximate number of 13,500 exposures. An exposure is looking at everyday as its own specific unit. The NCAA ISS determines injury rates per 1000 exposure. The NCAA ISS over that 7 year period was 0.98 per 1000 exposures (Pedowitz et al, 2008, p. 325). The injury rate of the test group was 0.07 per 1000 exposures with only one total ankle injury, proving to be statistically significant (Pedowitz et al, 2008, p. 325).

The second study measured time to stabilization (TTS). TTS is a measure of neuromuscular control that uses force plate measures to evaluate dynamic postural stability during a jump landing. Two ankle braces were tested to determine which one proved to be most effective. The three test groups were no brace, those wearing the Swede-O Universal Brace (AB) and those wearing the Active Ankle Brace (AA). The purpose was to see which brace would improve the athletes' dynamic stability after a jump using TTS. Between pre-testing/pre-fatigue and post-testing/post-fatigue, subjects completed different exercises. Jumps were then conducted anterior-posterior (AP) as well as medial-lateral (ML) for results. The results from pre-fatigue showed that for both AP and ML directions, all 3 groups yielded similar TTS scores. This means

that the use of bracing does not improve dynamic stability before fatigue sets in. In terms of post fatigue, ML TTS remained consistent but AP TTS increased for no brace and AA. These findings suggest that the AB is more effective in improving dynamic stability than no brace and AA after fatigue has set in (Shaw, Gribble, & Frye, 2008).

The third study examined ankle displacement and ankle velocity. The objective was to investigate the effect of an ankle brace in reducing ankle motions in terms of ankle displacement and ankle velocity during a simulated 23 degree sprain. Using a supination sprain simulator, each subject tested his/her ankle with and without the Air-Stirrup Ankle Brace. The results showed that the ankle brace reduced inversion angular displacement by 35% when comparing barefoot to a foot that applied the ankle brace (Tang et al, 2010, p. 824). The results also yielded that inversion angular velocity was reduced by 40% with the use of the semi rigid brace (Tang et al, 2010, p. 824).

The purpose of the fourth study was assess the effects of taping and bracing on functional balance, jumping performance, multi-joint coordination, and proprioception. The study compared taping and bracing against each other, as well as against barefoot. The brace worn in this study was Aircast A 60 Ankle Support Brace and the tape used was BSN Medical, Stappal+ Mueller Wrap. The test measures used were the single leg balance test, the standing long jump (broad jump), the vertical jump test, and the Functional Squat System Machine. This machine measures neurophysiological parameters that include isometric features, endurance, coordination, proprioception, and reaction time. There were no significant differences between the groups for balance or the broad jump. For vertical jump performance, the barefoot group yielded better results than the taping and bracing group. Coordination and proprioception were

better in the bracing and taping groups when compared to barefoot. However, when comparing bracing versus taping, there was no differences between the two (Ozer et al, 2009).

This fifth study examined the use of ankle braces on male and female recreational soccer players. They measured kicking accuracy, speed, and agility. The four performance measures were accuracy shooting at a target, 40-yard dash, S180 degree run, and the T Test. Subjects completed these four measures with and without the brace for session 1. The results showed that in session 1, kicking accuracy improved by 8.6 cm, the 40-yard dash and S180 degree run was 0.12 and 0.08 seconds slower respectively, and the T Test was 0.03 seconds faster (Putnam, Bandolin, & Krabak, 2012, p. 576). For session 2, the subjects were asked to take the brace home and use it at least four time for at least 20 minutes per time over the next week. The results showed that in session 2, kicking accuracy improved 3.0 cm, the 40-yard dash and S180 degree run was 0.11 and 0.05 seconds slower respectively, and the T Test was 0.12 seconds slower (Putnam, Bandolin, & Krabak, 2012, p. 576). These results show some decrease in performance but none of it yielded to be significant. During a post-test questionnaire, 65% of the subjects thought that the use of the ankle brace had negative effects on their performance (Putnam, Bandolin, & Krabak, 2012, p. 577).

