EFFECT OF BALANCE TRAINING EXERCISES ON KICKBOXING ATHLETE‘S BALANCE, MUSCLE STRENGTH AND REACTION TIME IN CHRONIC ANKLE JOINT INSTABILITY: A CASE STUDY

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Annotation

The purpose of this study was to evaluate the effect of 12 weeks of balance training on balance, muscle strenght and reaction time of an kickboxing athlete with chronic ankle instability. Ankle instability causes long-term pain, disability, negatively affects quality of life and reduces physical activity and time to returning to the sports. The novelty of this study is that there is a lack of research on the effect of balance training exercises on balance, reaction time and strength of the muscles surrounding the ankle joint in kickboxers with chronic ankle instability.

Key words: *Error based balance training, ankle sprain, chronic ankle instability, kickboxing.*

Introduction

Presentation of the problem:

In kickboxing 26,1 % of all injuries are to the lower limbs, frequently to knee and ankle ligaments [5;11]. The first ankle ligament sprain can adversely affect the function of the ankle joint, leading to chronic ankle instability and post-traumatic osteoarthritis. These injuries tend to be most symptomatic in high-demand athletes in whom ankle instability causes significant functional disability [7;2]. Evidence shows that at least 4 weeks of balance training can improve physical and functional parameters such as balance, reaction time and muscle strength in healthy individuals with chronic ankle instabilty [3;6]. There is a lack of research on the effect of balance training on balance, reaction time and strength of the muscles surrounding the ankle joint in kickboxers with chronic ankle instability.

The aim of the research:

To evaluate the effect of a balance training program on balance, muscle strength and foot reaction time of a kickboxing athlete with chronic ankle joint instability.

Research objectives:

To determine the effect of a balance training program on kickboxing athlete‘s, suffering from chronic ankle joint instability, balance, muscle strength of muscles surrounding the ankle joint and reaction time. Also to compare changes of balance, muscle strength of muscles surrounding the ankle joint and foot reaction time for a kickboxing athlete suffering from chronic ankle joint instability before and after the physiotherapy program.

Methodology:

Organization of the study: study was carried out in Faculty of Health Care, Šiauliai State University of Applied Sciences. Study started on 2021-12-17 and was fiinished on 2022-03-14.

A case study was used to evaluate and compare the effects of a physiotherapy program on balance, foot reaction time and strength of the muscles surrounding the ankle joint of a kickboxer with chronic ankle instability. The purpose of this study and its benefits for the participant were explained to the respondent. The research was conducted in accordance with the ethical principles of research ethics and the principles adopted in the Declaration of Helsinki concerning medical research on human subjects. *Subjects:* the subject was chosen in accordance of the selection criteria (type of sports - kickboxing, as 26% of injuries in kickboxing are lower limb injuries; male gender, as statically male kickboxers are more likely to sustain injuries than female kickboxers; subject has sustained multiple ankle sprains over the years and experiences symptoms of chronic instability). The subject – 1 male kickboxer, 21 years of age who suffered a sprain of the tibiofemoral ligaments (clinical diagnosis code S93.4), several

sprains of the ankle ligaments (clinical diagnosis codes S93.40 and S93.6), and a fracture of talus (clinical diagnosis code S92.1) since 2020. The subject underwent a 12-week physiotherapy program consisting of balance training exercises created by Cuğ et al. (2016), which was based on progressive difficulty based on errors. The main difference with Cuğ et al. (2016) study was that in order to better analyse effect of these exercise, study time was increased to 12 weeks and consisted of 3 assessments during the study. Balance training program consisted of 4 exercises on the BOSU ball. Each exercise had 12 step progression plan, where difficulty was increased every week. Before the balance training exercises a 5-minute warm-up was done consisting of range of motion exercises on the ankle joint.

Research methods: The assessment of the balance, muscle strength of muscles surrounding the ankle joint and foot reaction time were conducted three times: before the study (assessment 1), after 6 weeks (assessment 2) and after 12 weeks (assessment 3). The result analysis was carried out using Microsoft Excel program where percentage changes and graphs were made. For the assessement of dynamic balance the star excursion test was used. The test was done three times in each direction: anterior, posteromedial and posterolateral. Both legs were examined. The best result out of three trials was used for analysis of the results. For the assessement of static balance the flamingo test was used. The test was done on each leg and the test was considered as failed if the subject fell off the beam 15 times in 30 seconds. For the assessement of static and dynamic balance HUBER 360 multi-directional motorized platform was used. The subject had to follow the instructions on the screen of the HUBER 360 platform and perform the test without any instructions from the researcher. The testing was observed by the researcher. The following tests were done for the assessment: stability length, stability area, stability velocity, length of balance, area of balance, walking test and limits of stability. For the assessement of muscle strength of the muscles surrounding the ankle joint a hand-held dynamometer was used. The test was done on each leg three times for each muscle group and the average score was calculated. For the assessement of foot reaction time the reactiometer RA-1 was used. The test was done on each leg using pedals. Foot reaction time was tested on each leg seperately to auditory and visual stimulus and on both legs together to visual stimulus.

