JOURNAL OF PHYSICAL EDUCATION RESEARCH

Journal of Physical Education Research, Volume 3, Issue II, June 2016, pp.48-58
ISSN: Print-2394 4048, Online-2394 4056, Impact Factor: 0.519, IBI Factor: 4.29

IS THERE A RELATIONSHIP BETWEEN CORE MUSCULAR STRENGTH AND CHRONIC ANKLE INSTABILITY?

ANGELA CALICCHIO, GEN LUDWIG, MARK DEBELISO*
Physical Education and Human Performance Department, Southern Utah University, Cedar City, UT, USA.
***Email:** markdebeliso@suu.edu*

How to cite this article: Calicchio, A., Ludwig, G., & DeBeliso, M. (June, 2016). Is there a relationship between core muscular strength and chronic ankle instability? Journal of Physical Education Research, Volume 3, Issue II, 48-58.

Received: April 24, 2016 **Accepted:** June 24, 2016

ABSTRACT

Ankle sprains are among the most common injuries in athletics, leaving some athletes with instability issues long after the initial injury has occurred. This study attempted to determine if a relationship between chronic ankle instability and core strength exists. Forty-two Division I collegiate male (n=24 19.9±1.2 years) and female (n=24 19.6±1.0 years) athletes participated in testing. The Balance Error Scoring System (BESS), the Foot and Ankle Disability index (FADI), the FADI sport survey and Ankle Joint Functional Assessment Tool (AJFAT) were used to assess chronic ankle instability. Core muscular strength was measured using a 60 second back extension test. A Pearson Correlation (r) test was conducted comparing the ankle stability tests and the back extension test. Low to very low correlations were found for all comparisons: FADI/FADI Sport & Back Extension r = -0.04 (p<0.01), BESS & Back Extension r = 0.26 (p<0.01), AJFAT & Back extension r = 0.04 (p<0.01). A Pearson Correlation test was run between both ankle stability surveys and the BESS test as well. Very low correlations were found in these comparisons as well: FADI/FADI Sport& BESS r = -0.04 (p<0.01), AJFAT & BESS r = 0.02 (p<0.01). The low correlations assessed in this study do not support the notion that core muscular strength is related to chronic ankle instability.
Keywords: *Core, ankle instability, BESS, FADI, AJFAT.*

1. INTRODUCTION

Ankle sprains are among the most common injuries in athletics (Hiller, Kilbreath, & Refshauge, 2011). When an athlete experiences an ankle sprain most acute symptoms will resolve quickly and do not impede participation for an extended period of time (Hiller, *et al.*, 2011). However most athletes do experience residual problems such as some pain, swelling, and instabilities, which have been classified

Correspondence: Mark DeBeliso (Ph.D.), Professor, Department of Physical Education and Human Performance, Southern Utah University, Cedar City, USA, Tel: 435-586-7812, Email: markdebeliso@suu.edu

as chronic ankle instability or CAI (Hiller, *et al.*, 2011). There is little research regarding chronic symptoms experienced after an acute ankle sprain. The damaged structures from an ankle sprain include the functional and neural anatomy, ligaments, nerves, proprioceptors and mechanoreceptors (Docherty, Valovich, & Shultz, 2006). Disruption to these structures can lead to difficulties in maintaining postural equilibrium (Riemann, 2002). Damaged structures do not deliver afferent information effectively. For example, a person who has not experienced an ankle injury can easily close their eyes and balance on one foot with little sway. A person who has experienced an ankle sprain will not be able to hold this position without a significant amount of sway (Riemann, 2002). Many athletes describe the feeling after an acute sprain as "giving way" and may never regain normal balance and stability after an acute ankle sprain (Ross, Guskiewicz, Gross, & Yu, 2008). These athletes often feel the need for some other type of support such as taping or bracing.

Postural instability is one of the deficits often experienced with CAI (Docherty, *et al.*, 2006). The core muscles of the body, which include the spine, hip, pelvic and abdominal muscles, control postural stability and balance of the limbs. These core muscles also help generate force and transfer energy through the limbs (Kibler, Press, & Sciascia, 2006). Research has shown weakness in the musculature of the core can predispose an athlete to injury including ankle sprains (Hibbs, Thompson, French, Wrigley, & Spears, 2008; Sharrock, Cropper, Mostad, Johnson, & Malone, 2011). There is a possibility that much of the instability felt after an acute ankle sprain is due to a weakness in the core musculature. Since there is a known link between the function of the limbs and core strength during sport activity, one might assume that there is a relationship between core strength and CAI (Docherty, *et al.*, 2006).

