Effect of Sensorimotor Training on Joint Proprioception and Isokinetic Strength Ratios in Subjects with Unilateral Functional Ankle Instability

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ABSTRACT

Inversion ankle sprains can lead to a condition called functional instability (FAI). Sensorimotor deficits are well documented in subjects with FAI. This study investigated the effect of sensorimotor training on proprioception and isokinetic strength ratios in subjects with unilateral functional ankle instability, and to determine the association between functional level of the ankle and both proprioception and strength ratio. Forty subjects of both sexes with functional ankle instability were included in the study. Their main age was 19.7± 2.2 years; height 170 ± 3.1 cm and weight 72.6 ± 3.4 kg. They were divided into two equal matched groups. Control group, received no intervention and study group, received sensorimotor training. Blinded assessment was conducted at the beginning of the study and after 6 weeks. Assessment included proprioception, eversion to inversion isokinetic strength ratios (E/I ratios), and functional level of the affected ankle. Analysis of results revealed that study group receiving sensorimotor training recorded statistically significant improvements of proprioception, E/I ratio and functional level. While the control group receiving no training, recorded non significant changes of all measured parameters. Furthermore study group showed significantly better improvement of proprioception, E/I ratios and functional level than the control group. There were significant correlations between functional level and both proprioception E/I strength ratios. SMT could be an effective mean of improving joint proprioception and enhancing muscle balance around the joint which might have positive effects on functional level.

Key Words: Functional ankle instability, sensorimotor motor training, proprioception strength ratio.

INTRODUCTION

Functional ankle instability (FAI) is a subjective sensation of giving way or feeling joint instability after repeated ankle sprains episodes[11]. FAI may be present in up to 40% of subjects after a lateral ankle sprain[16]. Furthermore, it was reported that in subjects with FAI, as the joint becomes unstable over time and continues to roll past its physiologic limits, the risk of damaging the articular surface within the joint and developing osteoarthritis increases[2,18]. The pathogenesis of FAI is thought to involve loss of neuromuscular control. Components of neuromuscular control include proprioception, muscle strength, muscle reaction time, and postural control[17,30].

Damage to mechanoreceptors within the lateral ankle ligaments after injury is hypothesized to interrupt neurologic feedback mechanisms resulting in altered input to nervous system. This altered input can lead to weakness of muscles surrounding the joint or arthrogenic muscle inhibition[19,32,36]. Deficit in musculature of the ankle joints especially evertors and planter flexors had been recognized and reported[3,9].

Co-activation of antagonistic muscle groups has been identified as an important factor influencing dynamic joint stability[4]. It was hypothesized that providing strength information on the nature of the agonist and antagonist muscle group relation will create a more complete picture of the true dynamic nature of the muscles function[1].

Some studies had been conducted to examine the reciprocal muscle group ratios in the ankle joint particularly, dynamic strength control incorporating both concentric and eccentric muscle actions. They recommended the use of those ratios to detect muscle imbalances in an attempt to prevent injury and also to evaluate rehabilitation progress[6,15,36].

In functionally unstable ankle joint, the strength ratios measurements reported include concentric eversion /eccentric inversion ratio. This ratio expresses the viewpoint of the evertors acting concentrically to counteract the violent inversion mechanism that occurs

actually during ankle sprain. The normal E/I ratio is considered to be 60%: 80% as averaged through full range of ankle motion. As the ratio approaches 100%, the evertors have an increased functional capacity for providing stability to ankle joint[10,14,23].

Many rehabilitation programs have been recommended for individuals with unstable ankles to improve joint proprioception, muscle strength and postural control[5,7,8,13,24]. It was suggested that the sensation of joint movement may be enhanced by improved mechanoreceptor function, which may lead to the restoration of the neuromuscular control of the joint. This restoration of the neuromuscular feedback loop may be a key factor that determines a positive outcome of the rehabilitation program[5,32]. Furthermore it was suggested that neuromuscular control can be better restored through training that is mediated through central nervous mechanisms[30].

