VALIDITY OF PROPRIOCEPTIVE REHABILITATION FOR ANKLE INSTABILITY BASED ON FREEMAN BOARD TRAINING

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Abstract

Background: Ankle joint sprain and the subsequent development of chronic ankle instability (CAI) are commonly encountered by clinicians involved in the treatment and rehabilitation of musculoskeletal injuries. It has recently been advocated that ankle joint post-sprain rehabilitation protocols should incorporate dynamic neuromuscular training to enhance ankle joint sensorimotor capabilities.

Objective: up to date, many studies have reported the effects of Proprioception training on ankle joint stability. But fewer who studied the validity of dynamic Proprioception on ankle instability. The purpose of this pilot study was to conduct the effects of a 4-week dynamic neuromuscular training program in addition to the rehabilitation treatment for ankle instability

Methods: 26 sportive men were exposed to a progressive 4-week dynamic neuromuscular training program which incorporated postural stability, strengthening, plyometric. The following criteria were considered: Number of shaking of leg in a minute standing on freeman board (one minute stand), Time of balance on freeman board (balance), Maximal resistance for ankle dorsal flexion, plantar flexion, Inversion and eversion,Muscle reaction for ankle dorsal flexion, plantar flexion, Inversion and eversion. Measurements were rated within 3 trials for each criterion before and after each session for the affected leg. For the non-affected leg same criteria were measured before and after session without applying the rehabilitation protocol

Results: a high significant ($p=.000<0.05$) a progress is noted during rehabilitation protocol,. Results show high correlation between one minute stands and balance; one minute stand and muscle reaction; balance and maximal resistance was significant. Results show non-significance of correlation between muscle reaction and maximal resistance for ankle dorsal flexion, plantar flexion, Inversion and eversion. Moreover, we can notice that training period has had a slight effect on the non-affected side.

Conclusions: The 4-week dynamic neuromuscular training program improves the parameters of ankle joint sensorimotor control in an athlete with CAI.

Keywords: CAI: chronic ankle instability, MI: mechanical instability, FI: functional instability, RM: Maximal resistance

Introduction

The human ankle joint is one of the most frequently injured joints in the human body, with lateral ligament sprains being the most common type of ankle injury. Ankle sprain injuries are the most common injury sustained during sporting activities. It accounts for up to 40% of all athletic injuries and is most commonly seen in athletes participating in basketball, soccer, running, and ballet/dance. Up to 53% of basketball injuries and 29% of soccer injuries can be attributed to ankle injuries and 12% of the time lost in football is due to ankle injuries. Recent epidemiological studies in high school athletes have found ankle sprains to be the most prevalent soccer injury amongst boys and girls. (16% and 20% respectively).

Ankle ligament sprains were also the most common injury pattern in basketball, usually occurring from jumping and landing, being stepped on, and rotation around a planted foot.

Three-quarters of ankle injuries involve the lateral ligamentous complex with an equal incidence between males and females. Subjects who describe the presence of feelings of ankle joint instability and reported episodes of “giving way” are considered to have functional instability (FI). Two other frequently used terms include mechanical instability (MI) of the ankle joint and chronic ankle instability (CAI). MI of the ankle joint refers to the presence of increased hindfoot inversion laxity or excessive anterior talocrural excursion, while CAI is used as an all-encompassing term to indicate the presence of both FI and MI. Most ankle sprains do not develop lateral ligamentous instability and those that do are thought to be due to a loss of mechanoreceptors. Eighty percent of acute ankle sprains make a full recovery with conservative management, while 20% of acute ankle sprains develop mechanical or functional instability resulting in chronic ankle instability. Chronic ankle instability can lead to early degenerative changes in the ankle due to unbalanced loading on the medial side of the ankle. The treatment and rehabilitation of individuals with chronic ankle instability CAI poses a significant challenge for clinicians, and has enormous healthcare and economic costs. Numerous surgical procedures have been described for the treatment of chronic lateral ankle instability beginning with Elmslie, in 1934, who first reported using fascia lata graft to reconstruct the lateral ankle ligaments. Today, surgical treatment of lateral ankle instability can be divided into anatomic repair, non-anatomic reconstruction, and anatomic reconstruction. A number of studies have investigated the effect of various rehabilitation protocols on ankle joint sensorimotor control. However, many studies have examined the effect of neuromuscular training on ankle joint positioning at initial contact during walking and jump landing, the effects of dynamic neuromuscular training protocols on established ankle joint injury risk factors and sensorimotor control, and effect of proprioception treatment during ankle rehabilitation. Thus, the objective of the present study was to examine the validity of proprioception training program on parameters of sensorimotor function in an athlete with chronic ankle instability (CAI).

Material and methods

Ankle joint sprain and the subsequent development of chronic ankle instability (CAI) are commonly encountered by clinicians involved in the treatment and rehabilitation of musculoskeletal injuries. It has been recently supported that ankle joint post-sprain rehabilitation protocols should incorporate dynamic neuromuscular training to enhance ankle joint sensorimotor capabilities.Ankle inversion sprains are frequent injuries in sports and activities of daily living that mostly concern young physically active individuals. It has been estimated that its incidence is about one ankle inversion per 10,000 people per day. Ankle ligament injuries constitute between 15 and 45% of all sports-related injuries and occur in sports with a high level of jumping and cutting activities, especially in ball sports. Independent of the initial treatment, persistent symptoms or re-injury remains in 10–30% of individuals.Ankle joint instability can be defined as either mechanical or functional instability. Mechanical instability refers to objective measurements of ligament laxity, whereas functional instability is defined as recurrent sprains and/or the feeling of giving way. Causal factors include proprioceptive deficit, muscular weakness, and/or absent coordination. For rehabilitation after injury or prevention of re-injury, proprioceptive training has been recommended throughout literature. The contents of such programs vary, but most of them include some exercises, e.g., exercising on an ankle disk with a frequency of several times per week.