The purpose of this study was to examine the relationship between measures of CAI (BESS, FADI, FADI Sport, and AJFAT) and the back extension test, which is a measure of the core strength. It was hypothesized that there would be a moderate to high association between core strength and the CAI measures.

2. METHODS AND MATERIALS

2.1 Participants

Participants were volunteer Division I male and female athletes. The age of the participants ranged from 18-25 years (male: 19.9±1.2 yrs female: 19.6±1.0 yrs). This study was conducted during the fall semester, meaning some athletes were in season (24-male, 9-female) and some were in pre-season (0-male, 9-female) phases of competition. Permission was sought from all coaches before asking for volunteers. The Institutional Review Board Ethics Committee permission was obtained before conducting any assessments. Each participant was given a written

consent form to read and sign before any testing was done. Each participant was made aware that their participation was voluntary and they had the right to withdraw at any time during the study. Athletes were given instruction and demonstration prior to performing tasks. A certified Athletic Trainer (ATC) served as the administrator for the research effort and was present during all evaluation sessions. Athletic training students volunteered to help administer tests.

2.2 Instruments

Four tests were used to assess CAI. First, the Ankle Joint Functional Assessment Tool (AJFAT) determined CAI and pain via a 12-item questionnaire. The AJFAT assessed the participants' perceived level of function. This test had a total score of 48, the greater the score, the greater level of perceived function. When looking at the content validity the AJFAT contains specific information relating to impairment, disability, and participation problems (Eechaute, 2007). The reliability of the AJFAT assessment is 0.94 (Ross, *et al.*, 2008). Ross, *et al.* (2008) also showed a sensitivity score of 0.67 and specificity score of 0.73. When discriminating between stable and unstable ankles, the AJFAT is a very reliable testing tool based on test retest ratios (Ross, *et al.*, 2008).

Second, the Foot and Ankle Disability index (FADI) and FADI Sport were also used to measure ankle function and pain levels during daily activities and sport, respectively. The FADI combined with the FADI Sport consisted of 26 items scored from zero to four, with zero meaning an inability to perform the activity and four meaning no difficulty performing activity. This instrument had 104 possible points. Higher scores indicated lower amounts of dysfunction in completing sport specific tasks (Eechaute, Vaes, Aerschot, Asman, & Duquet, 2007). The FADI and FADI Sport scores were combined and reported as one score (FADI/FADI Sport). Hale, and Hertel (2005) found the FADI and FADI Sport are both strong in reliability and sensitivity in showing deficits and detecting limitations associated with CAI. Intra-class correlation coefficients after one week for the FADI and FADI sport are 0.89 and 0.84 respectively (Hale, & Hertel, 2005). The reliability of the FADI assessment ranges from 0.85-0.98 and the FADI sport assessment 0.67-0.92 indicating good reliability for both tests (Hale, & Hertel, 2005). The FADI sport assessment is considered a better detection device for athletes due to the items relating more to an athletic atmosphere (Hale, & Hertel, 2005).

The Balance Error Scoring System (BESS) was also utilized to measure CAI. In order to complete the test, participants were asked to balance unsupported with hands on their hips and eyes closed. Participants' balance was assessed under six conditions: double limb, single-leg and tandem stances on both firm and foam surfaces. A hard tile floor of the gym locker room was utilized for the firm surface. The foam surface consisted of a 48.25 cm L x 40.64 cm W x 6.35 cm H super-soft

specialty foam with destabilizing properties (Power Systems, Inc., Knoxville, TN). The BESS measured the number of errors participants had while holding the assigned position for 20-seconds. A stopwatch was used to time each of the 20-second trials. A BESS error was scored if the participant engaged in any of the following: (1) lifting the hands off the iliac crest, (2) opening the eyes, (3) stepping, stumbling, or falling, (4) moving the hip into more than 30 degrees of flexion or abduction, (5) lifting the forefoot or heel, or (6) remaining out of the test position for longer than five seconds. Error scores were calculated for each of the six conditions and summed to obtain a total BESS score. Docherty, *et al.*, (2006) reported that the BESS instrument has mainly been used in the past for preseason evaluation for head injuries as well as for acute head injuries but their results showed good reliability for using the BESS as a tool in assessing chronic ankle pain. The BESS test challenges the sensory systems while the athlete is balancing on two different surfaces and various different stances. An objective scoring system is used as well, which decreases test-retest error (Docherty, *et al.*, 2006). Inter-tester reliability is good (0.78-0.96) for the BESS test (Bell, Guskiewicz, Clark, & Padua, 2011). Intra-tester reliability is good as well (0.60-0.92) for the BESS test, the validity of the BESS test is moderate to high (r = 0.31-0.79) (Bell, *et al.*, 2011).

