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Effect of proprioceptive exercises on balance and center of pressure in athletes with functional ankle instability

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Abstract. The aim of the study was to analyze the effectiveness of proprioceptive exercises on joint position sense, balance and COP (centre of pressure) in athletes with functional ankle instability. *Material and Method.* 80 injured athletes (20 females, 60 males, age =18-25years) with a history of functional ankle instability volunteered to participate in this study. Athletes were randomly assigned to the experimental or control group. The experimental group participated in a 6-week proprioceptive-training protocol consisting of various proprioceptive exercises using rubber tube 3 times a week. The control group did not participate in the strength-training protocol. Wobble board balance test was performed to measure the balance and stability of athletes. Proprioception (Joint Position Sense) was measured using gravity inclinometer and center of pressure was analyzed by using force platform. *Conclusion:* The study concluded that six weeks of proprioceptive training had a significant effect on proprioception and balance measures in subjects with self reported unilateral functional instability.
Key words: *ankle instability, proprioception, balance, center of pressure, joint position sense.*

Introduction

Ankle ligamentous sprain injury is the most common single type of acute sports trauma (1). In cutting and jumping sports such as volleyball, football, soccer, and basketball, lateral ankle sprains are one of the most common injuries (2,3). Approximately 25% of all injuries in athletics are ankle sprains, and 85% of these injuries involve lateral ligament sprains (4). Lateral ankle sprains are also referred to as inversion ankle sprains or occasionally as supination ankle sprains. Individuals who suffer numerous repetitive ankle sprains have been reported as having functional instability (5, 2) chronic instability (6) and residual instability. The literature states that a combination of diminished proprioception and evertor muscle weakness could be a possible cause of recurrent ankle injury (7, 5) described this recurrent feeling of instability, or the sensation of the ankle ‘‘giving way,’’ as functional ankle instability. Functional ankle instability (FAI) is believed to occur from a combination of mechanical instability, ankle strength deficits, ligament deafferentation and proprioception deficits (1,8,9,).

The measurement of functional ankle instability up until recently, however, has been a challenge. Ankle Instability Instrument (10) and the Cumberland Ankle Instability Tool (11) have been developed to measure functional ankle instability. The literature shows that Ankle Instability Instrument a 12 item questionnaire is an objective and reliable method of identifying patients suffering from FAI based on instability symptoms(10). Cumberland Ankle Instability Tool is a simple, valid, and reliable tool to measure severity of functional ankle instability. Cumberland Ankle Instability Tool (CAIT) is a 9-item 30-point scale, for measuring severity of functional ankle instability. A score of $\leq$ 24 on the CAIT indicates the presence of Functional ankle instability (12).

Reviews have identified only a limited number of studies that have the appropriate methodology to examine the effectiveness of ankle sprain prevention measures in general (3, 13-16) examined the efficacy of proprioceptive training in particular. They demonstrated efficacy of balance training program by observing significant reduction in rate of ankle sprains in high school basketball and soccer players (13-14). Repetitive ankle joint injuries cause neurosensorial, proprioceptive and mechanical impairments.

Exercises that increase proprioception, balance and functional capacity are routinely performed after an ankle joint injury in addition to strengthening the muscles (17). The literature documented that ankle disk and balance training significantly reduces the risk of ankle sprains in adult athletes (13,11,18-20).

However, the efficacy of the balance training program has not been determined for the reoccurrence of the sprains in Indian athletes suffering from functional ankle instability.

Therefore, the purpose of our study was to determine whether an ankle-rehabilitation protocol consisting of proprioceptive exercises had an effect on joint position sense (JPS) and balance development in subjects with functionally unstable ankles.

Material and Methods

We conducted an experimental study to investigate the effect of propriocetive exercise training in athletes with Functional Ankle Instability. Measurements were completed in Human Performance Lab, Faculty of Sports Medicine and Physiotherapy, Guru Nanak Dev University, Amritsar. The study was approved by the Institution's Human Ethics Committee and written informed consent was gained from all participants before data collection commenced. Inclusion criteria for FAI included 1) self-report of a history of one sprain followed by at least 3 days of immobilization and 2)self-report of at least two ankle sprains and at least two episodes of "giving way" sensations during physical activity within the year before the subjects' enrollment in this study (21).