There is no much variance about the actual benefits of such programs. It has to be considered that not only strength, but also coordination should be addressed in various ways. In addition, there is the question of how to integrate these specific ankle disk procedures for several times per week within a normal training process. The effects of proprioceptive exercises have been evaluated with test procedures regarding angle reproduction, postural sway, or muscle reaction times.Only a few investigators used more than one test procedure simultaneously and there is also some debate on the actual benefit of proprioceptive exercise programs concerning the different testing procedures. Therefore, the purpose of this project was to investigate the validity of the effect of a 4-week proprioception training protocol on ankle sprain. The objective parameters were obtained by measuring the ankle balance, muscle reaction time and maximal resistance of ankle muscles. Proprioception training protocol for ankle sprain is valid concerning ankle muscle reaction, gaining balance and increase in ankle maximal resistance force.

Population: Inclusion criteria for the study were: 26 male patients between the ages of 18 and 40 years old with chronic ankle sprain unilateral or bilateral, has followed a proprioceptive training protocol 3 times/week for 4 weeks. Exclusion: patient don't having any operation on tested side.Procedure:Patient General History was taken at first session including general information, medical or surgical antecedents with ankle sprain frequency and ankle stability test. Three parameters were measured at the beginning and the end of each session. The data entry was filled during measurement on a draft sheet then on an excel sheet Ankle muscle reaction: Materials: freeman board, Chronometer , Specific device made by a mechanical engineer to measure muscle reaction AMRT (ankle muscle reaction test)

First, a patient stood on freeman board in a stable position. The board was placed in a stable and flat area AMRT, otherwise it doesn't mark any value. A 2kg was thrown down from 30 cm high, toward the board direction (plantar flexion FP, Dorsal flexion FD, Inversion, Eversion), the weight was always felt on freeman external side. The AMRT will display in millisecond the ankle muscle reaction for each movement.Mechanical characteristic of AMRT device: The following device uses mercury switches (the mercury switch is placed in an angle such that when the tilt angle is more than the predefined threshold the switch will connect its terminals). The output of the switch is then fed into a microcontroller (PIC16F887) which uses a 4 MHz crystal oscillator (a crystal oscillator is used because it is known for its high precession) as an input clock. The microcontroller then calculates the time in which the switch has been connected (this is the time needed for a person to go back into the steady state i.e. reflex time), and displays it on the screen.

This device also can be used to calculate how many times a person's leg has shaken in a given amount of time (1, 3, 5 minutes) or for an infinite period of time. To do so the output of the switches is summed together using AND gates and fed into the microcontroller.

The microcontroller then increments the count on each negative transition and then displays the result on the screen. Note that the device also displays the remaining time in case of timed operation. Ankle maximal resistance: Maximal resistance RM: A repetition maximum (RM) is the most weight you can lift for a defined number of exercise movements. A "1 RM", for example, is the heaviest weight you can lift if you give it your maximum effort. Then "1RM" is your personal weightlifting record for any particular exercise. A "10RM" will be the heaviest weight you can lift for 10 consecutive exercise repetitions.Material: ankle leg exercise machine / Weights .A patient was rested in a sitting position with 90˚ knee flexion and the foot reposed on the ankle leg exercise machine in neuter position. A weight was added on one side of the device, then starting from the beginning of range of motion, the patient was asked to move his foot to the opposite direction. For example for measuring FD, weight was put on the front side of the device, staring from full plantar flexion, the patient did dorsal flexion to its maximum range of motion. Maximal resistance was registered when the patient attained to lift the maximal weight one time. Balance .This part is divided into two exercises: stability duration and the number of repetition of leg shaken in a given amount of time (1, 3, 5 minutes). Stability duration .Materials: freeman board /Chronometer . The aim of this part is to measure the time of the patient's ability to retain balanced and stability on a freeman board. While the patient was standing up on the board, he was asked to maintain his balance (holding an immobile bar or the wall) and count to 3.Then after releasing his hands, the time spent was measured using chronometer and results registered in seconds. Shaking leg repetition :Materials: freeman board /Chronometer Specific device made by a mechanical engineer to measure muscle reaction AMRT (ankle muscle reaction test) .

The patient rested in the same position as in the stability duration test. The AMRT device was set up at 1 or 3 minutes, depending on the patient's ability. At the count of "3", the patient released his hand and stabilizes by finger. The AMRT device then counted the number of freeman board shaking during a precise time.

Training protocol

Strengthening EXERCISES: 3 times / week

- Soleus and gastrocnemius stretch: Hold for 30 s, rest for 10 s, and repeat exercise 15 time 2 set
- Calf stretch (using stairs): Hold for 30 s, rest for 10 s, and repeat exercise 15 time 2 set
- Tubing Exercises (PF, Inversion, Eversion): Hold for 30 s, rest for 10 s, and repeat exercise 15 time 2 set
- Weight around ankle in siting position (FD,IN,EV): Hold for 30 s, rest for 10 s, and repeat exercise 15 time 2 set
- Toe Raises, stairs exercises: Hold for 30 s, rest for 10 s, and repeat exercise 15 time 2 set

Balance training protocol: Hold for 30 s, rest for 10 s, and repeat exercise 10 time 2 set