Analysis of results

Results of the modified star excursion test

While comparing the results of assessment 1 and assessment 2 of the subject's left leg push-off distance we found an improvement of 6 cm (9%) in the anterior direction, 9.5 cm (8%) in the posteromedial direction and 7.5 cm (6%) in the posterolateral direction. While comparing the results of assessment 2 and assessment 3 we found an improvement of 5 cm (7%) in the anterior direction, 3,5 cm (3%) in posteromedial direction, and in the posterolateral direction by 4 cm (3%) (Figure 1). While comparing the results of assessment 1 and assessment 3 we found an improvement of 11 cm (16%) in the anterior direction, 13 cm (11%) in posteromedial direction, and in the posterolateral direction by 11 cm (10%) (Fig. 1).

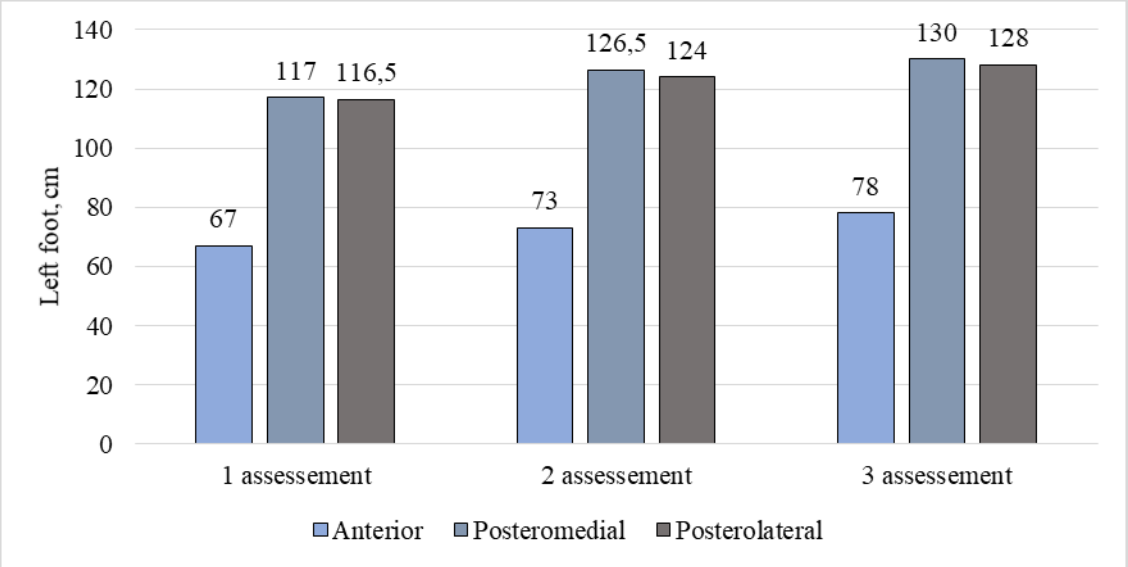

Fig. 1. Modified star test results before, after 6 and 12 weeks of physiotherapy.

While comparing the results of assessment 1 and assessment 2 of the subject's left leg push-off distance we found an improvement of 5,5 cm (8%) in the anterior direction, 10 cm (9%) in the posteromedial direction and 8 cm (7%) in the posterolateral direction. While comparing

the results of assessment 2 and assessment 3 we found an improvement of 3 cm (4%) in the anterior direction, 6,5 cm (5%) in posteromedial direction, and in the posterolateral direction by 4 cm (3%). While comparing the results of assessment 1 and assessment 3 we found an improvement of 8,5 cm (13%) in the anterior direction, 16,5 cm (15%) in posteromedial direction, and in the posterolateral direction by 12 cm (11%) (Fig. 2).