Study number six was conducted to determine if prophylactic ankle stabilizers influenced vertical leg stiffness during hopping. The subjects completed a ten minute treadmill jog at a comfortable pace, twenty figure-eight runs, and nine shuttle runs. The subjects completed each exercise cycle with no stabilizer, ankle tape, and ankle brace. The tape used was Coach Plain Tape with Medco pro trainer underwrap. The ankle brace used was a semi-rigid Air-Cast AirSport. After each exercise bout, subjects completed two thirty second hopping sessions on a

force plate to collect the data. The results showed that neither taping nor bracing affected vertical leg stiffness during hopping (Williams & Riemann, 2009).

The seventh study sought to determine the effect of different ankle braces on muscle stiffness. Subjects were split between 2 groups, stable and unstable, using the Ankle Instability Instrument oral questionnaire. Within these three groups, subjects were tested with no brace, with a non-rigid lace up brace (Ankle Lok), and a semi-rigid brace (AirCast Air-Stirrup). The authors designed and constructed a medial-lateral swaying cradle device that was used to measure ankle stiffness in the experiment. The results showed that participants with FAI (unstable group) did not differ from the group with stable ankles. The results also showed that the application of an ankle brace resulted in higher rotational stiffness values. These results were consistent with both types of braces, the lace up brace as well as the semi rigid brace (Zinder et al, 2009).

Discussion

Resistance and Balance/Coordination Training

The results of this systematic review showed that the majority of the articles stated that balance/coordination training was an effective technique to help prevent ankle injuries. Each study used a different training program as well as different measurement testing tools. The reasoning why they used different programs and tools is because they work to train different muscles/ligaments as well as improve different functions such as proprioception, postural stability, proximal control of the body, etc. For example, a foam stability pad may be used because it improves proprioception and/or proximal control of body mass (McHugh et al, 2007). Coordination training can be used as a therapy to rehabilitate and improve postural stability deficits associated with functional ankle instability (Ross et al, 2007). It is thought to enhance

sensorimotor function and as a result improve postural stability (Ross et al, 2007). Another result of enhanced sensorimotor function is improvements in ankle stability and therefore reduces the incidence of ankle injuries in those with functional ankle instability (Ross et al, 2007). The wobble board proved to be a successful technique (Emery et al, 2007). This program was also home-based which shows that a trainer does not need to be present. This is beneficial for college athletes because many times in the summer they are not able to be on campus with the team athletic trainer. This study shows that those athletes are able to complete a home based training program that will help with preventing ankle injuries.

After an ankle sprain, it has been reported that up to 40% of sufferers continue to report residual disability (Lee & Lin, 2008). This can be present for up to seven years after the ankle injury. The common term for this is functional ankle instability. Those suffering from functional ankle instability suffer from the feeling of their ankle “giving way” in their joint stability. Those with functional ankle instability also suffer from postural stability. Postural stability is defined as the ability to maintain an upright posture and to keep the center of gravity within the limits of the base support (Lee & Lin, 2008). This is very important in athletics and each sport has reasons for importance. For example in basketball, it is very important to keep postural stability when playing defense. The offense and defense usually collide when guarding the ball. Without good postural stability, the defense will be knocked off their spot, giving the offense an advantage. Similar results were shown in the study by Eils et al (2010) who examined postural sway in basketball players. After the training program, subjects had improvements in proprioception and postural sway, allowing them to compete at a high level, as these subjects were playing professional basketball in Germany (Eils et al, 2010).

Those suffering from FAI may also suffer from proprioception deficits (Lee & Lin, 2008). Proprioception refers to the body's ability to sense movement within joints and joint position (Lee & Lin, 2008). It is important in everyday movements but especially in complicated sporting movements when precise coordination is essential. It's believed that ankle proprioception is critical to the balance of the human body during functional activities such as standing, walking, and running (Lee & Lin, 2008). Damage to the proprioceptive system is thought to be the major cause of functional instability after ankle injuries (Lee & Lin, 2008). To combat this, the biomechanical ankle platform system (BAPS) has been commonly used by athletic trainers and physicians in rehabilitation after ankle injuries. The design of the system is to aid in re-educating the proprioceptive system by restoring normal neuromuscular coordination. Lee & Lin (2008) were the first who examined the effectiveness of BAPS on postural stability and ankle stability. A previous study that used the BAPS found it effective in treating and improving postural control. Lee & Lin (2008) found similar results that stated improved postural stability and improved ankle stability when using the BAPS for 12 weeks. This study also showed that the ankle joint reposition sense was strengthened after the 12 weeks. As a result, the subjects improved neuromuscular ability and better functional joint stability than before the training program (Lee & Lin, 2008).