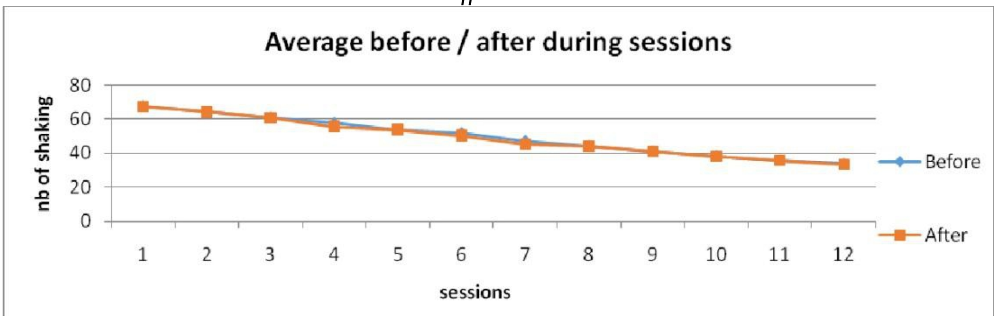
Phase	*Surface*	*Session*	*Exercises*	*Eye*
Week 1	Floor	1^{st}	Open Single-leg stance	Open
			Single-leg stance while swinging the raised leg	Open
		2^{nd}	Open Single-leg squat (30°-45°)	Open
			Open Single-leg stance while performing functional activities (dribbling, catching)	Open
		3^{rd}	Open Single-leg squat (30°-45°) while swinging the raised leg	Open
			Open Single-leg squat (30°-45°) while performing functional activities (dribbling, catching,)	Open
			Sitting quadriceps table gym ball multidirectional	Open
Week2	Floor	1^{st}	Open Single-leg squat (30°-45°) while swinging the raised leg against elastic band	Open
			Open Single-leg squat (30°-45°) while performing functional activities (dribbling, catching,) while swinging the raised leg against elastic band	Open
			Balancing against a gym ball (wall)	Open
		2^{nd}	Open Single-leg squat (30°-45°) while swinging the raised leg	Closed
			Open Single-leg squat (30°-45°) while performing functional activities (dribbling, catching,)	Closed
			Balancing against a gym ball (wall) with the throwing and catching ball	Open
		3^{rd}	Multidirectional jumping (10-15 repetition)	Open
	Towel		Open Single-leg squat (30°-45°) while swinging the raised leg	Open
			Open Single-leg squat (30°-45°) while performing functional activities (dribbling, catching,)	Open
Week 3	Towel	1^{st}	Open Single-leg squat (30°-45°) while swinging the raised leg against elastic band	Open
			Open Single-leg squat (30°-45°) while performing functional activities (dribbling, catching,) while swinging the raised leg against elastic band	Open
	Floor		Multidirectional jumping with throwing and catching ball (10-15 repetition)	open
	Towel	2^{nd}	Open Single-leg squat (30°-45°) while swinging the raised leg against elastic band	Closed

			Open Single-leg squat (30°-45°) while performing functional activities (dribbling, catching,) while swinging the raised leg against elastic band	Closed
			Multidirectional jumping (10-15 repetition)	Open
	Board	3rd	Open Single-leg squat (30°-45°)	Open
			Open Single-leg stance while performing functional activities (dribbling, catching)	Open
	Towel		Multidirectional jumping with catching and throwing ball (10-15 repetition)	Open
Week 4	Board	1st	Open Single-leg squat (30°-45°) while swinging the raised leg against elastic band	Open
			Open Single-leg squat (30°-45°) while performing functional activities (dribbling, catching,) while swinging the raised leg against elastic band	Open
			Multidirectional jumping (10-15 repetition)	Open
		2nd	Open Single-leg squat (30°-45°) while swinging the raised leg against elastic band	Open
			Open Single-leg squat (30°-45°) while performing functional activities (dribbling, catching,) while swinging the raised leg against elastic band	Open
			Multidirectional jumping with catching and throwing ball	Open
			Open Single-leg squat (30°-45°) while swinging the raised leg against elastic band	Closed
			Open Single-leg squat (30°-45°) while performing functional activities (dribbling, catching,) while swinging the raised leg against elastic band	Closed

1.1 Statistical Study.

1.1.1 **A: One minute stand**

Figure 1: The Average number of shaking in one minute stand before and after sessions for the affected side.



The graph shows approximate results of shaking value during the training protocol of each session with minor differences at 5th and 6th sessions.

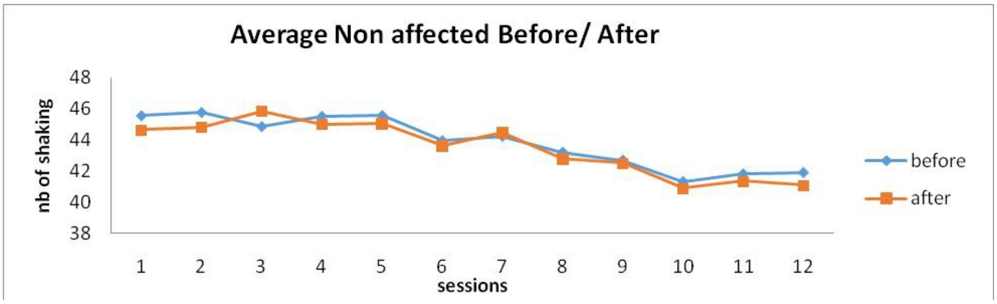


Figure2: Average number of shaking in one minute stand before and after sessions for the non-affected side.

The graph shows approximately the same level of the number of shaking for each session; however there is a slight decrease for shakings values throughout sessions.

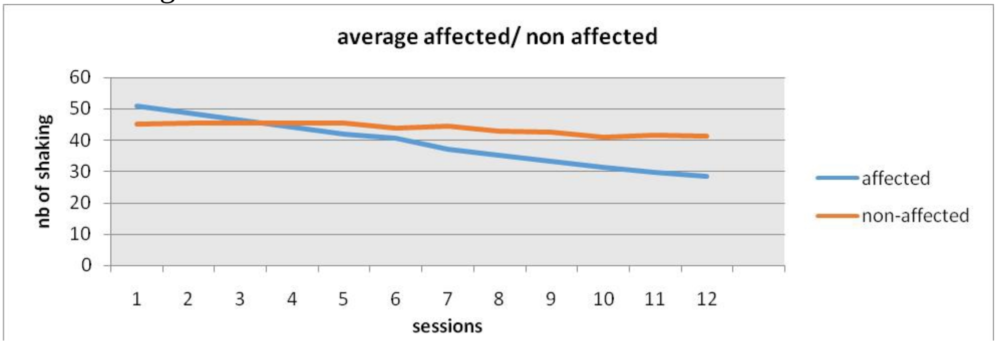


Figure3: Average number of shaking in one minute stand between affected and non-affected leg during training period,

The graph shows that the number of shakings in the affected leg is decreasing throughout sessions till it reaches a value less than that of the non-affected one at the end.