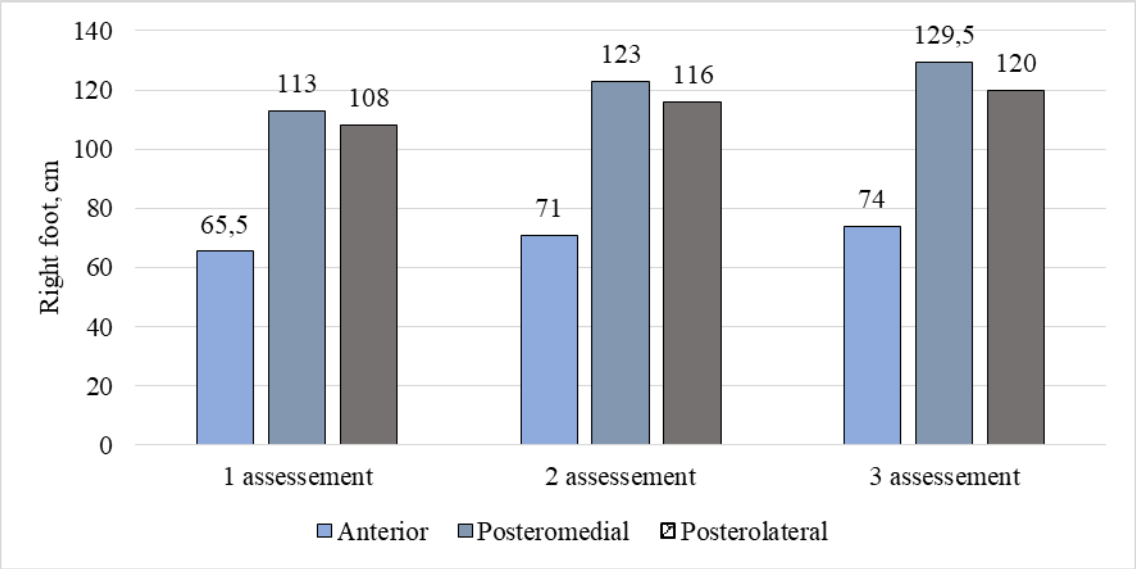

Fig. 2. Modified star test results before, after 6 and 12 weeks of physiotherapy.

Results of the flamingo test

While comparing the results of assessment 1 and assessment 2 of the subject's left leg number of errors we found an improvement of 3 points (25%). While comparing the results of assessment 2 and assessment 3 of the subject's left leg number of errors we found an improvement of 2 points (22%). While comparing the results of assessment 1 and assessment 3 of the subject's left leg number of errors we found an improvement of 5 points (42%) (Fig. 3).

While comparing the results of assessment 1 and assessment 2 of the subject's right leg number of errors we found an improvement of 2 points (14%). While comparing the results of assessment 2 and assessment 3 of the subject's right leg number of errors we found an improvement of 2 points (17%). While comparing the results of assessment 1 and assessment 3 of the subject's right leg number of errors we found an improvement of 4 points (29%) (Fig. 3).

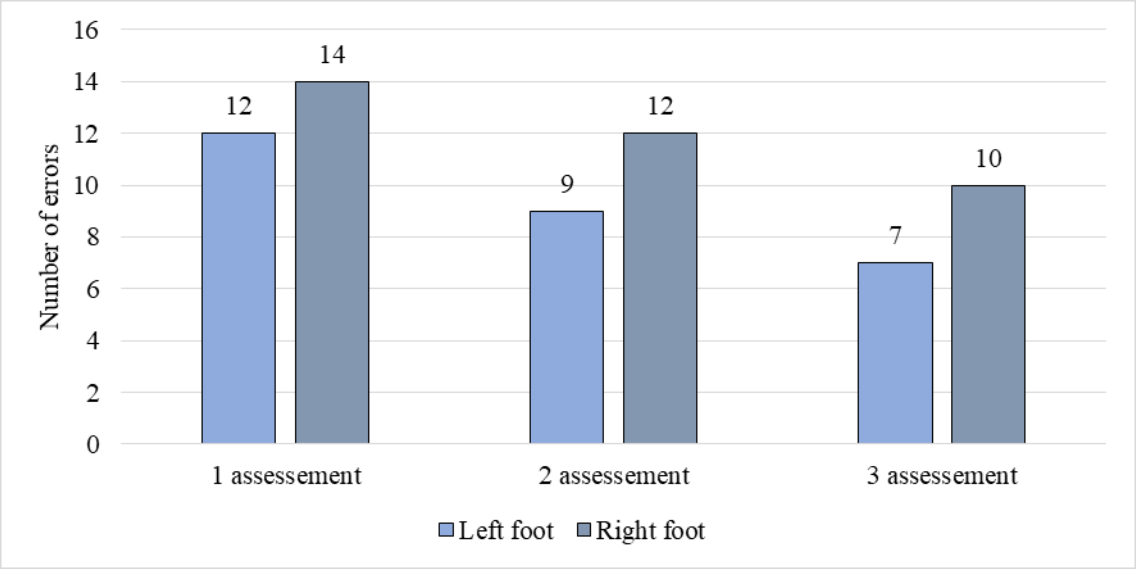

Fig. 3. Left and right foot flamingo test results before, after 6 and 12 weeks of physiotherapy

Results of dynamometry

While comparing the results of assessment 1 and assessment 2 of the subject's left lower leg muscle strength we found an improvement of 1 kg (6%) in dorsiflexion, 2 kg (14%) in plantarflexion, 1 kg (33%) in inversion and 2 kg (67%) in eversion. While comparing the results of assessment 2 and assessment 3 of the subject's left lower leg muscle strength we found an improvement of 3 kg (16%) in dorsiflexion, 1 kg (6%) in plantarflexion, 2 kg (15%) in inversion and 2 kg (14%) in eversion. While comparing the results of assessment 2 and assessment 3 of the subject's left lower leg muscle strength, we found an improvement of 5 kg (22%) in dorsiflexion, 3 kg (21%) in plantarflexion, 3 kg (20%) in inversion and 4 kg (33%) in eversion (Fig. 4).

