



## The Effect of 8-Week Comprehensive Combined Training Program on Parameters Elected Lower Extremity Kinematic Variables in the Men Athletes with Chronic Ankle Instability



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### ABSTRACT

**Background:** People with functional ankle instability are deficient in various factors that need to overcome all these problems via a multifaceted and combined exercises. Therefore, the main purpose of this semi- research is to study the effect of the comprehensive combined program on kinematic of lower limb in active men suffering from chronic ankle instability.

**Methods:** The subjects of this research will be active men at the university suffering from chronic ankle instability, of which 30 individuals will be purposeful chosen based on the values of the research inclusion criteria and will be divided into two group of control and experimental. Tools for collecting research inputs were motion analysis, and foot ankle inability index questionnaire.

**Results:** To compare the groups, Covariance test at 0.05 alpha level was used. Results showed that there are significant differences ( $P \leq 0.05$ ) before and after the exercise program, between the average scores of parameters elected kinematic lower limb variables, in the experimental group; while in the control group these changes were not statistically significant.

**Conclusion:** The general results of current research showed that comprehensive combined exercise program can be effective and secure on improving kinematic lower limb.

## 1. Introduction

The ankle injury is one of the most common body injuries during physical activity, especially in recreational and team play such as football, rugby, volleyball, handball, and basketball [1, 2]. An ankle sprain is a common disability that can affect the performance and daily activity of people [3, 4]. Fong et al. (2007) showed that the ankle was the most commonly traumatized member in 24 exercises of studied 70 exercises.

On the other hand, the incidence of ankle injuries and ankle sprains in indoor sports and team sports such as rugby, football, volleyball, handball, and basketball was really high [5]. Ankle sprains, commonly seen in athletes, cause functional-executive problems in the ankle and they will have a detrimental effect on the activity of individuals [6].

Two major factors in chronic ankle instability re mechanical and functional instabilities. Mechanical instability includes muscle weakness and joint stiffness.

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However, many people do not have any mechanical defects, but they often develop ankle sprain and stretch due to functional instability [7, 8]. In general, chronic ankle instability is attributed to mechanical instability and functional impairment of the ankle [9]. Although mechanical and functional instability may exist separately, the chronic ankle instability is due to a combination of both [9, 10].

Although early symptoms associated with ankle sprain are usually resolved in a short time, many people report that their problems are not solved and these problems are a pain, feelings of instability (emptying) [11, 12]. The remaining symptoms were reported 6 to 18 months after the first injury and were observed in 55-72% of the cases [13, 14]. People with chronic ankle instability have a weaker postural control than healthy people. These individuals use proximal muscles to compensate for the neuromuscular defects of the distal limbs [15]. Other features of these individuals include a change in the kinematics of the lower limb during walking and postural and functional impairment [7]. Also, a person's performance impairment can reduce the ability to exercise.

Specific sports exercises play an important role in restoring, rehabilitating, restoring the tendon function, as well as ligaments, bones, and muscles, at the rehabilitation stage, which improves the prevention of re-injury and rapid return of the athlete to sports competitions. Therefore, it is important to study the various interactions that cause or reduce complications in patients with chronic ankle instability [16, 17].

Combined exercises are used to prevent injury, increase performance and rehabilitation after injury or surgery. The goal of rehabilitation programs is to improve the functioning of the ankle muscles in order to reestablish the stability and normal functioning of the joint [18, 19]. Much of these exercises are neuromuscular exercises. The purpose of the neuromuscular exercises is mainly to improve the quality and efficiency of the movements. The neuromuscular training method is based on biomechanical and neuromuscular principles and aims at improving sensory control and achieving functional compensatory restoration. Sensory control is the ability to generate control movements through coordinated muscular activity and functional stability (also called dynamic stability) that maintain the ability of the joint to be sustained during physical activity.

Muscular neuromuscular exercises may also increase abnormal joint control over functional activities by making compensatory changes in muscle activity patterns.

These effects lead to optimal performance and increased muscle strength of the lower extremity, which can make muscle fixation more suitable thus disrupts the torque produced during the achieving operation [20, 21].