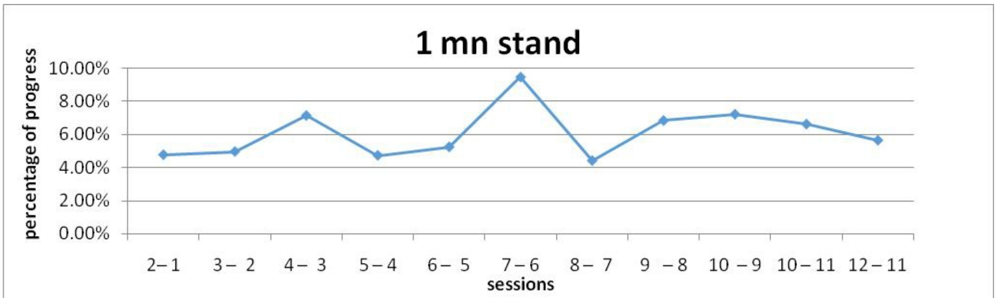


Figure 2 The difference of progress in percentage in a minute stand between sessions for the affected leg.

The graph shows unsteady progress among the sessions, with a peak on the 7th one followed by a slight increase to reach approximately the initial value.

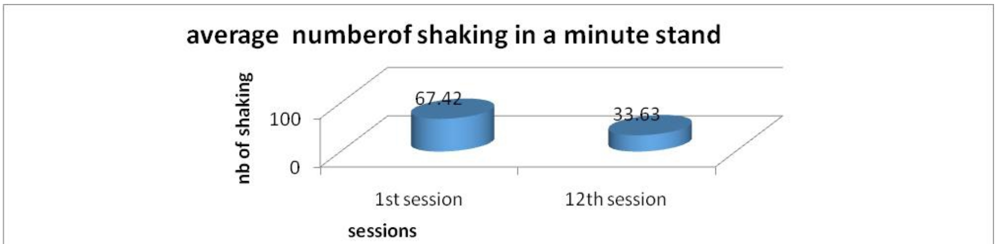


Figure5: the average of scores in a minute stand between 1st and last session for the affected side.

The graph shows clearly that there is a significant decrease in the shaking average during sessions

1.1.2 B: Balance

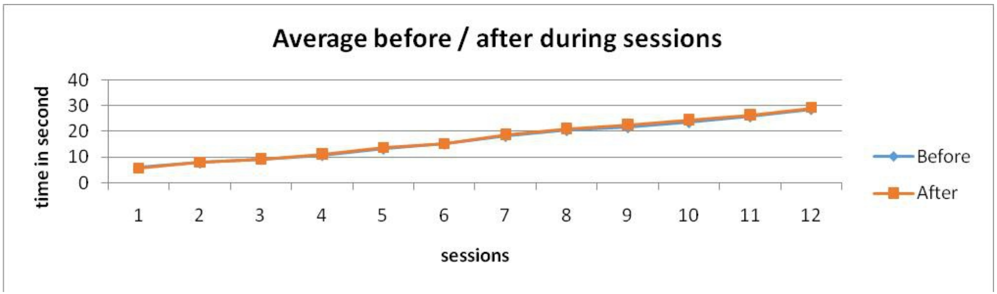


Figure 3: average of balance measurement on freeman board during sessions for the affected leg before and after sessions.

Patients have similar results during each session, but throughout sessions they have a considerable increase of value starting from the 7th till end of training.

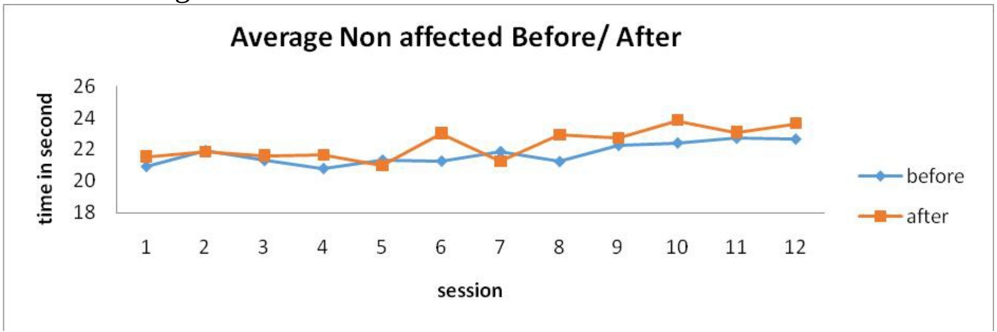


Figure7 : average of balance measurement for the non-affected leg before and after sessions.

Result shows the random variation in scores before and after each session.

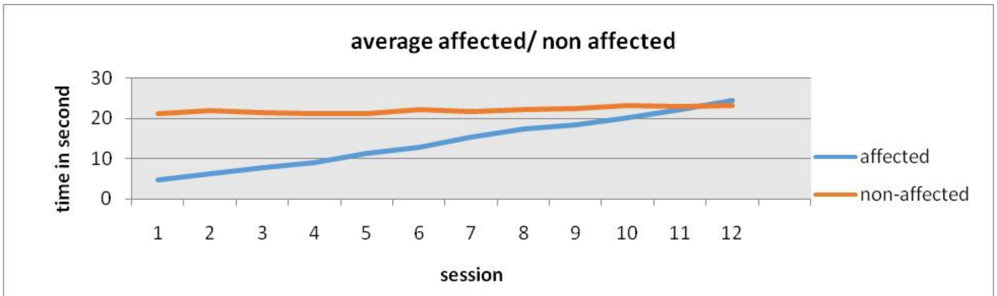


Figure8: average of balance for the affected and the non-affected side,

The graph shows that the balance of the affected leg has ascending increase in its value starting at a value >5s and ending at >20s compared to the non-affected which maintain same value throughout sessions and end with a value similar to the value of the affected one.

