International Journal of Medical and Health Research
ISSN: 2454-9142
www.medicalsciencejournal.com
Volume 4; Issue 6; June 2018; Page No. 96-99

The relationship between a history of ankle injury and current ankle proprioception deficit

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Abstract
The purpose of this study was to determine if a correlation exists between ankle injuries and ankle joint proprioception deficits when compared to non-injured individuals. Ankle injuries are one of the most common sports related injuries. Proprioception can be described as an unconscious perception of movement and spatial orientation. The standard care for ankle injury is to administer proprioception rehabilitation exercises, but consensus is lacking regarding the clinical evidence of the effectiveness of these interventions. To obtain various research articles that pertain to this subject, key phrases such as; effects of ankle sprains on joint proprioception, ankle rehab effects on joint proprioception, and balance exercises effects on joint proprioception were used. Current research does not have a definitive consensus when considering the effects that ankle injury has on joint proprioception. Consensus for ankle injury and rehabilitation includes determining the mechanism of injury and applying a proper exercise routine. The key to ensuring proper ankle proprioception is ankle injury prevention. Ankle rehab protocols have been shown to decrease the chances and recurrence of ankle sprains.

Keywords: ankle proprioception, joint proprioception, proprioception rehab, ankle injury, proprioception, prevention, injury prevention

Introduction
One of the most common lower extremity injuries in athletics are ankle sprains (Hung, 2015) [5]. According to Steib *et al*., (2013) [12], these injuries are usually associated with or related to a decrease in sensorimotor control, muscular strength and joint balance performance. A systematic review conducted by Fong *et al*. (2007) [3] found that 33 of the 43 sports researched had ankle sprains as the major ankle related injury. The sensorimotor control that is greatly affected with these injuries is proprioception. Proprioception can be described as an unconscious perception of movement and spatial orientation that stems from stimuli within the body (Witchalls *et al*., 2012) [15]. For the ankle to maintain its integrity and posture during physical activity, it requires active restraint from muscles, passive stability of noncontractile tissue (ligaments) and bony structure with the arbitrating effects of the sensorimotor system. If any of these components are physically injured it is assumed that the sensory proprioceptive response is also affected and thus leading to a diminished sensory feedback, which can lead to unstable joints and recurrent ankle injury.
McKeon and Hertel (2008) [9] suggest, balance and coordination training has become standard care in the treatment of ankle instability, but consensus is lacking regarding the clinical evidence of the efficacy and effectiveness of these intervention. Having a better understanding of how proprioception is affected after an athlete experiences an ankle injury will allow health care providers to have better treatment plans, accurate rehabilitation designs, and preventative procedures. The studies done thus far for ankle proprioception appear to have different methods and the results are inconclusive when compared. For example, the studies conducted by Yokoyama (2008) [16] and Willems (2002) [14] conducted a similar study to test ankle proprioception. However, the subjects were tested in a sitting/non-weight bearing position. Having a weight bearing joint may have a different effect on ankle proprioception and it is more realistic since injury and sports are usually performed standing.
It is still unclear how ankle injuries affect proprioception. Given this lack of research and the prevalence of ankle injury, the purpose of this study was to determine the relationship between proprioception accuracy of injured and non-injured ankles. What contribution does ankle injury make towards perceived ankle proprioception? By better understanding how joint positioning sense is affected post injury, a new standard for rehabilitation protocols for ankle injury can be formulated.

Methods
Participants
This study includes a control group of which the participants report no history of a diagnosed ankle injury and an injured group that consists of participants that have a history of ankle sprains. The individuals who participated are over the age of 18 and are currently active in a sport. The age of the participants ranges from 18 to 39 years old. Using adult participants allowed the study to be conducted without the need for parental consent. Current athletes were used because there is a higher prevalence for ankle injury in this population and these groups would be compared more relatively to non-injured counterparts. A total of 38 participants were tested, 10

were male and 28 were female. There were 10 participants in the injured group and 28 in the non-injured group.

Volunteers were recruited through flyers and word-of-mouth at a university in a major metropolitan community in the upper Midwest. Emails were sent to several coaches at a couple of college Universities within the community. The project was approved by the Institutional Review Board, Human Subjects Review Committee. Informed consent was obtained from all participants.

Measures

A basic sleeping mask was used for a blindfold to ensure sight was not a factor in testing. A Thera-Band Rocker Board was used to stand and test the ankle mobility in only two directions; plantar flexion and dorsiflexion. To measure the angle at which the board was tilted, a digital protractor (GemRed 82413 Digital Protractor Angle Finder Gauge Inclinometer) was secured to the board with athletic tape. The foot that was not being tested was set on weight plates, that were the same height as the rocker board, to be used as a stable surface adjacent to the board.