Combined exercises with appropriate physiological adaptations can play an effective role in learning the motor recall skill, increasing the plasticity of the motor cortex and improving muscle utilization. It is also closely related to the increase in spinal cord excitability [22, 23]. Myer et al. (2008) showed that equilibrium and plyometrics exercises

improve balance and landing force in athletes [20]. Hang and Lin showed that simultaneous balance and plyometric exercises reduce posture fluctuations during static state and improve stability and energy dissipation pattern in subjects with functional ankle instability [24]. Also, Dickery et al., showed that the use of specific posture during walking and jacking with a shoe on the treadmill results in a better position on the ankle, which would reduce the chance of ankle sprain [25].

Considering that many therapeutic interventions have investigated the effects of treatment strategies such as balance exercises, plyometrics, or strength exercises separately, and have focused on a comprehensive (combined) training program [9,18-22]. Therefore, the purpose of this study was to investigate the effect of a combined exercise program (neuromuscular and strength) on selected kinematic parameters of the lower extremity in active men with functional ankle instability.

## 2. Materials and Methods

The present study is a semi-experimental study with post-test and pre-test design and the control group.

Subjects were purposefully selected according to the inclusion and exclusion criteria. The statistical population of the present study included university students aged 20-27 years with functional ankle instability in Tehran and Alborz provinces, Iran. From the statistical population, based on the inclusion criteria, a group of 30 athletes with functional ankle instability were selected and randomly divided into two groups of 15 combined and control exercises. The ankle functional instability was assessed by ankle and foot disability index and an ankle disability index sport. All subjects had a history of ankle sprain during the last six months and experienced at least one ankle emptying at this time. Exclusion criteria are as follows, having a history of back pain, having any history of surgery in the spine or lower limbs, having a history of severe spinal damage and ligament damage or knee meniscus in the past year, the presence of visible musculoskeletal disorders in the lower extremity such as genu valgum, genu varum, ankle puncture and severe exercise were performed 24 hours before the test.

A summary of the research design was described in the introduction form of the research for the subjects, then the initial screening of the subjects was carried out based on the inclusion and exclusion criteria and those who wished to cooperate received the consent form. After identifying qualified athletes by using the relevant questionnaire, the subjects referred to the Kharazmi University's Corrective Action Laboratory in order to be tested, based on the previously announced time. On the test day, after completing the consent form by the subjects, their background information including height, weight, age, sport record and sport in the form of collecting recorded data and selected kinematic parameters of individuals such as knee and ankle angles during walking in both sagittal and frontal planes were evaluated in both groups (control and experimental) in the pretest.

**Table 1:** Comprehensive combined practice protocol

Range of motion	1-3 week	4-6 week	7-8 week
Gastrocnemius muscle stretching	15S × 2	20S × 3	20 S × 4
Soleus muscle stretching	15S × 2	20 S × 3	20 S × 4
Strength training			
Pick up the heel of the ground	2.10	3.15	4.15
Resistance by Theraband			
Dorsiflexion	2.10	3.15	4.15
Plantar Flexation	2.10	3.15	4.15
Inversion	2.10	3.15	4.15
Eversion	2.10	3.15	4.15
Plantar flexion / inversion	2.10	3.15	4.15
Plantar Flexation / eversion	2.10	3.15	4.15
Dorsiflexion/Inversion	2.10	3.15	4.15
Dorsiflexion/Eversion	2.10	3.15	4.15
Neuromuscular training			
Single-leg stand	50 s × 2	60 s × 2	60 s × 3
Single leg stand and ball throw	2.10	3.10	3.15
Throw foot backward (kickback)	2.10	3.10	3.15
Step down with a single foot in 4 directions	1.5	2.5	2.8
Motor function			
Square jump	2.8	3.6	3.8
Carioca	1.5 m × 1	1.5 m × 2	1.5 m × 3
8-hop	2.1	3.1	4.2

Experimental th group performed eight weeks of comprehensive combination exercises, including stretching, strength (Creation of resistance with red Thera Band) neuromuscular and functional training, 8 weeks and 3 sessions per hour each week [26]. After completing the training period, a post-test with pre-test condition was performed on both experimental and control groups.

### 2.1. Ankle and foot disability index and ankle disability index sport questionnaire

The FADI (Foot and ankle disability index) is a former version of the FAAM (Foot and ankle measure). The 2 instruments are identical except for an additional 5 items found on the FADI. Four of these items assess.