Sensorimotor training (SMT) is a form of exercise aiming to decrease muscle imbalance by maximizing the sensory input coming from three sites in the body where there is a large number of proprioception (the foot, sacroiliac joint, cervical spine), which in turn increases the nervous system's ability to generate a fast and optimal muscle firing pattern, increase dynamic joint stability and improve motor control. Sensorimotor training emphasizes motor control through progressive challenges to sensory motor system through static, dynamic and functional situations to restore normal motor programs[12,26,29,31]. SMT has been sued to improve sensorimotor function and motor control of many musculoskeletal disorders[21,34], but the effectiveness of SMT in improving sensorimotor function in subjects with functional ankle instability has yet to be investigated.

The current study was designed to investigate the effect of six weeks of SMT on ankle joint proprioception and isokinetic eversion to inversion strength ratios in subjects with unilateral FAI. Also, to determine whether there were relation between functional level of the involved ankles and both proprioception and strength ratios.

MATERIALS AND METHODS

Subjects

Forty subjects of both sexes with unilateral functional ankle instability selected from the students of Faculty of Physical Therapy, Cairo University participated in this study. Their main age was 19.7± 2.2 years, height 170 ± 3.1 cm and weight 72.6 ± 3.4 kg. Subjects were examined by the same clinician and were included if they had experienced at least one significant lateral ankle sprain of one ankle within the last year and suffered repeated episodes of giving way. Not undergoing any formal or informal rehabilitation of the unstable ankle. Subjects were excluded if they had mechanical instability, ankle joint swelling, any rheumatologic disorders, or any systemic disease that might interfere with sensory input. Also ankle surgery or fracture in either leg and gross limitation in ankle range of motion were excluded[22].

Study Design

This was Pretest- posttest control group design. Subjects were assigned into two equal groups which were matched in terms of age, weight, height and sex. Study group received SMT for six weeks. Control group received no intervention.

Testing Procedures

Measurements included ankle proprioception, isokinetic evertors to invertors strength ratios, and functional assessment. Measurements were conducted at the beginning of the study and after six weeks at termination of the treatment by an assessor who was blinded about subject group allocation.

Measurement of Proprioception

Proprioception accuracy was determined using the passive-active joint position reproduction method which has been reported to be a valid method in evaluation of proprioception[28]. Biodex 3 Pro multijoint Isokinetic dynamometer (Biodex medical inc., Shirley, NY) was used to test the ability of the patient to actively repeat the passively

positioned joint angle. The target angle was 15 degree eversion and the test was repeated 3 times and the difference between the target angle position and the patient perceive end range position was calculated and averaged.

Isokinetic strength ratio measurement

Isokinetic strength ratio of evertors to invertors was measured using Biodex 3 Pro multijoint Isokinetic dynamometer (Biodex medical inc., Shirley, NY). The assessment was conducted at the Isokinetic Lab, Faculty of Physical Therapy, Cairo University. Biodex Isokinetic dynamometer allows reliable measurement of muscle torque which reflects the muscle strength capacity[20]. Each patient was informed about the steps of the test procedures and the apparatus was calibrated according to the manufacture manual. The test was performed according to the protocol of Hartsell and Spaulding[14]. Each subject was seated on the dynamometer chair in a supine lying position with the tested lower limb in a position of hip flexion 60 degree, knee flexion 30 degree and ankle in neutral position. The subject was stabilized with straps securing the chest and waist. The lower leg was stabilized using universal stabilizer of the apparatus to prevent unwanted substitution. The foot was securely fastened into the ankle inversion/eversion footplate attachment using Velcro closures. All tests were performed with the subject wearing shoes. The start and stop angles for eversion to inversion motion were set at 15 and 25 degrees respectively and the inversion to eversion angles were set at 25 to 15 degrees respectively. These ranges of motion stops were chosen so that the test protocol was standardized for all subjects. This procedure allows all subjects to perform the required motion within a 40 degree range.