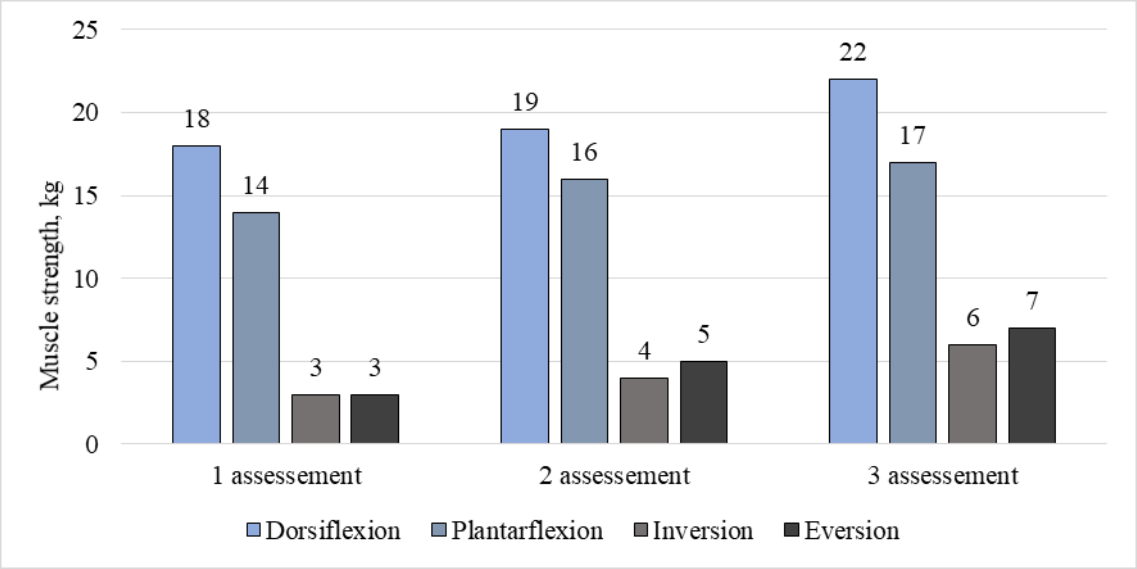

Fig. 4. Left calf muscle strength results before, after 6 and 12 weeks of physiotherapy

While comparing the results of assessment 1 and assessment 2 of the subject's right lower leg muscle strength we found an improvement of 2 kg (13%) in dorsiflexion, 3 kg (25%) in plantarflexion, 1 kg (25%) in eversion and no change in eversion. While comparing the results of assessment 2 and assessment 3 of the subject's right lower leg muscle strength we found an improvement of 3 kg (17%) in dorsiflexion, 2 kg (13%) in plantarflexion, 2 kg (67%) in inversion and 2 kg (67%) in eversion. While comparing the results of assessment 1 and assessment 3 of the subject's right lower leg muscle strength we found an improvement of 5 kg (31%) in dorsiflexion, 5 kg (42%) in plantarflexion, 2 kg (67%) in inversion and 3 kg (25%) in eversion (Fig. 5).