A 60-second back extension test was used to evaluate the trunk extensor muscles and was considered a measure of core strength. Participants were positioned prone on a table with the iliac crest at the edge of the surface. An administrator firmly secured the participant's lower body to the table. The subject was instructed to place their hands behind their head while keeping their spine straight. Additionally, athletes were given cues to assume a chest out, butt out, position while raising their trunk to a neutral position and then lower back down to 45 degrees of flexion. The subjects performed as many back extension as possible in 60 seconds. The subjects were given two to three trial attempts before the assessment to ensure proper technique and ample time to rest. Successful repetitions were counted out loud by an administrator. A repetition was not counted as successful if participant did not extend all the way to neutral. Lanning, Uhl, Ingram, Mattacola, English, and Newsom (2006) found excellent reliability using the intra correlation coefficient. The 60-second back extension test challenges muscles considered to make up the "core" which are considered to be stressed and evaluated by the test. The reliability of the Back Extension test has been reported as high with an intraclass reliability of 0.83 and the validity assessed as >0.80 considered high as well (Reiman, Krier, Nelson, Rogers, Stuke, & Smith, 2012).

2.3 Procedure

Participants only needed to be available for one day of testing. Stations were set up for each assessment with an administrator located at each station. Each station

had a separate administrator who was trained to administer the test: 60 second back extension test, Balance Error Scoring System, Foot and Ankle Disability Index and sport, Ankle Joint Functional Assessment Tool. Each participant was given both written and verbal instructions. For all functional tests, the participants were allowed two to three practice tries before completing the actual assessment, as well as three minutes of rest to ensure an accurate assessment. For the subjective portion of the assessments participants were asked to follow written instructions and were given additional verbal cues. Participants were asked to avoid consulting with anyone other than the administrator during the assessment. Subjects were tested in groups in order to maintain efficiency. At least one testing administrator was assigned to each of the assessment stations. At the individual testing stations, administrators gave all necessary instructions, demonstration, and cues for all assessments. Completion of all tests took approximately ≈45 minutes. Score sheets were distributed at each testing station and were maintained by the administrator who recorded the test scores.

2.4 Design and Analysis

Pearson Correlation Coefficients (*r*) were used to determine whether a relationship existed between CAI measures and core strength as measured by the 60-second Back Extension (BE) test. Specifically, a PCC was calculated between: the AJFAT and the BE test, FADI/FADI Sport and the BE test, as well as the BESS and the BE test. The level of statistical significance used for this study was $p \leq 0.05$. Statistical analysis was conducted using Microsoft Excel software.

3. RESULTS

Table 1: Mean, standard deviation for height, weight and age of participants

	Height (cm)	Weight (kgs)	Age (years)
Female n=18	173.1±7.7	70.5±11.1	19.6±1.2
Male n=24	187.5±7.3	100.2±16.4	19.9±1.0

Table 2: Pearson Correlation Coefficients (*r*) between back extension test and CAI tests (n=42)

	AJFAT	FADI/FADI Sport	BESS
60-Second Back Extension	0.04	-0.04	0.26

There were 42 Division I Intercollegiate athletes that participated in this study; 24 males (North American football athletes) and 18 females (softball and volleyball

athletes). All participants ranged from ages 18-22. There were no complications during the study and test results were collected and analyzed for all 42 participants. A Pearson Correlation (*r*) test was conducted for each of the ankle stability tests and the back extension test. A weak correlation was found in all comparisons: FADI/FADI Sport& Back Extension r= -0.04 (p<0.01), BESS & Back Extension r = 0.26 (p<0.01), AJFAT & Back extension r = 0.04 (p<0.01). After determining a weak correlation weak between chronic ankle instability and core strength a Pearson Correlation (r) was conducted using data from both ankle stability surveys and the BESS test. A weak correlation was found within these comparisons as well: FADI & BESS r = -0.04 (p<0.01), AJFAT & BESS r = 0.02 (p<0.01).