Subjects. 80 injured athletes (60 males, 20 females) were randomly assigned to the experimental (40 subjects, 30 males and 10 females, with mean age= 21.8±3.2years) and control group (40 subjects, 30 males and 10 females, with mean age=21.6±2.4 years). All athletes had a history of functional instability of the ankle diagnosed by a sports physician/orthopedic surgeon and no history of other lower extremity injuries or other neuromuscular deficits. Athletes with unstable ankles were tested on the same leg (dominant or nondominant) as their match. Dominance was defined as the preferred leg used to kick a ball. Exclusion criteria included acute ankle sprain or any bone fracture or any current musculoskeletal injury other than lateral ankle sprains that could interfere with the measurement procedure.

Test Procedures. Both the groups had undergone the testing procedure. Functional ankle instability was measured using the Ankle Instability Instrument. The tool is a questionnaire with 12 adjectival scale questions. The subjects were selected for the FAI group if they answered 'yes' to question 1 and 4 of the Ankle Instability Instrument (10).

Baseline readings of both the groups were recorded for Center of Pressure over Zerbis Force platform and Balance was measured on Electronic Wobble Board (KMS - Kinematic Measurement System, Fitness Technology, Australia). Proprioception was also analyzed by using Gravity Inclinometer. Athletes of the experimental group performed proprioception exercise training before undergoing the post readings.

Joint reposition sense measurements (Joint Reposition Sense Testing) were taken with a custom-designed Gravity Inclinometer. To initiate the test, the foot was placed in the neutral 0° position. All subjects were blindfolded to eliminate the contribution of visual cues during the repositioning of the joint. For familiarizing with the testing device, subjects were instructed to perform three active repetitions of all ankle movements. Subjects were unable to see their feet throughout the examination and had their eyes closed to concentrate on the measurements. For the passive angle reproduction, the foot was brought into one of the four testing positions (10°, 20° dorsiflexion, 15°, and 30° plantar-flexion) and was held for 2 sec. Then it was brought back in neutral position and back toward the testing position until the subjects indicated that they felt they had reached the same position. The foot was brought back in neutral position, and the next angle was chosen. Angles were given in random order and each angle was tested six times. Mean of all the movements dorsiflexion, planter-flexion, inversion and eversion had been taken. All joint position tests were performed by the same investigator. The difference of all predefined and reproduced angles was saved for analysis.

Static balance was measured by using Zerbis force platform (provided with WinFDM software). Prior to testing, subjects were allowed several practice trials with their eyes open and closed. To initiate the test, subjects placed their hands on their hips and raised the non-test limb. Contact was not allowed between the raised limb and the test limb. Subjects were instructed to stand as motionless as possible, looking straight ahead at a point on the wall 65 cm away. Tests were performed without shoes and socks to negate any extraneous skin sensation from clothing touching the foot area. Once subjects were in this position and stated that they were ready, data collection was initiated (22). Additionally, this single-leg balance protocol has been used in previous ankle instability studies (23,24). Subjects performed one 10-s practice trial, followed by three 20-s testing trials. Subjects rested 20 s between each trial. Trials were repeated if subjects hopped on the weight-bearing leg or touched down with the non-weight-bearing leg.

Balance and stability of the ankle was checked by using electronic wobble board, Kinematic Measurement System (KMS). The electronic wobble board was attached with the KMS software and the duration of the test was 20 seconds. During each 20-second testing procedure, subjects of the experimental group were asked to focus on an "X" marked on a wall directly in front of them while trying to maintain their balance on the board and simultaneously preventing the edge of the board from touching the ground. They stood with their knees slightly flexed (5°-15°) and their arms held at their sides. The test was considered valid if the wobble board did not touch its metal surface and was paralleled to the ground in neutral position.The test was repeated for 3 trails and the mean of these values was taken.

Training Procedure. Athletes in the experimental group trained with the unstable ankle 3 times a week for 30 minutes each day for 6 weeks (10). The training protocol was designed to provide propriocetive training and progressive resistive exercise and a sufficient training overload. The progressive training protocol (Table I) consisted of 6 weeks of strength training using elastic tubing (Thera-Band Tubing Resistive Exerciser, The Hygenic Corporation, Akron, OH) (10).