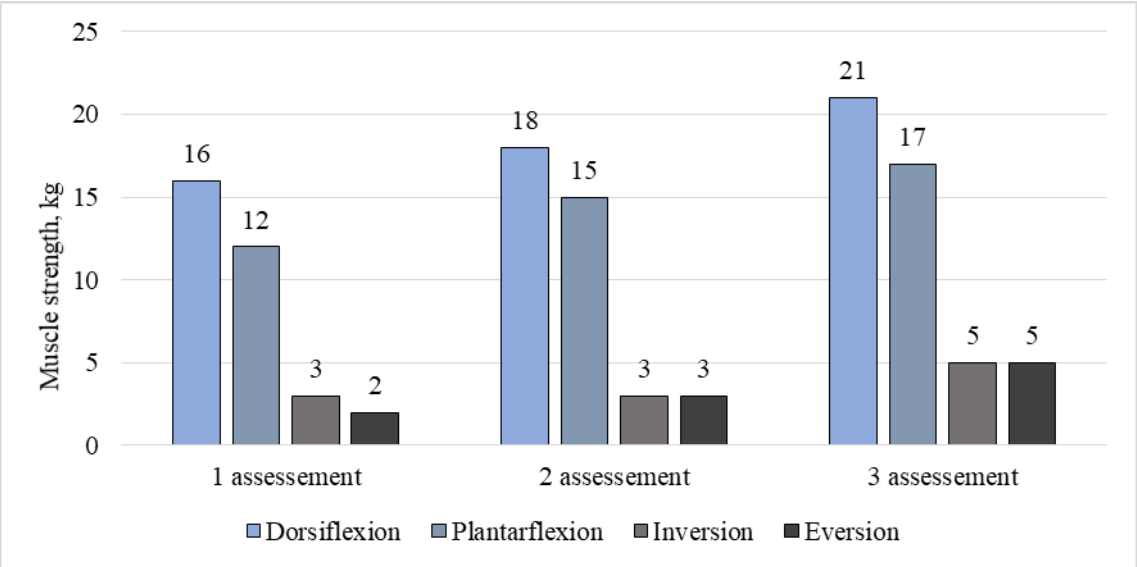

Fig. 5. Right calf muscle strength results before, after 6 and 12 weeks of physiotherapy

Results of the reactiometer RA-1 results

While comparing the results of assessment 1 and assessment 2 of the subject's reaction time to light stimulus we found an improvement of 5.12 ms in left leg, 23.5 ms in right leg, 70.9 ms in both left and right legs. While comparing the results of assessment 2 and assessment 3 of the subject's reaction time to light stimulus we found an improvement of 48.88 ms in left leg, 8.3 ms in right leg, 36.83 ms in both left and right legs. While comparing the results of assessment 1 and assessment 3 of the subject's reaction time to light stimulus we found an improvement of 54 ms in left leg, 31.8 ms in right leg, 107.73 ms in both left and right legs (Fig. 6).

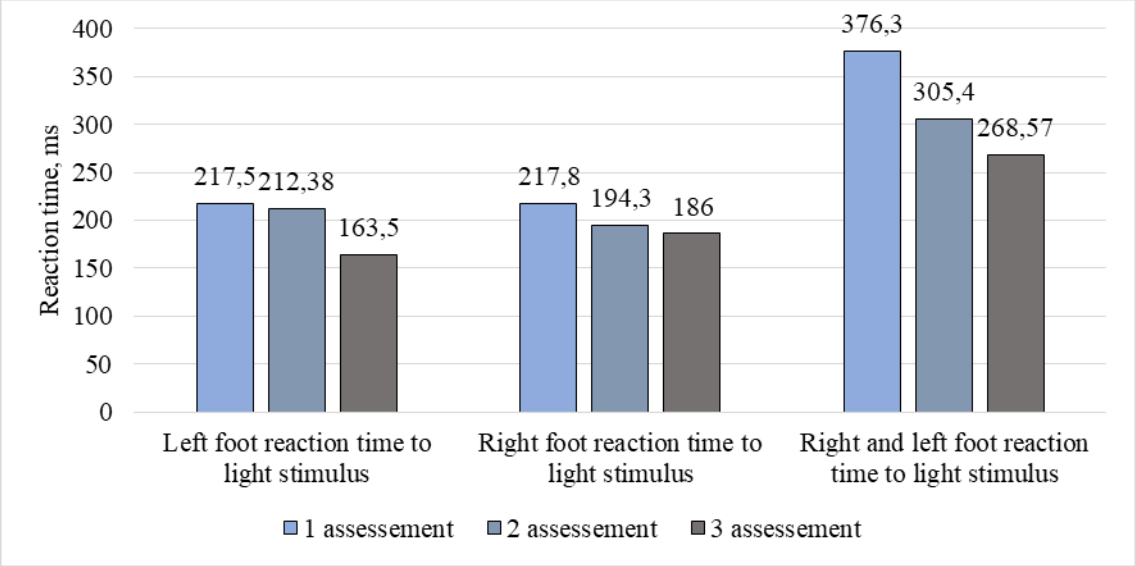

Fig. 6. Right and left foot reaction time to light stimulus results before, after 6 and 12 weeks of physiotherapy

While comparing the results of assessment 1 and assessment 2 of the subject's reaction time to light stimulus we found an improvement of 23.7 ms of left leg, 16.5 ms in right leg. While comparing the results of assessment 2 and assessment 3 of the subject's reaction time to light stimulus we found an improvement of 30.47 ms in left leg, 41.17 ms in right leg. While comparing the results of assessment 1 and assessment 3 of the subject's reaction time to light stimulus we found an improvement of 54.17 ms in left leg, 57.67 ms in right leg (Fig. 7).