The ankle and foot disability index questionnaire includes 3 questions, with 4 questions related to pain and 22 questions related to activity, but the ankle disability index sport has 8 questions. Each question is scored on a 5-point Likert Scale (from 0 to 4). The maximum score for the ankle and foot disability index is 104 and for the athletic index of ankle and foot disability is 32 and the points are expressed as percentages. People were identified as a group with chronic ankle instability, which had one of the following conditions: Getting a score less than or equal to 95% in the index of foot and ankle disability and score less than or equal to 75% in the Foot and Ankle Disability Index Sport [27].

### 2.2. Motion Analyzer

In order to evaluate with the American Motion Analysis System, the subjects traversed 8 meters with natural tracking rhythm. During the walk, all movements of the subjects were captured by six motion-sensing cameras with a frequency of

240 Hz. In this study, the plug-in-gait marking method was used so that the markers on the second toe, heel, inner and outer ankle, middle of the leg, internal and external hip

condyles, middle of the hip, large trochanter, posterior superior iliac spine and anterior superior iliac spine.

During the walking exercise, some of the lower limb kinematics parameters (angles of the knee and ankle, tracks on both sides of the frontal and sagittal pages) were recorded by means of motion analyzer then the data were analyzed by the software [28].

### 2.3. Statistical Analysis

Data were analyzed by SPSS-22 software. Descriptive statistics were used to obtain a mean and standard deviation. Kolmogorov-Smirnov test was used for data normalization and covariance test with a significant level of 95% was used to compare the groups. Also, a dependent t-test was used to obtain the difference between groups.

### 2.4. Research Findings

Specifications regarding age, height, weight, body mass index of the samples tested are presented in Table 2. Also, the results of independent t-test for homogeneity of data are presented in this table. The results from Table 2 show that the measured alpha value is greater than 0.05, therefore, considering that the alpha value is greater than 0.05, it is concluded that there is no significant difference between the groups and the groups are homogeneous in these variables.

The data presented in Table 3 shows the comparison of the scores of these variables (tracking rhythm, ankle, and knee joint angles) in experimental and control groups before and after the exercise program. The results of this table show that there is a significant difference between the mean scores of these variables in the experimental group before and after the exercise program. Therefore, the null hypothesis is rejected and the statistical assumption is confirmed.

**Table 2:** General characteristics of subjects (mean and standard deviation) and independent t-test results to examine the homogeneity of variables in the control and experimental groups

Variable	Experimental group (Mean ± standard deviation)	Control group (Mean ± standard deviation)	P value
Age (year)	3.27 ± 20.00	2.94 ± 21.50	0.600
Height (centimeters)	8.25 ± 185.80	5.57 ± 183.50	0.340
Weight (kg)	7.36 ± 80.75	5.84 ± 78.00	0.800
BMI <sup>1</sup>	2.50 ± 21.60	3.21 ± 22.78	0.920
FADI-S <sup>2</sup>	11.2 ± 68.5	9.4 ± 66.8	0.700
FAI <sup>3</sup>	8.5 ± 85.5	7.4 ± 82.4	0.580

1. Body mass index                      2. Ankle and foot disability index sport                      3. Ankle and foot disability index

**Table 3:** Statistical results of covariance

Variable	Sagittal plane			Frontal plane		
	Mean-square	F	P value	Mean-square	F	P value
Tracking	4.11	5.14	0.030	4.11	5.14	0.030
The angle of the knee joint during heel contact with the ground	4.98	6.28	0.010	3.96	4.63	0.040
The angle of the ankle during heel contact with the ground	15.75	4.56	0.040	10.71	20.9	0.010
Knee joint angle during heel lifting	9.48	15.99	0.010	22.6	5.14	0.030
Angle of the ankle during heel lifting	5.74	10.63	0.030	3.51	7.38	0.010

**Table 4:** Comparison of mean kinematic scores in control and experimental groups before and after the exercise program by Paired t-test