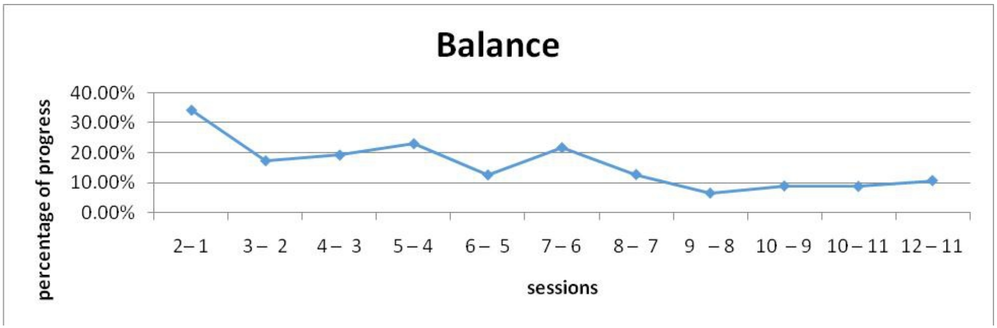


Figure9: shows the percentage of difference of progress for balance between sessions for the affected leg.

Results demonstrate unsteady progress value of balance between first eight sessions. Then at the 8th it experienced a stable percentage of increase.

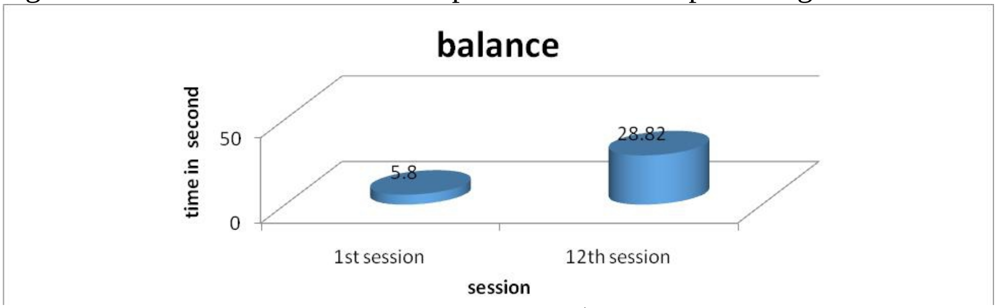


Figure10: the average of scores in balance between 1st and last session for the affected side.

The graph clearly shows the significant increase of average of scores in balance throughout training sessions

1.1.3 C: Maximal resistance

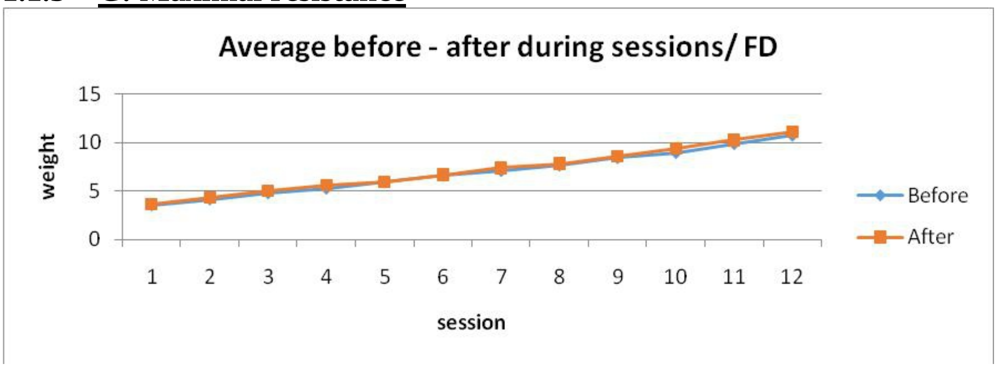


Figure 4: the average of maximal resistance for dorsal flexion of the affected leg.

Graph shows that the line score adopted the samevalue during training protocol of each session. Patients have started and ended approximately at close value

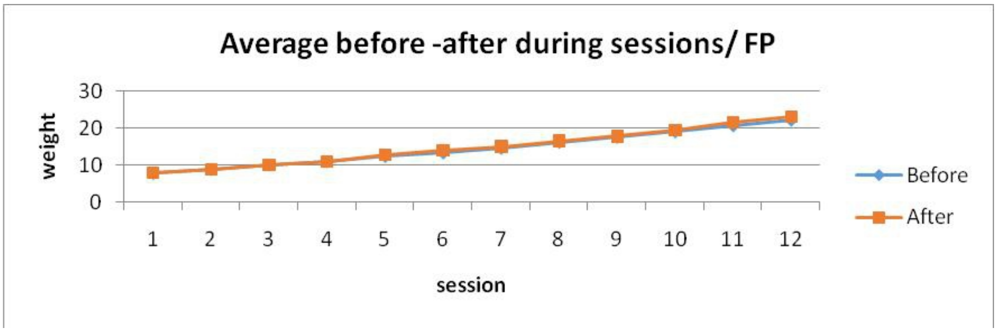


Figure 5: the average of maximal resistance for plantar flexion of the affected leg before and after sessions.

The graph clearly shows that patients have a straight line of increasing value during sessions.