Design and Procedures

First, the participant was asked to answer questions on a questionnaire to acquire more information on their ankle health history. Each athlete recorded their name, today's date, sport and position, date of birth and the name of their University. The first part of the questionnaire was health history with the following yes or no questions: broken a bone in the leg/foot/ankle within the last 12 months, diagnosed with a concussion within the last 12 months, have current hip, knee, or ankle pain when walking/standing, and moving the ankle in any direction causes pain. The next set of questions pertained to ankle injury which included: which foot is dominant, and have you experienced an ankle sprain within the last 6 months. The participants that did not injure an ankle within the last 6 months were then asked to skip the remaining questions and move onto the informed consent. The participants who did injury their ankle(s) within the last 6 months were asked the following associated questions: did the injury stop you from playing your sport and how long, which ankle(s) were injured, did a doctor confirm your ankle injury, do you know the grade of the ankle injury, did you were a brace after your injury, and were you given ankle rehab exercises/stretches after your injury. Once the questionnaire was complete, the participants were asked if they have any questions. Once questions and concerns were answered and the testing portion of the study was next.

Once the questionnaire was completed and the informed consent signed, the participants were asked to remove their footwear. The participants were asked to stand with one foot on the stable surface and the other on the rocker board. They were then asked to move the rocker board back and forth to get a feel of the movement. Next, a blindfold was administered to eliminate visual cues during testing. They were also instructed to stand with equal weight on both feet and knees locked. The examiner laid prone in front of the inclinometer to read the angle measurement clearly. Next, the examiner explained that the board was going to move, and the examiner positioned the board to about 15 degrees plantar flexion. The exact angle (starting angle) and ankle (right or left) was recorded on the reverse side of their questionnaire paper.

The participant was then told to continue to move the board down (plantar flexion) then back (dorsiflexion) and to stop their ankle when they thought the original angle was reached (starting angle). The subject was told to verbalized when they thought they reached the original angle and the examiner recorded their perceived original angle (ending angle) next to the starting angle value on the paper. Both ankles were tested three times each. On average, the testing for each athlete took about eight minutes.

Statistical Analysis

Point-biserial correlation and regression equation analyses were conducted to identify the participant characteristics and correlates contributing to the ankle proprioception outcomes. One-way multivariate analysis of covariance (MANCOVA) using total proprioception as the fixed factor was used to examine proprioception differences among participants. The participants used were chosen by contacting numerous sport coaches. The coaches announced to the various sports teams that a study was conducted using current athletes. Athletes who were interested were able to sign up as a participant online and meet at the Universities gym or clinic to be tested. The group of participants that have a history of ankle injury is considered the independent variables and the angle at which the ankle is measured is the dependent variable. The group of participants who report no previous history of ankle trauma is considered the control group.

Results

All 38 participants (mean age=23.2, SD=5.76) that began the study completed all proprioception measurements. The number of females (n=28) outnumbered the number of males (n=10) participating in the study. Point-biserial correlation and regression equation analyses were conducted to identify the participant characteristics and correlates contributing to the ankle proprioception outcomes (Table 1). The correlation analysis revealed a few statistically significant relationships. There was a significant correlation between the proprioception values of the left and right foot of the participants. There was a number of statistically significant correlations that were expected. These include: ankle injury and ankle rehab, ankle injury and ankle injured (left or right), and ankle rehab and ankle injured (left or right). A paired-samples t-test was conducted to compare proprioception of injured and healthy ankle conditions. There were no significances in total proprioception for injured (M=3.27, SD=2.10) and healthy (M=3.95, SD=2.67) conditions; t (1) = 0.524, p = 0474.

Table 1: Correlations among participant and proprioception outcomes.

Variable	1	2	3	4	5	6
Ankle Injury (<6 months)	1	-.04	-.09	.21	.61**	.86**
Proprioception (Right)	-.04	1	.65**	-.15	-.24	-.01
Proprioception (Left)	-.09	.65**	1	-.19	-.26	-.02
Dominate foot (left or right)	.21	-.15	-.19	1	.22	.23
Ankle injured (left or right)	.61**	-.24	-.26	.22	1	.56*
Ankle rehab	.86**	-.01	-.15	.23	.56*	1

**. Correlation is significant at the. 01 level (2-tailed)

*. Correlation is significant at the. 05 level (2-tailed)

To further examine proprioception differences between participants, one-way multivariate analysis of covariance (MANCOVA) using total proprioception s as the fixed factor indicated no significant differences for soccer (3.25 versus 3.15), track (3.80 versus 2.30), of football (5.04 versus 5.25) although there was a tendency for greater proprioception among healthy participants (Table 2).

Table 2: Summary of proprioception MANCOVA results for healthy and injured participants.