Variable	TIME	Group	Before		After		T	P value
			Mean	Standard deviation	Mean	Standard deviation		
Tracking (step by minute)		Control	83.47	11.59	83.62	11.36	0.45	0.650
		Experimental	83.58	12.04	84.47	12.10	13.90	0.010 *
The angle of the ankle joint during heel contact with the ground in the sagittal plane (degrees)		Control	-1.60	4.28	-0.94	4.54	1.11	0.280
		Experimental	-1.28	5.81	0.29	6.27	7.23	0.030 *
The angle of the ankle joint during heel contact with the ground in the frontal plane (degrees)		Control	-0.49	2.61	-0.59	2.87	-0.63	0.530
		Experimental	-2.20	1.68	-3.69	1.93	-6.715	0.010 *
Knee joint angle during heel contact with the ground in the sagittal plane (degrees)		Control	9.07	10.33	8.98	10.46	-0.34	0.730
		Experimental	9.25	10.58	9.97	10.89	4.66	0.010 *
Knee joint angle during heel contact with the ground in the frontal plane (degrees)		Control	3.02	4.79	2.82	4.63	-1.15	0.260
		Experimental	2.56	4.53	1.67	1.4	-2.807	0.010 *
Angle of the ankle when lifting the heel of the ground in the sagittal plane (degree)		Control	-0.76	10.24	-0.65	10.19	0.60	0.550
		Experimental	0.52	7.70	1.50	7.76	5.13	0.010 *
The angle of the ankle when lifting the heel of the ground in the frontal plane (degree)		Control	-1.16	1.99	-1.14	1.87	0.19	0.850
		Experimental	-1.56	2.17	-2.19	2.08	-2.606	0.020 *
The knee joint angle during lifting the heel of the ground on the sagittal plane (degree)		Control	27.41	12.33	27.24	12.15	-0.62	0.540
		Experimental	28.36	10.41	29.31	10.31	9.54	0.010 *
The knee joint angle during lifting the heel of the ground on the frontal plane (degree)		Control	9.21	6.12	9.07	6.35	-5.38	0.590
		Experimental	9.81	5.12	7.92	4.92	-2.67	0.010 *

The data presented in Table 4 shows the comparison of the scores of these variables (tracking rhythm, ankle and knee joint angles) in the experimental and control groups before and after the exercise program. The results of this table show that there is a significant difference between the mean scores of the variables in the experimental group before and after the exercise program, while in the control group, this difference is not statistically significant.

### 3. Results and Discussion

The obtained results showed that in tracking, knee joint angle during heel contact with the ground in the sagittal and frontal plates, as well as the ankle joint angle during

ankle contact with the ground on the sagittal and frontal planes, the

ankle angle during the heel lifting of the ground on frontal and sagittal planes and knee joint angle in the frontal and sagittal planes while lifting the heel of the ground in the active men with chronic anesthetic instability, there is a significant difference between the two groups in the control and training groups ( $P \leq 0.05$ ), so that the scores of all kinematic parameters of men with functional ankle instability improved after combined exercises. The results of the present study are consistent with the results of studies by Vickers et al. (2008) and Teixeira-Salmela et al. (2001), and are contrary with a study by McKeon et al. (2009) [24, 29, 30]. Teixeira-Salmela et al. (2001) performed a combinational program on the lower body in people who had

a chronic heart attack in the past, to observe its effect on kinematics and kinetics variables of walking by collecting data with the cinematographic apparatus and the force plate [29].

Eventually, an increase was observed in the operation of the dorsiflexor and ankle plantar flexors and hip extension and this improved muscle strength and balance in walking energy production [29]. On the other hand, Vickers et al. (2008) examined the effect of combined exercises for 12 weeks on improving the physical and kinematic performance of joints during walking in elderly women, which ultimately led to an improvement in limb strength along with a significant reduction in the time walking on the desired track. In relation to walking kinematics, in the middle phase, the hip, knee and ankle angles oscillation changed to flexion, the ankle plantar angle of the ankle flexion was increased at the step of separating the claws [30]. On the other hand, Patrick et al examined the effect of equilibrium exercises on walking parameters in patients with chronic ankle instability. The researchers did not report significant differences in the kinematics of inversion and eversion, and the leg rotation during walking after 4 weeks of equilibrium training.

This study is not consistent with the results of the present study. The possible reasons for the difference in outcome are the type, severity, duration of each session and, most importantly, the type of exercise protocol used in this study.