Isokinetic tests protocol was selected (eversion concentric/inversion eccentric at 30˚/s). To become familiar with the test, especially the eccentric mode, each subject was allowed three submaximal (50% capacity) warm up repetitions then a two minutes rest was provided at the end of the warm up. Three maximal eccentric and concentric test repetitions were completed through the 40 degree range of motion. The subject was allowed of one minute rest between each repetition. Subject was instructed to provide maximal effort during test and was given both verbal and visual feedback and encouragement. Peak torque was recorded and averaged for the three trials in Newton-meters. The evertors/ invertors (E/I) ratios were then derived by taking the concentric eversion value and dividing it by the eccentric inversion values for the peak torque.

Functional Assessment

Ankle Joint Functional Assessment tool (AJFAT) was used to assess functional level of the ankle. The validity and the repeatability of this scale have been demonstrated [33]. It is composed of 12 questions rating the ankle's functional ability. For each question, 5 possible answers were assigned a point value, which ranged from 0 to 4. The overall test score was calculated by the summation of the point values from the answers of the 12 questions (maximum value = 48). A higher overall score represented a greater perceived functional ability of the involved ankle.

Sensorimotor training program:

Subjects in the study group were engaged in 6 week SMT, 6 times per week, for 30 minutes per session, each exercise was repeated 3-5 times during session and with two minutes period of rest between each set of exercises. The program gradually increased in difficulty and the subjects were supervised to ensure that the training was performed accurately and the patient was not graduated to a more difficult stage until performing the easier one. Patients were trained through three stages, static, dynamic and functional. Within each stage patients progress through exercises in different postures, bases of support, and challenges to their center of gravity according to the following protocol[21,26,29].

1st and 2nd weeks. First phase (Static)

1- Short foot: formation of an actively shortened longitudinal arch of the foot without flexion of the toes (The Subject was progressed to forming the ‘‘short foot’’ with the active assistance (semi-active), and then finally they performed it actively.

2- Standing upright position (30 seconds) On firm surface then on soft surface (on a mat).
3- Single leg Stance with closed eyes (affected limb then non affected limb) for 10 seconds on firm surface then on soft surface (on a mat).

3rd and 4th weeks. Second stage (Dynamic) in addition

Forward stepping lunge.

5th and 6th weeks. Third phase (Functional) in addition

1- Walking exercise, on a firm surface then on a foam surface.

a) Toe skipping with toes straight a head for 20 meters, toes pointing outward for 20 meters and toes pointing inward for 20 meters.
b) Heel skipping with toes straight a head for 20 meters, toes pointing outward for 20 meters and toes pointing inward for 20 meters.

2- Balance exercise on wobble board.

a) Anteroposterior rolling movement from sitting using both feet then affected foot with eyes open then eyes closed.
b) Mediolateral rolling movement from sitting using both feet then involved foot with eyes open then eyes closed.
c) Multidirectional rolling movement from sitting using both feet then involved foot with eyes open then eyes closed.
d) Anteroposterior rolling movement from standing using both feet then affected foot with eyes open then eyes closed.
e) Mediolateral rolling movement from standing using both feet then involved foot with eyes open then eyes closed.
f) Multidirectional rolling movement from standing on both legs then affected one with eyes open then eyes closed.

Data Analysis

Statistical analysis was performed using "SPSS" for windows evaluation version 15.0. Descriptive statistics in the form of mean and standard deviation of the pre and post treatment were calculated. Paired t test comparing pre and post measurements was performed for individual group. Independent t test was used to determine differences between both groups at pre and post measurements. The degree of association between functional level of ankle joint and both joint proprioception and E/I strength ratios was estimated using Pearson correlation. Significance level was set at (0.05).

RESULTS

There were no significant differences between both groups with respect to age, body weight, or height (P> 0.05) as shown in table 1.

Table (1): Characteristics of the patients in both groups.