Table 1. Resistive Tubing Training Protocol (10)

Week	Tubing Sets x Repetitions
1	blue-extra heavy 3 x 10
2	blue-extra heavy 4 x 10
3	black-special heavy 3 x 10
4	black-special heavy 4 x 10
5	silver-super heavy 3 x 10
6	silver-super heavy 4 x 10

Proprioceptive training includes T-band kicks, balancing against the gym ball, balancing on wobble board, exercise mats, air squab and uneven walkway (25).

These exercises were aimed to improve primarily the proprioception as well as the strength of the ankle musculature in whole. For training, each subject sat on the floor with one end of the elastic band attached to a table and the other end attached to the leg. For all exercises, subjects remained on the floor in the seated or semi reclined position, with the knee fully extended. Subjects were instructed to use only the ankle joint and not to allow leg movement during the exercises. Once seated, subjects stretched the elastic band to a designated mark on the floor, which was calculated to be 70% of the band's maximal stretch. During each exercise session, subjects performed inversion, eversion, plantar flexion, and dorsiflexion. Control subjects were asked to refrain from proprioceptive training or applying other treatments to their ankles during the study period. However, they were permitted to continue normal daily activities and to maintain current physical activity levels (10).

Statistical Analysis. A simple paired t-test was used to compare the pre and post data values between the groups. An alpha level of $P < 0.05$ was used in determining statistical significance using the SPSS program for Windows, version 16.0.

Results

In table II, significant difference of ($p<0.05$) was observed in Path length and Standard Deviation Y in the experimental group. However, Standard Deviation X did not show much difference in the pre and post values with $p<0.05$. In table III, no significant difference ($p>0.05$) was observed in Pre and post values of Path length, Standard Deviation X and Y in Control group.

In table 4, Joint position Sense covariates like dorsiflexion, plantarflexion, inversion and eversion were measured. High significant difference ($p<0.05$) was seen in all the covariates in Pre and Post values of Experimental group.

In table V Joint position Sense, Significant difference of ($p<0.05$) was seen in Pre and Post values of dorsiflexion, inversion, plantarflexion and eversion in Control group.

In table VI, Variables of Balance testing like number of contacts, frequency, balance time, off balance time and balance ratio were measured using electronic Wobble board. In Experimental group, significant difference ($p<0.05$) were observed in pre and post values in number of contacts, frequency.

However, off balance time, balance time and balance ratio did not show significant difference. In table VII, significant difference (P<0.05) were observed in variables like number of contacts and off balance time in pre and post values of Wobble board balance testing in control group.

Table 2

Groups	Path length		Standard deviation X		Standard deviation Y	
	PRE	POST	PRE	POST	PRE	POST
Mean ± SD	956.63 ± 673.77	946.63 ± 673.16	101.54 ± 27.04	98.46 ± 32.36	19.13 ± 14.45	19.62 ± 13.83
T value	.695		.562		-.181	
P value	P <.491		P <.577		P <.857	

Table 3

Groups	Path length		Standard deviation X		Standard deviation Y	
	PRE	POST	PRE	POST	PRE	POST
Mean ± SD	1170.79 ± 627.30	873.50 ± 455.08	110.85 ± 25.92	103.30 ± 26.19	16.71 ± 12.87	17.86 ± 13.58
T value	7.28		1.879		-.460	
P value	P < 0.000		P<0.068		P< 0.648	

Table 4

Variables	Dorsiflexion		Plantarflexion		Inversion		Eversion	
	PRE	POST	PRE	POST	PRE	POST	PRE	POST
Mean ± SD	8.82 ± 3.12	2.82. ± 1.83	9.12 ± 3.09	2.67 ± 2.05	4.5 ± 1.03	1.4 ± 0.92	5.1 ± 1.41	1.85 ± 1.31
T value	15.55		15.86		23.30		15.86	
P value	.000		.000		.000		.000	

Table 5

Variables	Dorsiflexion		Plantarflexion		Inversion		Eversion	
	PRE	POST	PRE	POST	PRE	POST	PRE	POST
Mean ± SD	8.11 ± 3.22	6.19 ± 1.83	7.59 ± 2.77	6.73 ± 2.92	4.66 ± 1.39	3.80 ± 1.90	4.07 ± 1.06	3.14 ± 1.92
T value	8.22		2.99		3.53		2.94	
P value	.000		.005		.001		.005	