4. DISCUSSION

The purpose of this study was to examine the relationship between measures of CAI (BESS, FADI/FADI Sport, and AJFAT) and the back extension test, which is a measure of the core strength. It was hypothesized that there would be a moderate to high association between all of the variables being tested establishing a link between core strength and CAI in athletes. The data from this study suggests that there is not a meaningful relationship between chronic ankle instability and core strength.

Several limitations are considered to have led to these results; first the subjects used was collegiate athletes competing at a high level within their sport. The amount of strength training required of the athletes for their sports is substantial enough that a weakness in the hip musculature would be rare. The average scores on a 60 second back extension test is 30±8 (Lanning, *et al.*, 2006). The participants in this study averaged a score of 47. Division I collegiate athletes have superior athletic capabilities; one could consider them to have the ultimate overall strength necessary to perform in their specific sport. This overall strength is the primary reason they are able to compete at such a high level. Overall core strength is not generally an issue for athletes performing at this level. All athletes used in this study were in peak stages of their respective sports, which could have affected the results being non-conclusive. Hence there could have been a compression effect with regards to the dispersion of the back extension scores which would ultimately impact the correlation coefficients.

Another limitation in this study may be related to the selection of CAI measures. Although the CAI measures (BESS, FADI/FADI Sport, and AJFAT) used in this study have been previously demonstrated to be both reliable and valid it is possible that other CAI measures maybe more appropriate in this population. We unexpectedly found very low correlations between the CAI measures used in this study, suggesting that there may be a more appropriate method of measuring CAI. Research has shown that the Star Excursion Balance Test may be a superior

instrument for determining CAI (Docherty, *et al.*, 2006). Using a different diagnostic tool such as the Star Excursion Balance Test may provide better insight regarding the potential relationship between core strength and CAI. Research has shown that core strength may be related to time under tension (Lee, & McGill, 2015). In this study the 60 second back-extension test was used, Lee and McGill (2015) state that multiple repetition exercises result in far less time under tension whereas an exercise like a plank hold would place the muscle under tension the entire duration of the exercise. An isometric assessment approach such as the plank duration test may have proven a superior way to test core strength and the amount of time the core musculature is under tension (Lee, & McGill, 2015).

CAI is a condition that many athletes suffer from, and continue to have problems with throughout their careers because there is no real way to completely relieve symptoms. Following an ankle sprain there is potential damage to ligaments, nerves, proprioceptors and mechanoreceptors (Docherty, *et al.*, 2006). This damage could lead to postural sway deficits. Mechanoreceptors play a significant role in the postural control system, meaning an athlete with chronic ankle instability is going to have a harder time holding a single leg balance position than someone who does not have any instability problems (Riemann, 2002). This study was conducted to analyze the relationship between ankle instabilities and core strength. The hips, pelvis and spine all provide stabilizing functions, which allow the limbs to perform specific functions (Kibler, *et al.*, 2006). Core strength is a primary factor in stabilization of the spine and pelvis as well as the generation and transfer of energy from larger to smaller body parts (Kibler, *et al.*, 2006). The idea that core strength is a factor in CAI is suggested by the relationship between the trunk and pelvis and the extremities. Simply put, the trunk and pelvis provide the stability for extremity activities to be executed. With persistent ankle pain and instability, assessing movement and function at the trunk and pelvis is necessary. In this study the primary focus was on core endurance strength at the low back and hamstrings. A better approach for further research would be to focus on proprioception and strength at the hips and pelvis. Strength at the hips is important to gait mechanics and foot position during heel strike; weakness in these muscles could cause improper placement of the foot and lead to rolling or twisting of the ankle (Friel, McLean, Myers, & Caceres, 2006). Foot placement is dependent on the movements produced by the hip abductors and adductors during the swing phase of gait. If an error is made and the foot is placed more medially during heel strike, subtalar inversion occurs (Friel, *et al.*, 2006). The argument could be made that CAI is developed and/or exacerbated from muscle weakness in the hips and pelvis. This point is further emphasized by a recent study by Cejudo, de Baranda, Santonja, and Ayala, (2016) who proposed a range of motion test of the hip abductors in athletes as a tool for the prevention of injuries incurred as a result of sport participation.