Studies varied between only having the training program as the only source of exercise and subjects continuing their normal daily exercise routines or in some cases practices/games. This can affect the outcome of some studies because it has been shown that balance can be improved with only being exposed to high levels of physical activity (Eisen et al, 2010). However, as an application of this, it shows that balance training while in season can be great for balance and ankle injury prevention. Over the course of the study by Eisen et al (2010), the

injury rate per 1000 athletes was zero. This was extremely good compared to the national rates of approximately 1.18 per 1000 for the specific athlete population in this study. However, in another study, all of their subjects continued on with their normal activities but those in the training group yielded better results, three times less injuries than the control group (Eils et al, 2010, p. 2102). These two articles show that training programs coupled with normal activity is the most beneficial.

There is also differences between the types of stance that are used. Some use two legs (bipedal) while other use one leg (unipedal). Along with that, some used stable surfaces while others used unstable surfaces, whether than be uniaxial or multiaxial. As a whole, the research has shown that any type of balance and coordination training can be effective. The difference between many of these variables is how one wants to train the ankle. Different exercises improve different things such as postural stability, ankle instability, balance, etc. Also, some muscles/ligaments need more repair if an ankle injury has occurred. For example, soleus activation aids in promoting a greater recruitment of muscle fibers that help rehabilitation after there was a previous injury (Borreani et al, 2013).

Ankle Bracing/Taping

Ankle braces were shown to be an effective way of preventing ankle injuries. They were shown to reduce ankle injuries by fourteen times when compared to the NCAA ISS (Pedowitz et al, 2008, p. 325). There are two sports with a high incidence rate of ankle injuries, volleyball and basketball. The lateral ankle sprain rates of these two are 87% and 79% respectively (Shaw, Gribble, & Frye, 2008, p. 164). The reason why these two sports are at a high rate is because they are termed “jumping sports”. Landing in these sports account for 58% of basketball injuries and 63% of volleyball injuries (Shaw, Gribble, & Frye, 2008, p. 164). Factors that affect this are

muscle fatigue, which then affects neuromuscular control, resulting in a decrease of stability (Shaw, Gribble, & Frye, 2008). The ankle brace has shown effective in improving stability when one lands from a jump, especially after fatigue has set in.

There are many different ankle braces out there to choose from. Different braces will key on preventing certain actions such as inversion, supination, etc. Overall, they all perform at a similar level and were shown prevent ankle injuries. It was concluded that there were no difference between the two and that both helped improve coordination and proprioception (Ozer et al, 2009). Those desiring to wear an ankle brace should get the one that feels most comfortable to them. Some of the studies only examined the effectiveness of the brace while other compared certain ones. One study concluded that the AB brace was more effective than the AA brace when looking at TTS (Shaw, Gribble, & Frye, 2008). TTS is important because the faster the ankle can stabilize, the less chance there is for an ankle injury.

Four articles discussed the negative effects bracing/taping may have. One concluded that the tape and brace group had a decreased vertical jump compared to the barefoot group (Ozer et al, 2009). Another looked at the effect taping and bracing has on vertical leg stiffness. There has been some speculation from different authors that state the possibility of ankle restriction negatively affecting the knee and hip in the shock absorption process (Williams & Riemann, 2008; Zinder et al, 2009). This study concluded that there was no vertical stiffness obtained from tape or braces. One reasoning is the ability for tape/brace to loosen once beginning competition (Williams & Riemann, 2008). Looking at rotational stiffness, it was concluded that there was a decrease in rotational stiffness when the application of an ankle brace is present (Zinder et al, 2009). When comparing tape and brace, tape will generally loosen more than bracing will, which poses the question on whether loosening is a good or bad thing. It could be good in the

instance such as this where it doesn't allow for stiffness during competition. However, it can possibly be a negative response too because of the decrease of support when the tape/brace loosens (Williams & Riemann, 2008).