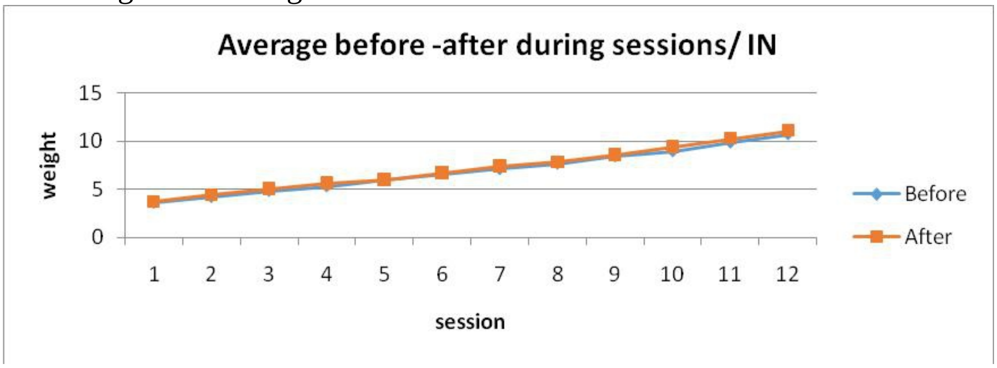


Figure 6 : average of maximal resistance for ankle inversion for the affected leg before and after sessions.

The graph indicates increased value of the average of maximal resistance for patients during training protocol by the increase in weight lifted during sessions.

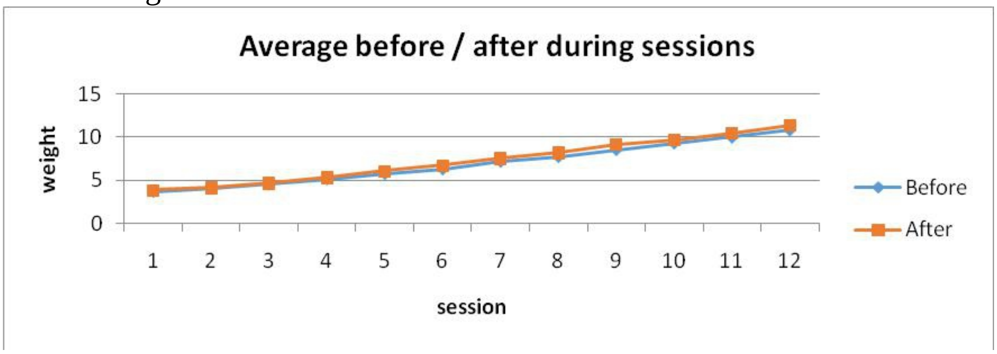


Figure 7 average of maximal resistance of the affected leg for ankle eversion.

Chart show the significant increasing of value during training period.

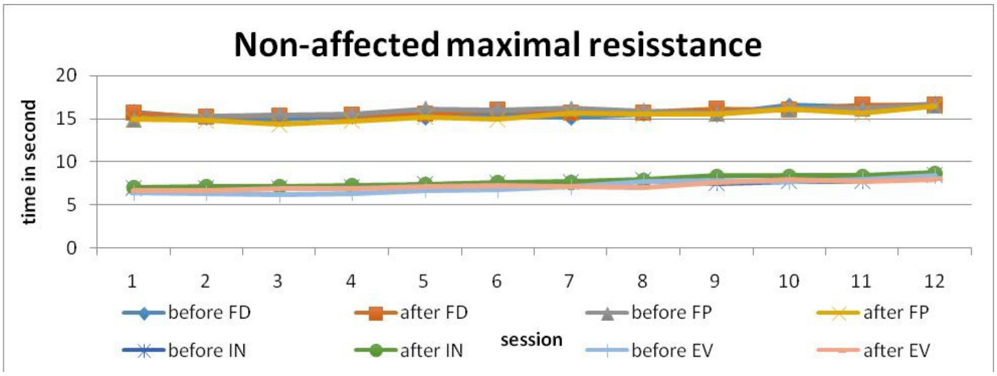


Figure 8 average of maximal resistance of the non- affected leg for ankle function.

This shows that patients had an alteration of value during training period

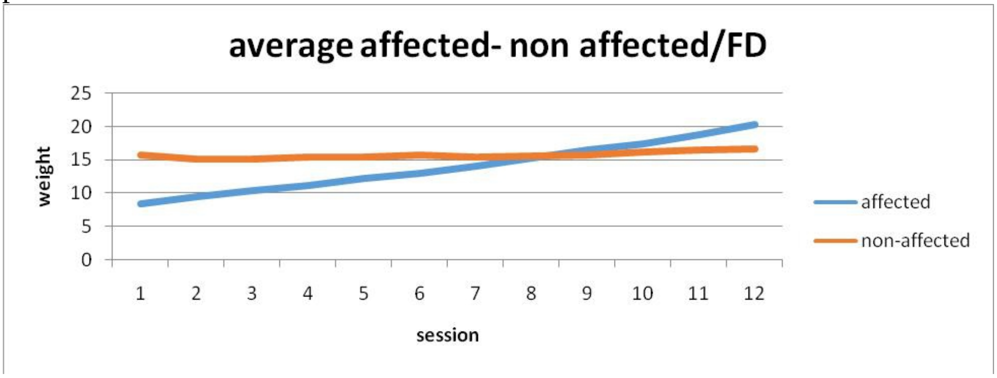


Figure 9: Comparison of the average of maximal resistance between affected and non-affected for ankle dorsal flexion.

This shows increased value of the affected legs during sessions started at <10kg and ended at>20kg, better with comparison to that of the non-affected which started at >15 and ended at <18kg

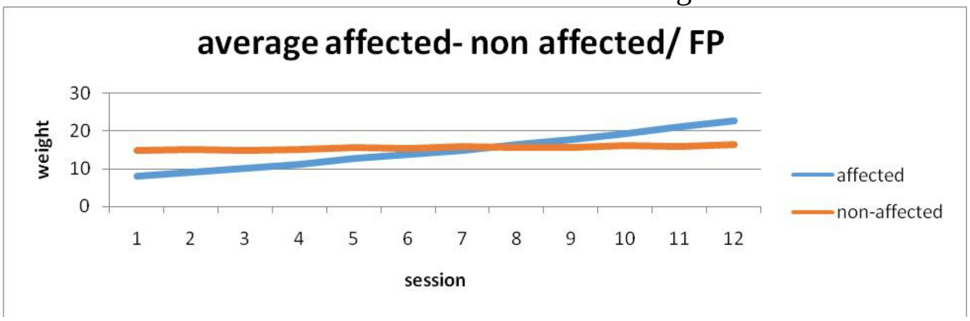


Figure 10: Comparison of the average of maximal resistance between affected and non-affected for ankle plantar flexion.