Table 6

Variables	No. of contacts		Frequency		Off balance ratio		Balance time		Balance ratio	
	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST
Mean ± SD	18.77 ± 3.77	13.22 ± 2.69	0.90 ±0.23	0.66 ± 0.13	13.33 ± 8.81	9.63 ± 4.62	6.86 ± 8.89	10.37 ± 4.62	-1.23 ± 8.47	1.93 ± 2.12
T value	11.96		6.66		2.47		-2.36		-2.14	
P value	.000		.000		.018		.023		0.39	

Table 7

Variables	No. of contacts		Frequency		Off balance ratio		Balance time		Balance ratio	
	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST
Mean ± SD	15.52 ± 3.77	13.75 ± 3.70	0.74 ±0.20	0.68 ± 0.18	12.89 ± 7.88	13.22 ± 10.38	7.32 ± 7.94	6.79 ± 10.38	0.77 ± 5.79	-.66 ± 8.93
T value	5.56		1.63		7.67		0.31		0.86	
P value	.000		.111		.000		.751		0.411	

Discussion

Our results indicate that ankle proprioceptive exercises improve inversion, planterflexion, dorsiflexion and eversion joint position sense in athletes with FAI in experimental group as compared to the athletes in the control group. The results are supported (10,26,19) who stated that there is a relationship between ankle joint function and proprioception. Theoretically, there are two possible sensory mechanisms that may have produced the change. It is possible that joint mechanoreceptors were stimulated by the motion of the exercise, resulting in an increased sensitivity. However, we also feel that Joint mechanoreceptors respond specifically to extremes in the range of motion and local compression. Since our testing procedure was done in extreme ROM, so we may say that joint mechanoreceptors were stimulated due to extreme ROM and compression (10,26,19). Docherty CL et al (10) has also mentioned the role of muscle spindle in improvement of joint proprioception. Muscle spindle receives static and dynamic gamma efferent nerves which enhances the afferent responses. The muscle spindle has two basic physiologic responses. The static response signals sustained spindle length (i.e. sustained muscle stretch) and instantaneous spindle length (27,28), while the dynamic response signals the rate of length changes. In addition to the sensory endings, the spindles also receive connections from static and dynamic gamma-efferent nerves, which enhance the afferent responses (29,30). We believe it is possible that the strength training may have increased gamma-efferent activity. Specifically, the spindle may have been more sensitive to instantaneous stretch, resulting in greater acuity in sensing joint position. It is also possible that dynamic gamma efference increased the sensitivity to the rate of length changes. However, because we used a relatively slow, active motion to assess JPS, it is unlikely that the dynamic spindle receptors were stimulated by our testing protocol.

One possible mechanism of improving balance in ankle injury has been documented in terms of muscle mechanoreceptors. Previous researches show that muscle and tendon vibrations produce a sensation of joint movement (31). Specifically, movement is sensed in the direction that a vibrating muscle would have been stretched. This indicates that muscle mechanoreceptors may aid in controlling joint motion and suggests that ankle rehabilitation might alter the sensitivity of these receptors. One mechanism of acutely altering muscle mechanoreceptor sensitivity is via muscular contraction. Previous research has shown increased Group I alpha sensory activity following muscle contraction (3). Researchers have also reported that coordination training alone has not impacted certain single leg balance COP measures of subjects with FAI (32,25,9). Our results corroborate with previous literature stating balance training to be an effective tool in reducing the reoccurrence of ankle sprains.

Thus our studies have shown an improvement in correlation with functional ankle instability symptoms. By promoting proprioception and balance in the athletes with functionally unstable ankle we can reduce the incidence of injury.

Conclusion

This study concluded that Six weeks of balance and proprioception training had shown an improvement in correlation with functional ankle instability symptoms. Our results are most likely due to changes in muscle spindle sensitivity or in central mechanisms related to the spindles, rather than joint mechanoreceptor sensitivity. We believe the training protocol may have increased the gamma motor activity, (30,29) improved central mechanisms of motor control (31) or produced a combination of central or spindle mechanisms. Future research should be designed to more specifically detect differences due to gamma activity, alpha-gamma coactivation, or central mechanisms.

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