There has been some concern on the effect ankle braces may have on speed and agility. While it proved not to be significant, there was a slight increase in time all three tests, the 40-yard dash, the S180 degree run, and T Test. Also in this study, there was a post-test questionnaire that stated 65% of the subjects thought the ankle brace decreased their performance (Putnam, Bandolin, & Krabak, 2012). This is worth mentioning because sports are very much a mental game. Athletes have to get themselves ready mentally and physically before competition. If athletes feel that their performance is being hindered, they may not perform to their full potential. This poses the question on what is more valuable, decreasing the chances for an injury or competing at one's most optimal level?

Preventing First Time Injuries vs Recurring Injuries

The topic of prevention of ankle sprains was sparked by the author's occupation, a collegiate basketball coach. The desire to have healthy players throughout the season is a major predictor in the success of the season. As stated before, the most common injury for athletes and especially basketball players is the sprained ankle. If a coach was able to prevent these from occurring, he/she would have the higher chance to engage in a successful basketball season. Unfortunately, the research has shown that this cannot always be the case.

The study with high school football players showed the effectiveness of a balance training when comparing those with a previous injury versus those without (McHugh et al, 2007). The study also looked at those overweight when it comes to BMI. One key note is that a high BMI in football players may not mean those individuals are excessively fat, but they are

still high in weight which is a risk factor. Of the three groups that received the training program, the high risk group was the only group with all of its members having a history of an ankle sprain. That group suffered 4.1 times less ankle injuries pre-intervention to post intervention (McHugh et al, 2007, p.1292). The other two groups which had a combination of those with a history of a sprain and those without, only decreased injury rates by 2.2 times less, making the program almost twice as effective for those with a history of ankle sprains (McHugh et al, 2007, p.1292). Likewise, another study mentioned that prior injury is an important risk factor for an ankle sprain (Pedowitz et al, 2008). In a study they examined, 79% of ankle injuries were re-injuries, stating that there is a need to concentrate on those with a history of ankle sprains (Pedowitz et al, 2008, p.326). In their specific study, they used ankle braces as a technique for prevention. They had only one subject that sustained an ankle injury and that subject also had a history of ankle injuries (Pedowitz et al, 2008, p. 325).

Limitations

One limitation is looking at all sports and athletes of all kinds. As mentioned before, more authors would have allowed for more data bases to be used. With that, the author could have focused on a more specific group of subjects. Ideally the author would have been able to only review articles pertaining to athletes' participation at high levels of basketball, ranging from high school, to college, to professional. The results/findings are still accurate but they are not as generalizable for the author in specific.

Conclusion

In conclusion, the use of balance/coordination training was shown to be successful. When coupled with other variables such as continued daily activity or resistance, the effectiveness of training programs are generally even greater. Many times athletes may not be

able to prevent an initial injury to the ankle but it is very important to use these preventive measures to decrease the chances of sustaining another injury to the same ankle. This goes beyond rehabilitation techniques that an athletic trainer may have one do. Rehab may only last until the athlete is able to get back into competition but many times there is weakness in the ankle that needs to be addressed. Also, on many occasions high school athletes may not have the correct resources available and come into the college setting already at a disadvantage because they have not received the proper rehab when sustaining an ankle injury. This is where these programs can be implemented. When implementing a program, there is no one size fits all model. There are a multitude of exercises one can do that fall under the category of resistance/balance/coordination training. It is important to perform exercises that cover a broad list of benefits. These benefit areas are increased flexibility, balance, stability, and muscle strength (in the ankles and hips). The program that is being utilized should have exercises that affect all of these benefits.

It is important to know that there can be many modifications to programs and they all have similar effects. For example, it will not change the effectiveness of a program whether one uses a dynadisc or a wobble board. Both of these tools are multi-axial surfaces and will allow the ankle to be trained in a very similar way. With that being said, it is always important to have exercises in the program that the athletes completing them enjoy and will cooperate with. Many times athletes go home for the summer and it's their responsibility to perform these training programs on their own. With that in mind, one always wants to create a training program that the athlete will want to do that still keys on all of the benefits desired. Some exercises that work on general flexibility and will key on the ankle in specific are: Knee to Chest with Calf Raise and Ankle Circle, Heel to Toe Raises, Alternate One-Legged RDL's, Lunges with an Over-Head

Reach, Inchworms, and Squat Holds. These exercises will work on flexibility of all the lower extremities which in turn will help the ankles. Also, these exercises are a great warm-up before the actual training program exercises.