This shows that the affected legs started at a value <8kg smaller than non- affected legs >13kg and continues with a straight line of increase till the end of sessions at an amount ≥22kg higher than the ending value of non-affected legs ≥ 16kg.

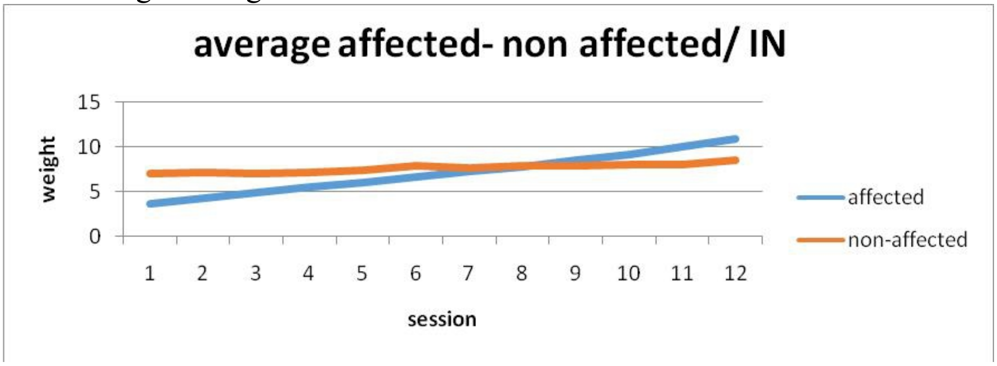


Figure18: Comparison of average maximal resistance between affected and non-affected for ankle inversion.

The affected legs have a straight line of increase for maximal resistance that ends sessions at a value ≥11kg higher than that of non-affected legs ≥8kg.

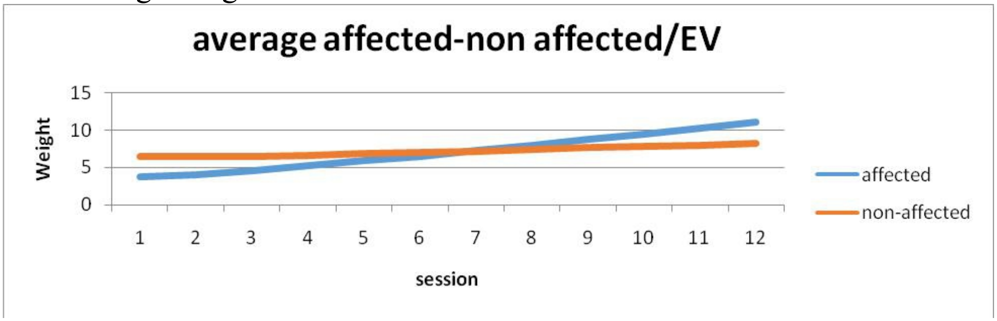


Figure 11: Comparison of the average of maximal resistance for ankle eversion between affected and non-affected.

The affected legs have a significant increase in maximal resistance till they end sessions at an amount ≥10kg higher than the ending value of non-affected legs ≥ 8kg.

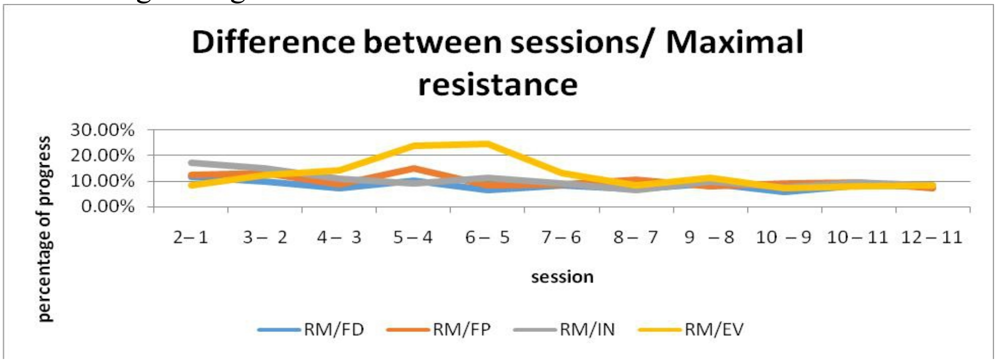


Figure20: average of percentage of difference between sessions for ankle function for the affected leg.

As seen the best value of progress for ankle eversion is at 5th and 6th session. After that, patients continue with similar value of progress from 7th session till 12th session.

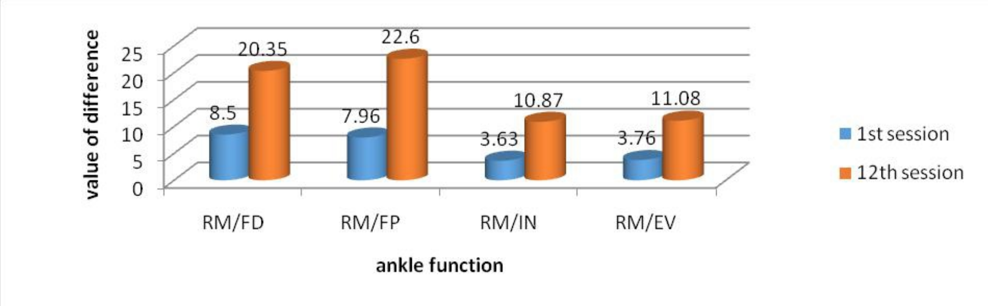


Figure 12: the value of progress for the affected leg by comparing results between first and last sessions.

This shows that ankle dorsal and plantar flexions have better scores of progress than that of ankle inversion and eversion.