	Age (Years)		Weight (Kg)		Height (Cm)	
	Study	Control	Study	Control	Study	Control
Mean	19.8	19.9	71.5	72.7	171	169
SD	1.9	2.5	4.8	3.9	2.9	3.3
t	1.23		0.11		0.89	
P	0.23		0.91		0.37	

Proprioception accuracy

As shown in table (2) and figure (1), Regarding changes in proprioception, when comparing pre and post exercise scores statistically significant improvement was obtained in proprioception in the study group trained with sensorimotor training (P< 0.0001) with a percentage of change 44.26%. While there was no statistically significant change of proprioception in the control group receiving no training (P= 0.15) with a percentage of change -5.7%. On comparison of both groups, there were no significant differences at pre exercises (P= 0.48) but at post exercise there were significant improvements of proprioception in the study group compared to control group (P< 0.000) (Table 3).

Table (2): Comparison of measured parameters at pre and post in both control and study groups.

Measured parameters	Control		Study	
	Pre	Post	Pre	Post
	Mean± SD	Mean± SD	Mean± SD	Mean± SD
Proprioception	5.2± 0.65	5.5±0.77	6.1±0.22	3.4±0.36
	t= 1.47, P= 0.15		t=6.3, P= 0.000*	
E/I ratio	0.42±0.09	0.41±0.07	0.43±0.04	0.77±0.05
	t= 0.64, P= 0.6		t=3.3, P= 0.007*	
Functional level	15.3±2.3	14.6±1.7	16.5±3.2	30.4±2.1
	t= 1.1, P= 0.2		t=8.5, P = 0.000*	

E/I ratio: evertors/Invertors ratio, Significant:*

E/I strength ratios

When comparing pre and post measurements using paired t-test, there was significant increase of E/I strength ratio of the study group (P= 0.007), meanwhile there was non significant decrease (P= 0.6) in that of the control group receiving no training, table (2). The percentage of changes in both study and control groups were 79% and -2.3% respectively figure 1. When comparing the E/I strength ratios between both groups using independent t-test, revealed no significant difference between both groups at pre measurement (P= 0.51), while at post measurement study group recorded significant increase than control group (P= 0.000), table 3.

Table (3): Comparison between control and study groups at pre and post measurements.

Measured parameters	Pre		Post	
	t	P	t	P
Proprioception	0.7	0.48	9.2	0.000*
E/I ratio	0.66	0.51	12.2	0.000*
Functional level	1.26	0.21	17.5	0.000*

E/I ratio: evertors/Invertors ratio, Significant:*

Functional level

Table (2) and figure (1) demonstrated the AJFT scores which reflect the functional level of the affected ankle pre and post treatment for both groups. In the study group, there was a significant increase of the post scores compared to pre scores (p= 0.000) with a percentage of change 84.2%, while in the control group there was non significant decrease of post scores compared to pre scores (P= 0.2) with a percentage of change -4.5% . When comparing both groups, there was non significant difference between both groups at pre measurement (P= 0.21) and significant increase of the functional level of the study group than those of the control group (P=0.000), table 3.

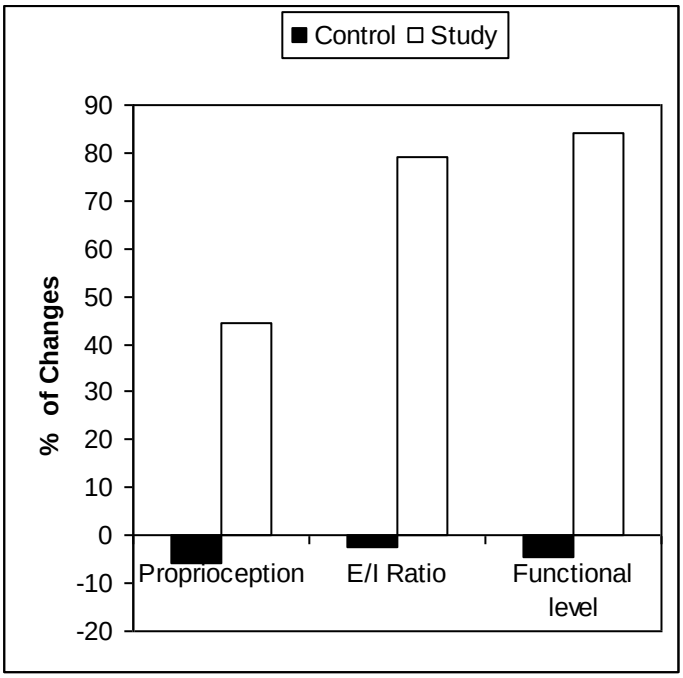

Fig. (1) Percentage of changes of the measured parameters in study and control groups.