Future research should focus on the sensory and functional deficits occurring during severe ankle sprains and how these deficits affect the sensory information being relayed to more proximal joints (Friel, *et al.*, 2006). A disruption in sensory information could lead to changes in function at the hip and pelvis. This disruption in muscle firing and recruitment could impede the hip abductors from being able to counteract lateral sway after a distal injury (Friel, *et al.*, 2006). Postural control is achieved by three different factors; 1) the body's position relative to support surface, gravity and the position of each segment, 2) all of the afferent information gathered from those three sources, and 3) the actual execution of the motor command (Riemann, 2002). With an injury such as an ankle sprain, all of these factors are disrupted. When damage occurs in these three areas the ankle relies more on the hip to achieve postural corrections. Again if the hip adductors and abductors are weak the necessary corrections cannot be made. All of these factors should be considered in future research regarding the treatment and rehabilitation CAI.

Injuries at the ankle joint also disrupt the mechanoreceptors in the lower limb, which would cause problems in gait mechanisms. Hip strength is critical in determining foot position during the heel strike. After an injury at the ankle joint, changes in the gait pattern may occur because of pain factors. These subjects may be more likely to over pronate at initial contact during gait; this would be exasperated if the hip abductors are weak (Friel, *et al.*, 2006). When these changes in the gait mechanics occur for prolonged periods of time the motor patterns maybe altered. As such, future research should focus on how an injury at the ankle leads to disruption in relaying information through proprioception (Riemann, 2002). An athlete with CAI will have a hard time recovering their equilibrium after an outside stimulus is presented, or for example have trouble maintaining and control their balance while being pressured by an opponent during a basketball game.

5. CONCLUSIONS

CAI is a disability affecting athletic performance and impedes playing/practice time. Minimal research has been conducted thus far to indicate ways to improve the instability, postural sway associated with CAI. Much research has shown that sensory information gathered and delivered at the ankle is deficient after an injury. When sensory deficiencies occur, other systems have to adjust and compensate to ensure that the CNS receives enough information to send a proper response (Forkin, Kczur, Battle, & Newton, 1996). Research has shown that the core musculature is a key factor in providing stabilization and postural control during activity (Hibbs, *et al.*, 2008). This study was inconclusive regarding the relationship between core strength and CAI. However, if future research does establish such a relationship,

then it would be possible to develop exercise strategies directed towards relieving impairments associated with CAI.

6. REFERENCES

Bauby, C.E., & Kuo, A.D. (2000). Active control of lateral balance in human walking. *Journal of Biomechanics, 33*, 1433-1440.

Bell, D.R., Guskiewicz, K.M., Micheal, C.A., & Padua, D.A. (2011). Systematic review of the balance error scoring system. *Sports Health, 3*, 287-295.

Cejudo, A., de Baranda, P.S., Santonja, F., & Ayala, F. (2016). Scanning procedures and reference values in the range of motion of the hip abduction in athletes. A tool for the prevention of injuries? *Sport TK-Revista EuroAmericana De Ciencias Del Deporte, 5*(1), 35-45.

de Vries, J.S., Kingma I., Blankevoort L., & van Dijk, C.N. (2010). Difference in balance measures between patients with chronic ankle instability and patients after an acute ankle inversion trauma. *Knee Surgery Sports Traumatology Arthroscopy Journal, 18*, 601-606.

Docherty, C.L., McLeod, T.C., Valovich, & Shultz, S.J. (2006). Postural control deficits in participants with functional ankle instability as measured by the balance error scoring system. *Clinical Journal of Sport Medicine, 16*, 203-208.

Eechaute, C., Vaes, P., Aerschot, L.V., Asman, S., & Duquet, W. (2007). The clinimetric qualities of patient-assessed instruments for measuring chronic ankle instability: A systematic review. *BioMed Central Musculoskeletal Disorders, 8*(6), 01-11.

Forkin, D.M., Koczur, C., Battle, R., & Newton, R.A., (1996). Evaluation of kinesthetic deficits indicative of balance control in gymnasts with unilateral chronic ankle sprains. *Journal of Orthopaedic and Sports Physical Therapy, 23*, 245-250.

Friel, K., McLean, N., Myers, C., & Maria, C. (2006). Ipsilateral hip abductor weakness after inversion ankle sprain. *Journal of Athletic Training, 41*, 74-78.