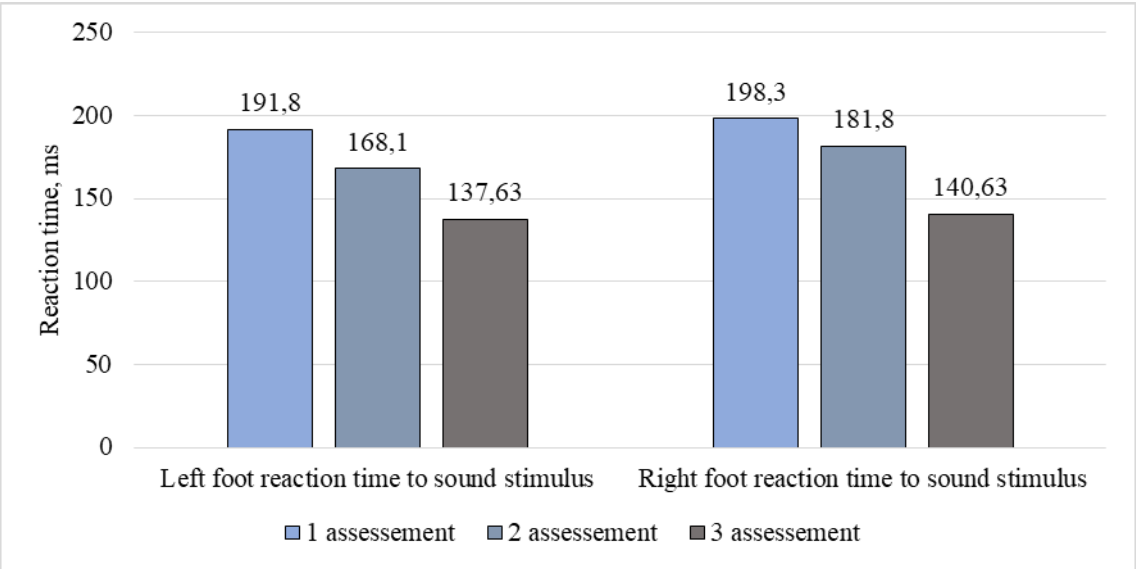

Fig. 7. Right and left foot reaction time to sound stimulus before, after 6 and 12 weeks of physiotherapy

The results of HUBER 360 multi-directional motorized platform

Stability assessment. The stability of the subject was assessed using the following parameters: stability length, stability area and stability velocity. While comparing results of

assessment 1 and assessment 2 in the subject stability length we found an improvement of 23.27 mm (4%) with eyes opened and 69.61 mm (8%) with eyes closed. While comparing results of assessment 2 and assessment 3 in the subject stability length we found an improvement of 69,83 mm (13%) with eyes opened and 85,78 mm (11%) with eyes closed. While comparing results of assessment 1 and assessment 3 in the subject stability length we found an improvement of 93,1 mm (17%) with eyes opened and 155,39 mm (18%) with eyes closed (Fig. 8).

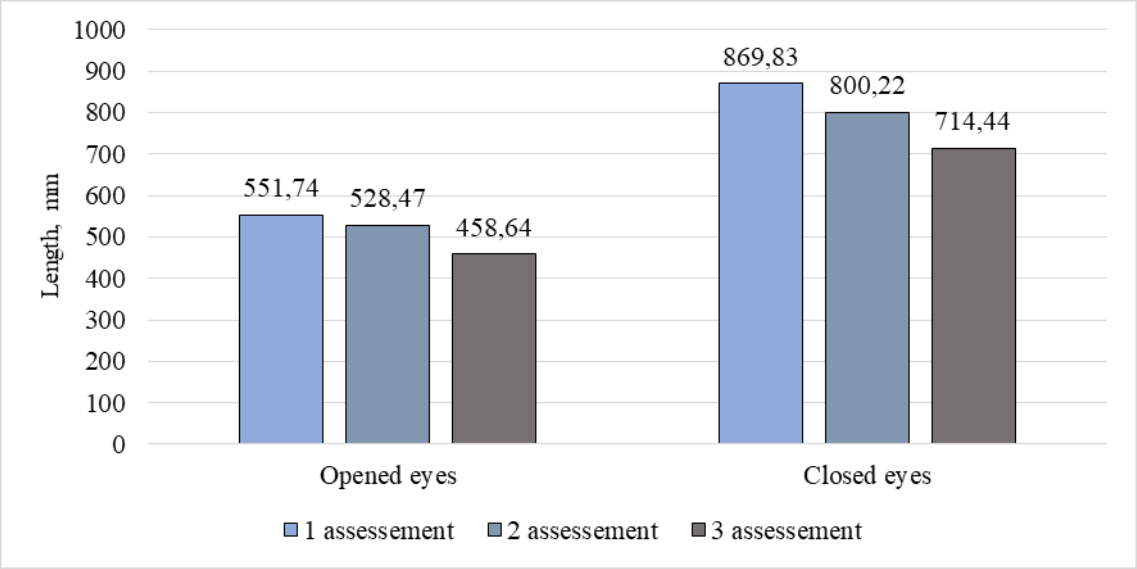

Fig. 8. Stability length with opened and closed eyes results before, after 6 and 12 weeks of physiotherapy