Correlation of quadriceps CAR and tested parameters

At pre, and at post measurement, a significant indirect correlation was observed between functional level and proprioception accuracy. Also significant direct correlation was observed between functional level and E/I strength ratio, table (4).

Table (4): Correlation coefficient between functional activity level and both proprioception and E/I ratio measures at pre and post exercise.

Balance measures	Pre		Post	
	R	P	R	P
Proprioception	0.6	0.0004*	0.8	0.0001*
E/I ratio	0.5	0.0007*	0.6	0.0004*

E/I ratio: evertors/Invertors ratio, Significant:*

DISCUSSION

Functional ankle instability after ankle sprain is frequently seen in clinical. FAI is proposed to be due to a deficit of sensorimotor control. It was suggested that damage to mechanoreceptors which are present in the structures of the lateral aspect of the ankle including the lateral ligaments, capsule, and retinaculum by inversion ankle sprain might result in functional instability[11,16]. This damage to joint receptors leads to delays in afferent conduction to recruit corrective muscle contractions from efferent signals in response to perturbation, ultimately altering joint stability. Also disruption of muscle spindle activity after joint injury as possibly was proposed as contributing to deficits in neuromuscular control among FAI sufferers[17,25,28,30,32].

The purpose of the current study was to determine changes of proprioception E/I strength ratios and functional level after six weeks sensorimotor training in subjects with unilateral functional ankle instability.

Subjects in both groups were matched in age, height and weight, as there was no significant difference between the two groups regarding age, height and weight. So this

indicates that the differences found in this study were due to the effect of the training.

The results of the current study demonstrated that six weeks of sensorimotor training improves proprioception in subjects with FAI. SMT retrain altered afferent pathways so as to enhance the sensation of joint movement[29,34]. In the training protocol used in the current study, joint stability was trained by co-contraction and balance training with closed-chain exercises which might induce maximal stimulation of joint, muscles and mechanoreceptors found about the lower limb. During sensory motor training, subjects in this study had to consciously manipulate their ankle position and keep balance to coordinate the various exercises. Moreover, to incorporate the visual and vestibular inputs, subjects were trained with the eyes opened then closed, during the sitting and standing positions, through firm and then soft surface and in stable and then unstable surface[21,26,29].

Furthermore it was proposed that for a training program to be successful, it must include activities that involve three levels of motor control. The first level is the reflex joint stabilization responses of the spinal cord which can be improved by activities that focus on sudden changes in joint positioning and stimulate reflexive neuromuscular control. The second is motor function at the brain stem level which can be enhanced by performing balance and postural activities with and without visual input. The third is motor control at the cerebral level which can be improved by performing joint repositioning activities. These activities will promote conversion of conscious to unconscious motor programming so that the cerebral cortex can determine the most appropriate motor response for a given activity[35].

In the current study, we planned to measure dynamic muscle function not isolated muscle action. So choosing to measure E/I strength appeared appropriate. Reciprocal muscle action and strength ration between agonist antagonist have received considerable attention from clinicians for assessment and in monitoring rehabilitation progress[10,14,15,22]. With the advance in isokinetic dynamometers, it is now possible to assess both concentric and eccentric muscle actions which enable to examination of the reciprocal muscle group ratios[1].

The E/I strength ratios measured from both study and control groups were lowered than normal reported values in both groups. It was reported that incomplete and delayed activation of the muscle surrounding ankle joint could prevent adequate control of the ankle joint leading to repeated episodes of instability[19]. Also it was reported that dynamic peroneal activity is impaired in subjects with FAI which may contribute to recurrent joint instability and may leave the ankle vulnerable to injurious loads[27].

The present study presented significant increase in E/I strength ratios in the study group which received sensorimotor training compared to the control group which received no training. On an attempt to explain that affect, it was proposed that SMT maximize sensory input about joint position and change in muscle length and tension to the central nervous system which in turn improves nervous system's ability to generate a fast and optimal muscle firing pattern. Moreover SMT decreases muscle imbalance and improve motor control[12].