Hale, S. A., & Hertel, J. (2005). Reliability and sensitivity of the foot and ankle disability index in subjects with chronic ankle instability. *Journal of Athletic Training, 40*, 35-40.

Hibbs, A.E., Thompson, K.G., French, D., Wrigley, & Allan, S. (2008). Optimizing performance by improving core stability and core strength. *Sports Medicine, 38*, 995-1008.

Hiller, C.E., Kilbreath, S.L., & Refshauge, K.M., (2011). Chronic ankle instability: evolution of the model. *Journal of Athletic Training, 46*, 133-141.

Kahle, N.L., & Gribble, P.A. (2009). Core stability training in dynamic balance

among young, healthy adults. *Athletic Training and Sports Health Care, 1*, 65-73.

Kaminski, T.W., & Hartsell, H.D. (2002). Factors contributing to chronic ankle instability: A strength perspective. *Journal of Athletic Training, 37,* 394-405.

Kibler, B.W., Press, J., & Sciascia, A. (2006). The role of core stability in athletic function. *Sports Medicine, 36,* 189-198.

Lanning, C.L., Uhl, T.L., Ingram, C.L., Mattacola, C.G., English, T., & Newsom, S. (2006). Baseline values of trunk endurance and hip strength in collegiate athletes. *Journal of Athletic Training, 41*, 427-434.

Lee, B.C.Y., & McGill, S.M. (2015). Effect of long-term isometric training on core/torso stiffness. *Journal of Strength and Conditioning Research, 29,* 1515-1526.

Leetun, D.T., Ireland, M.L., Willson, J.D., Ballantyne, B.T., & Davis, I.M. (2004). Core stability measures as risk factor for lower extremity injury in athletes. *Medicine and Science in Sports and Exercise, 36,* 926-934.

Mandarakas, M., Pourkazemi, F., Sman, A., Burns, J., & Hiller, C.E. (2014). Systematic review of chronic ankle instability in children. *Journal of Foot and Ankle Research, 7*(1), 21.

McKeon, P.O., & Hertel, J. (2008). Systematic review of postural control and lateral ankle instability, part II: Is balance training clinically effective? *Journal of Athletic Training, 43,* 305-315.

Olmsted, L.C., Carcia, C.R., Hertel, J., & Shultz, S.J. (2002). Efficacy of the star excursion balance tests in detecting reach deficits in subjects with chronic ankle instability. *Journal of Athletic Training, 37,* 501-506.

Riemann, B.L. (2002). Is there a link between chronic ankle instability and postural instability? *Journal of Athletic Training, 37,* 386-393.

Reiman, M.P., Krier, A.D., Nelson, J.A., Rogers, M.A., Stuke, Z.O., & Smith, B.S. (2012). Comparison of different trunk endurance testing methods in college-aged individuals. *The International Journal of Sports Physical Therapy, 7,* 533-539.

Ross, S.E., Guskiewicz, K.M., Gross, M.T., & Yu, B. (2008). Assessment tools for identifying functional limitations associated with functional ankle instability. *Journal of Athletic Training, 43*, 44-50.

Rozzi, S.L., Lephart, S.M., Sterner, R., & Kuligowski, L. (1999). Balance training for persons with functionally unstable ankles. *Journal of Orthopaedic and Sports Physical Therapy, 29*, 478-486.

Sharrock, C., Cropper, J., Mostad, J., Johnson, M., & Malone, T. (2011). A pilot study of core stability and athletic performance: is there a relationship? *The International Journal of Sports Physical Therapy, 6*, 63-74.

Tyler, T.F., McHugh, M.P., Mirabella, M.R., Mullaney, Mi. J., & Nicholas, S.J.

(2006). Risk factors for noncontact ankle sprains in high school football players. *The American Journal of Sports Medicine, 34*, 471-475.

Wikstrom, E.A., Tillman, M.D., & Borsa, P.A. (2005). Detection of dynamic stability deficits in subjects with functional ankle instability. *American College of Sports Medicine, 37*, 169-175.

Willems, T., Witvrouw, E., Verstuyft, J., Vaes, P., & De Clercq, D. (2002). Proprioception and muscle strength in subjects with a history of ankle sprains and chronic instability. *Journal of Athletic Training, 37*, 487-493.