Exercises that will work on balance and stability are: Double and Single Leg Line Jumps (both front to back and side to side jumping from one side of the line to the other), Alternate Front Sticks (jumping forward as far as possible, landing on one foot), Lateral Sticks (jumping side to side landing on one foot each time), using an Agility Ladder (many different choices that one can perform), Single Leg Box Drops (standing on a 3-4 foot tall box, free falling one's weight and landing on one foot), and Single Leg Stance on a multiaxial surface while catching a tennis ball (balancing on one leg throwing a tennis ball with a partner or against the wall).

Exercises that will work on muscle strength are: Lateral Band Walk, Standing External Rotation Series, Band Quick Abductions, Single Leg Box Squats, Calf Raises, and 3-way Ankle Band Exercises using resistance bands. These exercises are used to strengthen both the ankles and the hips. As stated earlier, these exercises are a foundation and can be modified for the specific person that is completing them. This program, or any program, should be completed multiple times a week and can continue for as long as the athlete wants. As the research showed from the results of the study, the longer one completes these programs, the better the results (McKeon & Hertel, 2008, p. 312). The recommended program the author created is attached in the appendix.

Ankle bracing/taping also showed to be effective in the prevention of ankle sprains. The results showed a variety between ankle supports directly decreasing the injury rate as well as decreasing the causes of ankle sprains such as ankle velocity and ankle displacement. Much of the research on this topic is in favor of the use of ankle supports to decrease the injury rate. However, there are some effects of using braces/tape that need to be considered before using

either. Some of the research showed that ankle supports may hinder performance in areas such as jumping ability and speed (Ozer et al, 2009; Putnam, Bandolin, & Krabak, 2012). It is also believed that these supports can weaken the ankle even though it protects it from injury. Due to these findings, one should pick and choose when he/she wears ankle braces/tape. Research showed that over half of injuries come from games, which could suggest only wearing supports during games (McCriskin et al, 2015, p. 164). This would limit the amount of times the athlete has to wear the support and therefore the ankle would not be getting weaker. Also, it's important to note that every athlete is different. Some coaches make all of the players wear ankle braces/tape and don't allow for the players to decide. However, not all players need to wear these braces and the coach would be doing a disservice to athletes that don't need them. Each coach should leave it up to the athlete if they want to wear these supports.

In terms of combining training programs with ankle supports, athletes should not wear supports when completing the exercise programs. These programs are designed to strengthen the ankle and the brace/tape would counteract that process, not allowing for optimal results. If the athlete completes the training program and still feels that he/she needs to wear ankle supports, the recommendation would be to only do so during in-game competition. The reason for this is as stated before, over half of the injuries happen during games versus practice or competition (McCriskin et al, 2015, p. 164). Also stated before is the hindrance ankle supports can have on the athlete (Ozer et al, 2009; Putnam, Bandolin, & Krabak, 2012). Therefore, an athlete can still protect the ankle and not hinder the body long term if he/she only wears supports during competition. However, no matter what measures one decides to do, it is very important to address the issue immediately. Right when the athlete feels he/she needs to strengthen up the

ankle and increase balance and stability, it is time begin a resistance/balance/coordination training program.

Appendix

Ankle Program:

Knee to Chest with Calf Raise and Ankle Circle-
2x20 yards

Heel to Toe Raise-2x20 yards

Alt RDL-2x20 yards

Lunge with OH Reach-2x20 yards

Spiderman-2x10 yards

Inchworms-2x10 yards

Squat Hold 5x15"

DL Line Jumps- 2x15 sec F, 2x15 sec L

SL Line Jumps- 2x10 sec F, 2x10 sec L

Alt Front Sticks- 4x20 yards

Lateral Sticks- 2x10 each

SL Box Drops- 4x5 each

Agility Ladder- 2x each (Be creative)

SLS with Ball Toss (foam, bosu, ankle disk)

Lateral Band Walk- 4x10 yards

Standing ER Series- 2x10 each

Band Quick Abd- 2x10 each

SL Box Squat-3x10 each

Calf Raise- 3x15

3 Way Ankle Band Ex's- 3x12 each direction

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