Another finding of the present study was the positive effect of sensorimotor training on functional level of involved ankle joint as reflected in the significant higher scores of AJFAT in the study group than that of control group. This may be due to the improved mechanoreceptor function, which could lead to restoration of neuromuscular control of the joint. This restoration of the neuromuscular feedback loop may be a key factor that causes a positive outcome. Also in SMT subjects progress through static, dynamic, and functional phases which challenged their balance capabilities. The additional exposure to these activities may have allowed them to develop adequate motor skills for dealing with potentially destabilizing forces on the ankle that may be encountered during recreational activities and activities of daily living[29]. The AJFAT used in the study to rate the functional level of the ankle joint was reported to be valid method of quantifying the subjective changes following intervention, which aided the clinicians in rating the functional ability of ankle[33].

The finding of the study demonstrated significant relation between functional level of the involved ankles and both joint proprioception and E/I strength ratios. This again may explain the positive effect of sensorimotor training on functional level shown in the study, which may be due to improvements of both proprioception and E/I strength ratios recorded in the current study. Consistent with our results previous researches reported that lowered functional level of ankle joint was associated with decline in muscle strength and impaired sensorimotor control[2,8]. Also improvement of functional level of ankle joint in subjects with FAI after rehabilitation and training programs was reported to be correlated with improvement of proprioception and muscle strength[13].

Conclusion

From this study, it might be concluded that six weeks of sensorimotor training could be useful in improving proprioception and muscle balance which might result in higher functional level of subjects with FAI. Clinically, as sensorimotor training is efficient and safe, the implementation of this training into clinical practice is feasible. Further studies comparing the effect of sensorimotor training with other types of training in subjects with FAI are needed. More studies with long term follow up are needed.

REFERENCES

1- Aagaard, P., Simonsen, E.B. and Magnusson, S.P.: A new concept for isokinetic hamstring: quadriceps muscle strength ratio. Am J Sports Med. 26: 231-237, 1998.
2- Ananda, A. and Barnsley, L.: Long term outcomes of inversion ankle injuries. Br J Sports Med. 39(3): 14-20, 2005.
3- Arnold, B.A., Linens, S.W., Motte, S.J. and Ross, S.E.: Concentric evertor strength differences and functional ankle instability: A meta-analysis. J Athl train. 44(6): 653-662, 2009.
4- Baratta, R., Solomonov, M. and Zhou, B.H.: Muscular coactivation: the role of the antagonist musculature in maintaining knee stability. Am J Sports Med. 16: 113-122, 1998.
5- Blckburn, T., Guskiewicz, K.M. and Petschauer, M.A.: Balance and joint stability: the relative contributions of proprioception and muscular strength. J Sport Rehabil. 9: 315-328, 2000.
6- Buckley, B.D., Kaminiski, T.W. and Powers, ME.: Using reciprocal muscle group ratios to examine isokinetic strength in the ankle: a new concept. J Athl Train. 35:S93, 2001.
7- Clark, V.M. and Burden, A.M.: A 4-week wobble board exercise programme improved muscle onset latency and perceived stability in individuals with a functionally unstable ankle. Phys. Ther. Sport. 6: 181-187, 2005.
8- Docherty, C.L., Arnold, B.L. and Moore, J.H.: Effects of strength training on strength development and joint position sense in functionally unstable ankles. J Athel Train. 33: 310-314, 1999.
9- Fox, J., Docherty, C.L. and Applegate, T.: Eccentric planter flexor torque deficits in participants with functional ankle instability. J Athl Train. 43(1): 51-54, 2008.
10- Frankline, P.J., Kaminski, T.W. and Horodiski, M.P.: An examination of eversion/inversion isokinetic strength rations between uninjured and functionally unstable ankles. J Athl Train. 34: S72, 1999.
11- Freeman, M.A., Dean, M.R. and Hanham, I.W.: Instability of the foot after injuries to the lateral ligaments of the ankle. J Bone Joint Surg (Br). 47: 678-685, 1965.
12- Gruber, M., Gruber, S.B., Taube, W., Schubert, M., Beck, S.C. and Gollhofer, A.: Differential effects of ballistic sensorimotor training on rate of force development and neural activation in humans. J. Strength cond. Res. 21(1): 274-282, 2007.
13- Hale, S.A., Hertel, J. and Olmsted-Kramer, L.C.: Lower extremity function improves after rehabilitation for chronic ankle instability. J. Orthop. Sports Phys. Ther. 37: 303-311, 2007.
14- Hartsell, H.P. and Spaulding, S.J.: Eccentric/concentric ratios at selected velocities of the invertors and evertors muscles of the chronically unstable ankle. Br J Sports Med. 33: 255-258, 1999.
15- Hartsell, H.P.: Isokinetic muscle strength ratios of the ankle invertors/evertors: a pilot study. Isokinetic Exercise Science. 4: 116-121, 1994.
16- Hertel, J.: Functional instability following lateral ankle sprain. Sports Med. 29 (5): 361-371, 2000.
17- Hertel, J.: Sensorimotor Deficits with ankle sprains and chronic ankle instability. Clin. Sports Medicine. 27(3), 2008.