While comparing results of assessment 1 and assessment 2 in the subject stability area we found a regression of 103,08 mm2 (68%) with eyes opened and 31,25 mm2 (8%) with eyes closed. While comparing results of assessment 2 and assessment 3 in the subject stability area we found an improvement of 170,88 mm2 (67%) with eyes opened and 5,74 mm2 (1%) with eyes closed. While comparing results of assessment 1 and assessment 3 in the subject stability area we found an improvement of 67,8 mm2 (45%) with eyes opened and a regression of 25,51 mm (7%) with eyes closed (Fig. 9).

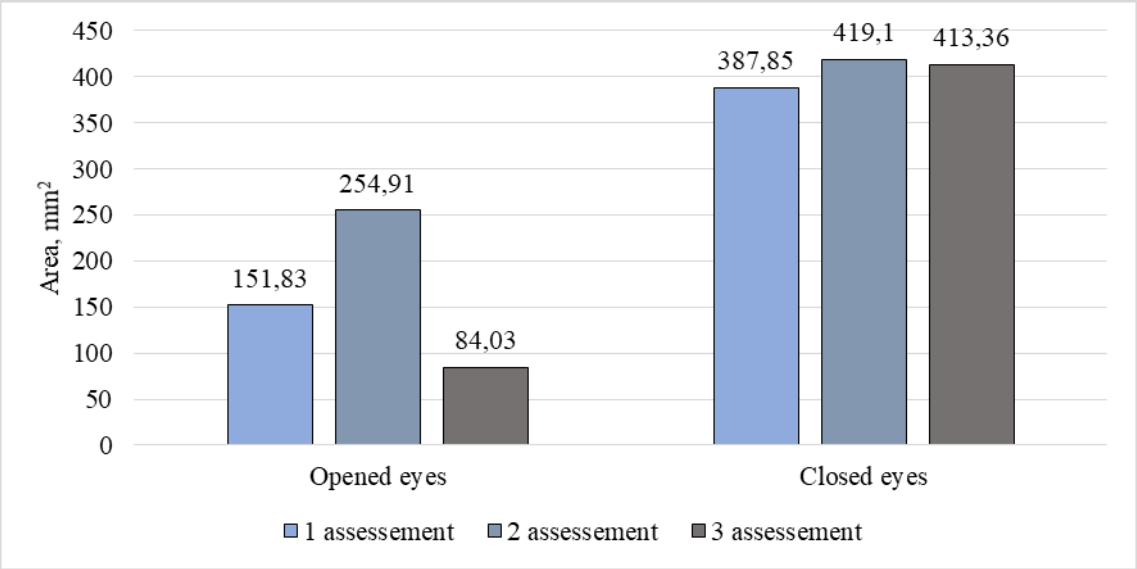

Fig. 9. Stability area with opened and closed eyes results before, after 6 and 12 weeks of physiotherapy

While comparing results of assessment 1 and assessment 2 in the subject stability velocity we found an improvement of 0.53 mm/s (5%) with eyes open and 1.4 mm/s (8%) with eyes closed. While comparing results of assessment 2 and assessment 3 in the subject stability

velocity we found an improvement of 1.33 mm/s (13%) with eyes open and 1.71 mm/s (11%) with eyes closed. While comparing results of assessment 1 and assessment 3 in the subject stability velocity we found an improvement of 1.86 mm/s (17%) in eyes open and 3.11 mm/s (18%) in eyes closed (Fig. 10).