Discussion

Ankle injuries are the most common injuries across a wide variety of sports. Athletes who suffer from ankle sprains are more likely to reinjure the same ankle which can result in disability and can lead to chronic pain or instability in 20% to 50% of these cases.

There is a high rate of ankle sprain incident in sport game. Which prevents athletes from future sports participation. Braces and tape are widely used measures to prevent ankle sprains. It is known from previous research that use of braces reduces incidence of ankle sprain, and it is argued that tape also has a preventive effect because the working mechanism is thought to be similar to braces. However, both measures have negative side effects; for example, whereas braces can be irritating if not fitted properly and are argued to negatively affect performance, tape loosens during play, needs to be applied by qualified personnel, and can cause skin irritation. Proprioceptive balance board training is another measure, presumably as effective as braces and tape but without the above-mentioned negative side effects. This measure is already used in the rehabilitation following ankle sprain to strengthen muscles and ligaments and to restore proprioception of the damaged structures around the ankle. However, previous studies failed to show a significant reduction of ankle sprains, presumably because of low sample size and/or inadequate study design. This study is conducted to examine the validity of Proprioception training effects on ankle stability, force and the muscle reaction. The effectiveness of the rehabilitation program determines the success of rehabilitation and athletic performance.

Rehabilitation of ankle injuries should be structured and individualized. In the acute phase, the focus should be on controlling inflammation, reestablishing full range of motion, and gaining strength. Once pain-free ranges of motion and weight bearing have been established, balance-training exercises should be incorporated to normalize neuromuscular control. Advanced-phase rehabilitation activities should focus on regaining normal function. This includes exercises specific to those that will be performed during sport. While having a basic template to follow for the rehabilitation of ankle injuries is important, clinicians must remember that individuals respond differently to exercises. Therefore, each program needs to be modified to fit the individual's needs. Rehabilitation of the Ankle after Acute Sprain or Chronic Instability.

The findings general in this intervention study reveal a decrease in number of repetition of ankle shaking during a minute on a freeman board for patients, increased time in second for balance on freeman board, an increase of maximal resistance lifted on leg ankle exerciser machine with reduced time of ankle reaction for dorsal flexion, plantar flexion, inversion and eversion.

Our study contradict with the result of Söderman et al, who found no effect of proprioception training on the incidence of ankle sprains. However, their study was carried out in female soccer players. In contrast, other studieshave suggested a preventive effect of a proprioceptive training program on the risk of sustaining ankle sprains. According to the studies of Bahr et al Sander E and Tropp et al,the effect of the intervention is greater for players with a history of ankle sprains. It is known from the literature that proprioceptive function at the ankle joint is reduced in athletes after injury, which is suggested to lead to the high risk of reinjury after an initial injury.This might suggest that in our study, as in the previous studies on Proprioception training, we are not looking at a primary preventive effect of the balance board training program but at a rehabilitative effect.

We can clearly notice the effect of proprioception training protocol for ankle instability moreover, statistical analysis using Pearson's correlation and paired simple test show that there's a significant progress during rehabilitation period on ankle one minute stand, balance, muscle reaction and maximal resistance $p=.00<0.05$

Whereas, the correlation is very high between ankles one minute stand and balance. This is a negative correlation which means the number of shaking in one minutes standing on freeman board decreases, the balance time increases. On the other hand, the correlation between maximal resistance and muscle reaction for ankle dorsal flexion and plantar flexion shows a weak relationship between variables; in other words the changes in one variable are not correlated with changes in the second variable. Because the correlation for ankle inversion and eversion for muscle reaction and maximal resistance is significant it's set to be a positive correlation, that is when one variable increases in value, the second variable also increases. The correlation between one minute stand and balance is not significant with ankle dorsal flexion and inversion maximal resistance but significant with ankle plantar flexion and eversion muscle reaction.

As result there is evolution in value for the non-affected leg comparing the first and last sessions 8.18% for ankle one minute stand; 7.99% for balance; 7.01% for ankle maximal resistance dorsal flexion, 10.18% plantar flexion, 19.45% inversion, 20.90% eversion, 15.59% muscle reaction ankle dorsal flexion, 19.69% plantar flexion, 12.46% inversion and 15.36% eversion. Thus we can conclude that patient have gained minor talent during rehabilitation period (for the non-affected limb) without being involved in Proprioception rehabilitation protocol.

The final result of this study is consistent with our hypotheses, which propose the validity of proprioception rehabilitation on instable ankle function.

Conclusion

The ankle and foot are two complex structures and the arthokinematics allow for versatile function. Moreover, the stability of the ankle is critical for bipedal motion. An intricate part of the functionality of the ankle is due to somato-sensation, primarily proprioception. Ankle injury is the most common musculoskeletal injury and athletic performance places the ankle at high risk for injury.

Ankle sprains are the most common injury that occurs during athletic events, with the lateral ligamentous complex most frequently injured. Approximately 20% of acute ankle sprains develop functional or mechanical instability resulting in chronic ankle instability. Over the years, an improved understanding of the biomechanics and path anatomy has expanded our treatment options for lateral ankle instability. However, the optimal means of prevention and treatment is still not fully ascertained. Proprioceptive rehabilitation remains the mainstay of treatment for acute ankle sprains.

There is substantial literature supporting proprioceptive training as a preventative measure for ankle injury, but a large amount of the literature is of low grade; few studies were of a high grade of evidence. Programs including proprioception, balance, and endurance have been shown to decrease the incidence of ankle injuries, specifically traumatic ankle inversion.

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The present study shows that a proprioceptive program is effective in improving ankle function as balance, muscle reaction and maximal resistance.

Future studies focusing on the cortical changes of the brain in populations with documented chronic ankle instability should be performed to study the changes that take place from proprioceptive training. Other areas of future study should address: what roles can the central nervous system play in the regulation of ankle stability, the influence of athletic ability on ankle stability, and the effects of age on proprioceptive training.

Therefore, the use of such a program in sport games is recommended for players with a history of ankle sprains.

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