The ankle is a hinged joint that consists of tibia, fibula, and talus. This joint provides the necessary context for performing dorsiflexion and plantar flexion movements. The talus bone in the front part is wider than the posterior part, and this feature transforms the shape of the bone into a wedge shape. When the ankle is placed in the dorsiflexion, the thicker side of the talus is placed between the inner and outer ankles, and it does not allow the inversion and eversion movements of the subtalar joint. Therefore, the ankle has the highest stability in the dorsiflexion state and has the lowest stability in plantar flexion and increases the chance of ankle joint movement. Dorsiflexion motion limitation does not make the ankle to reach the normal end of the dorsiflexion during various activities, such as hopping and landing and remain in the plantar relative flexion. This condition does not allow the ankle to achieve its maximum mechanical stability, and failure of this joint to achieve its maximum mechanical stability increases the risk of an abnormal inversion. When the ankle is placed in the dorsiflexion state, the talus bone engages in its wider portion of the joint, and most joint stability is provided by form closure. But when the ankle is placed in the plantar flexion, most of the joint strength is provided by the external lateral ligament of the ankle, and the sudden and excessive forces can cause a tear of these ligaments [31].

Therefore, increasing the ankle flexion angle after combined training reduces the risk of external ankle injury.

Investigating the kinematic parameters of the ankle sprain injury in the frontal plate indicates that the external ankle sprain is often due to excessive ankle overlapping, which

causes almost an external rotation of the foot, slightly after touching the foot during walking or landing. Excessive inversion of the ankle is coupled with an ankle sprain, which leads to stretching of outer ankle ligaments. Also, Plantar Flexion in the initial contact with the ground increases the probability of developing outer ankle sprain. The results of some studies have shown that if the ankle is in the position of the plantar flexion at the moment of contact with the ground, the collision of the foot with the ground is done by the toe, and this increase the torque of subtalar and subsequently create a rotating motion in this joint, which can ultimately lead to an ankle sprain. The pathomechanical model described by Fuller suggests that increased supination in the subtalar joint is the root cause of the external ankle sprain so that the increased supination is in line with the status and scope of the ground reaction force. These results indicate that the damaged foot with a higher internal pressure compared with the subtalar joint axis has a larger displacement motion than the joint axis. Increased supination can cause inertia and internal articulation of the ankle in the closed chain and potentially lead to damage to the external ligament. Therefore, a rehabilitation program that can reduce the ankle movements in the frontal plane, especially the supination and inversion movement, can reduce the occurrence of an ankle injury. Because the knee extension torque before the touch of the foot generates the torque needed to move.

The knee flexion torque is activated immediately at the moment of impact to reduce the possibility of damage caused by hyperextension greater than the extensor torque.

The temporal relationship between these two phenomena determines the successful impact velocity. The initial flexion torque reduces the speed of the limbs and the feet before the impact, thus reducing the speed of movement to some extent. Meanwhile, the researchers believe that hamstring has an eccentric contraction at the end of the knee extension, and in high-speed and high-power blows, hamstring has an eccentric contraction to reduce the knee extension. From the moment of the collision of the foot to the moment of impact, we will have flexion and extension of the knee, and extension and flexion of the hip. At the moment of impact, both groups of agonists and antagonists reach the maximum level around the knee [28, 29]. Therefore, due to the elasticity of the leg muscles, shortening the distance between the flexion and knee extensions that occur before the impact can increase the impact strength; this feature is considered as an important aspect of walking motion. The displacement of the knee and thigh in the direction of the external-internal axis means the internal-external displacement of the thigh bone, and research results indicate more abduction and adduction. The researchers said that precisely prior to the impact of the torque, the abduction of the thigh would be significant, and the indicated that the thigh adductors are important in controlling the entire leg during the impact.

Therefore, according to the above findings, it can be concluded that athletes at the moment of impact with greater knee flexion and possibly using more elasticity of the

muscles and according to the length ratio, apply more muscle tension force to the ground and the risk of injury, including ankle sprain, is reduced, so increasing the angle of the knee at the moment of the collision to the ground after comprehensive combinations training in people with functional ankle instability predicts a reduction in their risk of injury.

#### 4. Conclusion

Considering the significant effect of combined exercises on selected kinematic parameters of athletes with functional ankle instability, it can be said that performing combined exercises improves the kinematic selected variables. Therefore, it is suggested that combined training should be used in designing rehabilitation protocols to improve kinematic variables and prevent future damage to athletes with functional ankle instability.

#### Authors' Contributions

F.R., S.S.Sh., and A.L., designed the study and wrote the manuscript; F.R., conducted the experimental work; F.R., S.S.Sh., and A.L., analyzed the data. All authors revised and approved the final manuscript.

#### Conflict of Interest

The authors affirm that there is no conflicts of interest that may have influenced the preparation of this manuscript.

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