18- Hintermann, B., Boss, A. and Schafer, D.: Arthroscopic findings in patients with chronic ankle instability. Am. J. Sports Med. 30:402-409, 2002.
19- Hopkins, J.T., McLoda, T. and McCaw, S.: Muscle activation following sudden ankle inversion during standing and walking. European Journal of Applied Physiology. 99(4): 371-378, 2007.
20- Iossifidou, A.N. and Baltzopoulos, V.: Peak power assessment in isokinetic dynamometry. Eur J Appl Physiol. 82: 158-160, 2000.
21- Janda, V. and Vavrova, M.: Sensory motor stimulation. In: C. Liebenson, Editor, Spinal rehabilitation: a manual of active care procedures, Williams and Wilkins, Baltimore, 319-328, 1996.
22- Kaminiski, T.W., Buckley, B.D. and Powers, M.E.: Effect of strength and proprioception training on eversion and inversion strength ratios in subjects with unilateral functional instability.Br J Sports Med. 37: 410-415, 2003.
23- Kaminiski, T.W., Buckley, B.D. and Powers, M.E.: Eversion and inversion strength ratios in subjects with unilateral functional instability. Med Sci Spors Exerc. 33: S 135, 2001.
24- Kidgell, D.J., Horvath, D.k, Jackson, B.M. and Seymour, P.J.: Effect of six weeks of dura disc and mini-trampoline balance training on postural sway in athletes with functional ankle instability. J. strength Cond. Res. 21(2): 466-469, 2007.
25- Lentell, G., Baas, B. and Lopez, D.: The contributions of proprioceptive deficits, muscle function and anatomic laxity to functional instability of the ankle. J. Orthop. Sports Phys. Ther. 21: 206-215, 1995.
26- Liebenson, C.: Sensory motor training- an update. J. Bodywork and Movement Therapies. 9(2): 142-147, 2005.
27- McVey, E. D., Palmereri, R.M. and Docherty, C.L.: Arthrogenic muscle inhibition in the muscles of subjects exhibiting functional ankle instability. Foot Ankle Int. 26(12): 1055-1062, 2005.
28- Nakasa, T., Fukuhara, K. and Adachi, N.: Deficit of joint position sense in the chronic unstable ankle as measured by inversion angle replication error. Arch. Orthop. Trauma Surg. 128: 445-449, 2008.
29- Page, P.: Sensorimotor training: A 'global' approach for balance training. J. Bodywork and Movement Therapies. 10(1): 77-84, 2006.
30- Richie, D.H.: Functional instability of the ankle and the role of neuromuscular control: a comprehensive review. J. Foot Ankle Surg. 40(4): 240-251, 265-267, 2001.
31- Riemann, R.L. and Lephart, S.M.: The sensorimotor system. Part I: The physiologic basis of functional joint stability, J Athlet Train 37 (1): 71-79, 2002.
32- Riemann, R.L. and Lephart, S.M.: The sensorimotor system, Part II: The role of proprioception in motor control and functional joint stability. J. Athl. Train. 37(1): 80-84, 2002.
33- Ross, S.E., Guskiewicz, K.M. and Gross, M.T.: Assessment tools for identifying functional limitations associated with functional ankle instability. J. Athl. Train. 43(1): 44-50, 2008.
34- Tsauo, J.Y., Cheng, P.F. and Yang, R.S.: The effects of sensorimotor training on knee proprioception and function for patients with knee osteoarthritis: a preliminary report, Clin Rehabil, 22(5): 448-457, 2008.
35- Warren, W.H.: The dynamics of perception and action. Psychological Review. 113: 358-389, 2006.
36- Willems, T., Witvrouw, E., Verstuyft J., Vaes P. and De Clercq, D.: Proprioception and muscle strength in subjects with a history of ankle sprains and chronic instability. J. Athl Train. 37: 487-493, 2002.