Variable	Healthy (n= 28)		Injured (n= 10)			
	M	**SD**	**M**	**SD**	**F**	**P**
All Sports	3.95	2.67	3.27	2.09	2.20	0.15
Soccer	3.25	2.19	3.15	2.13	1.74	0.21
Track	3.80	1.96	2.30	0.00	0.53	0.51
Aussie Football	5.04	3.42	5.25	0.08	0.02	0.97

Using Location of Ankle Injury as Covariate
* $p<.05$
** $p<.01$

One-way analysis of variance (ANOVA) indicated no significant differences between left and right ankle proprioception among all sports [F (1, 37) = 1.49, p=0.23] (healthy *M* proprioception = 1.43, SD=.94, injured *M* proprioception = .97, SD=1. 200). One-way multivariate analysis of variance (MANOVA) using health as the fixed factor indicated a trend for higher outcome scores after Bonferroni adjustment on proprioception differences between the left and right ankle for soccer (1.37 correct versus .97), track (.97 versus .90), and football (1.72 versus .65) all favoring healthy over injured athletes (although the differences were not significant).

Table 3: Individual differences between left and right ankle proprioception.

Variable	Healthy (n= 28)		Injured (n= 10)			
	M	**SD**	**M**	**SD**	**F**	**P**
All Sports	1.43	0.94	0.97	1.20	1.49	0.23
Soccer	1.37	1.05	1.25	1.49	0.04	0.85
Track	0.97	0.64	0.90	0.00	0.01	0.92
Aussie Football	1.72	0.93	0.65	0.07	2.46	0.14

Note
* $p<.05$
** $p<.01$

Discussion

It is generally acknowledged that when a person experiences an ankle injury, they also suffer from a decrease in joint position sense (Han *et al*., 2016). Other impairments may be present as well, including: an antalgic gate, swelling, decreased range of motion, etc. As a result, these individuals are given various "proprioceptive" rehabilitative exercises to possibly correct this deficient. The results of this study concluded that there was no statistical significance difference in proprioception between injured and non-injured participants. Based on the literature, this finding is not expected. According to Mattacola and Dwyer (2002), deficits are prevalent in proprioception after an injury.

Although the analysis did not show a statistically significant correlation between ankles injured and proprioception deficit, there were other relationships noted which will be discussed next. There was a significant positive linear relationship between the proprioception values of the left and right foot of the participants, suggesting the inclinometer may also be of value in clinical practice where definitive measures of joint position sense, and/or an accurate reassessment of the individual's progress with rehabilitation, are desired. When comparing the other variables, some results were expected. These include: ankle injury and ankle rehab, ankle injury and ankle injured (left or right), and ankle rehab and ankle injured (left or right). The relationship between ankle injury and ankle rehab was expected because if an athlete injures their ankle, they are usually given a rehab protocol compared to non-injured athletes. The relationship between ankle injury and which ankle injured is expected because the injured athletes documented which ankle was injured, whereas it was not necessary for the non-injured group to document. It was also expected for there to be a relationship between ankle rehab and ankle injured, since the athletes who performed rehab had an ankle injury (left or right).

Current research is inconclusive when comparing ankle proprioception to functional ankle instability (FAI). The role of proprioception in daily activities, exercise, and sports has been extensively investigated, yet the proprioceptive mechanisms underlying movement control are still unclear. One issue is that numerous methods and instruments have been used to quantify joint position sense for the ankle. A similar study conducted by Witchalls *et al*. (2012) [15] found that individuals of the unstable ankle group were less accurate in differentiating inversion angles on a stepping mechanism. However, Hung (2015) [5] states that a consensus has not been reached as to whether or not neuromuscular control and proprioception are compromised in unstable ankles. The present study agrees with this finding, which did not clearly demonstrate that join position sense deficits exist following ankle injury.

One of the most common lower extremity injuries in athletics are ankle sprains. An ankle sprain occurs when the passive structures, likely the anterior talofibular ligament, of the foot or ankle are compromised. Once an athlete injures an ankle, they are more likely to suffer from a subsequent injury. The evidence to support the claim that joint proprioception is affected by ankle injuries is still inconclusive. With this, it is common practice to assign proprioceptive rehabilitative exercises to athletes with ankle sprains. Current evidence suggests that the best care for ankle sprains is injury prevention and this also aids in decreasing the chances of re-injury.

A limitation of the current study was the retrospective self-reporting analysis of the ankle sprains. Currently, there is no standard method of measuring joint proprioception of the ankle. Future research should consider a reliable method of testing ankle joint proprioception accurately and effectively. Future studies should also investigate the success of rehabilitation programs aimed at improving ankle joint position sense. Previous studies have conducted this type of research with the participants standing, sitting, and laying. Although, their p+urpose is to test ankle proprioception, weight bearing/body position should stay consistent when testing these variables.

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