الملخص العربى

تأثير التمرين الحسى الحركي على وضع المفصل من الحركة ومعدل القوة العضليه الأيزوكينيتيه في الأشخاص الذين لديهم عدم ثبات وظائفي لمفصل الكاحل

إلتواء مفصل الكاحل إلى الداخل يمكن أن يؤدى إلى عدم ثبات وظائفي لمفصل الكاحل .أن الإختلال الحسى الحركى تم إثباته فى حالات عدم ثبات وظائفي لمفصل الكاحل. قامت هذه الدراسه بدراسة تأثير التمرين الحسى الحركي على وضع المفصل من الحركة ومعدل القوة العضليه الأيزوكينيتيه في الأشخاص الذين لديهم عدم ثبات وظائفي لمفصل الكاحل وكذلك لتحليد العلاقة بين المستوى الوظيفى لمفصل الكاحل وكل من وضع المفصل من الحركة ومعدل القوة العضليه الأيزوكينيتيه.أجريت هذه الدراسة على أربعون شخص من كلا الجنسين لديهم عدم ثبات وظائفي لمفصل الكاحل و متوسط أعمارهم 19,7± 2,2 عاماو و أطوالهم 170±3,1سم و أوزانهم 72,6±3,4 كجم. تم تقسيم الأشخاص إلى مجموعتين ، المجموعة الضابطه لم تتلقى اى نوع من التمرينات ومجموعة الدراسة تم تدريبها بالتدريبات الحسية الحركية . تم تقييم جميع المرضى بواسطة مقيم خارجى فى بداية التجربه و بعد ستة اسابيع. اشتملت القياسات على وضع المفصل من الحركة ومعدل القوة العضليه الأيزوكينيتيه و المستوى الوظيفى لمفصل الكاحل. أظهرت المعالجات الإحصائية للنتائج وجود تحسن ذو دلالة إحصائية فى في مجموعة الدراسة التي تم تدريبها با لتدريبات الحسية الحركية وضع المفصل من الحركة ومعدل القوة العضليه الأيزوكينيتيه و المستوى الوظيفى لمفصل الكاحل. بينما كان هناك ذيادة ليست ذات دلالة إحصائية في اى من القياسات بالنسبه للمجموعة الضابطة. بالمقارنة بين المجموعتين تبين وجود تحسن ذو دلالة إحصائية في مجموعة الدراسة عنه في المجموعه الضابطة فى كل من وضع المفصل من الحركة ومعدل القوة العضليه الأيزوكينيتيه و المستوى الوظيفى لمفصل الكاحل. كما وجدت علاقة ذات دلالة إحصائية بين المستوى الوظيفى لمفصل الكاحل وكل من وضع المفصل من الحركة ومعدل القوة العضليه الأيزوكينيتيه. أثبتت هذه الدراسه ان استخدام التدريبات الحسية الحركية يمكن أن يحسن كل من وضع المفصل من الحركة و التوازن العضلى حول المفصل و يؤثر إيجابيا على المستوى الوظيفى .