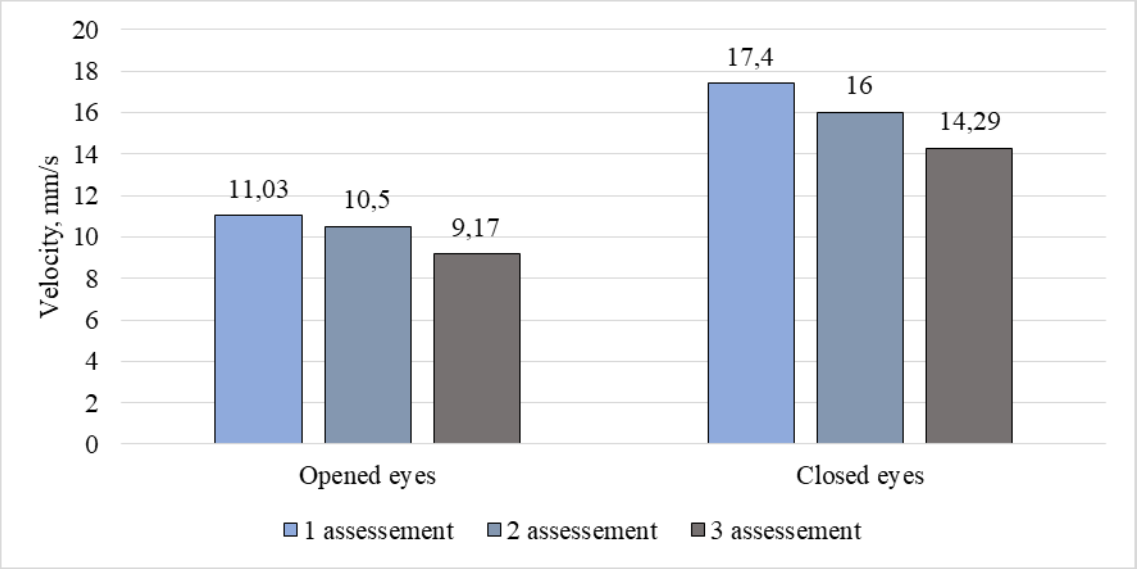

Fig. 10. Stability velocity with opened and closed eyes results before, after 6 and 12 weeks of physiotherapy

Balance assessment. The indicators used to assess the subject's balance were: length of balance and area of balance. While comparing results of assessment 1 and assessment 2 in the length of balance we found an improvement of 13.62 mm (0.8%) while standing on the left leg and a regression by 19.6 mm (0.9%) while standing on the right leg. While comparing results of assessment 2 and assessment 3 in the length of balance we found an improvement of 376.88 mm (23%) while standing on the left leg and 333.23 mm (15%) while standing on the right leg. While comparing results of assessment 1 and assessment 3 in the length of balance we found an improvement of 390.5 mm (23%) on the left leg and 313.63 mm (15%) on the right leg (Fig. 11).

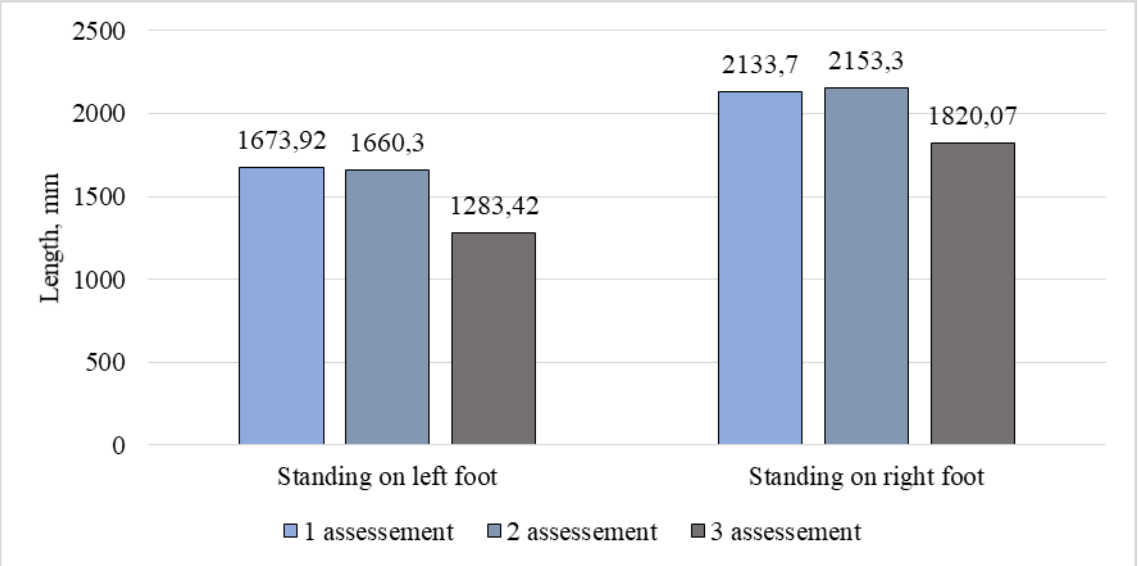

Fig. 11. Balance length standing on left and standing on right foot results before, after 6 and 12 weeks of physiotherapy

While comparing results of assessment 1 and assessment 2 in the area of balance we found a regression of 291.38 mm2 (32%) on the left leg and 199.59 mm2 (15%) on the right leg. While comparing results of assessment 2 and assessment 3 in the area of balance we found a regression of 780.37 mm2 (64%) on the left leg and an improvement of 163.88 mm2 (11%) on

the right leg. While comparing results of assessment 1 and assessment 3 in the area of balance we found a regression of 1073.75 mm2 (215%) on the left leg showed and 35.71 mm2 (3%) on the right leg (Fig. 12).

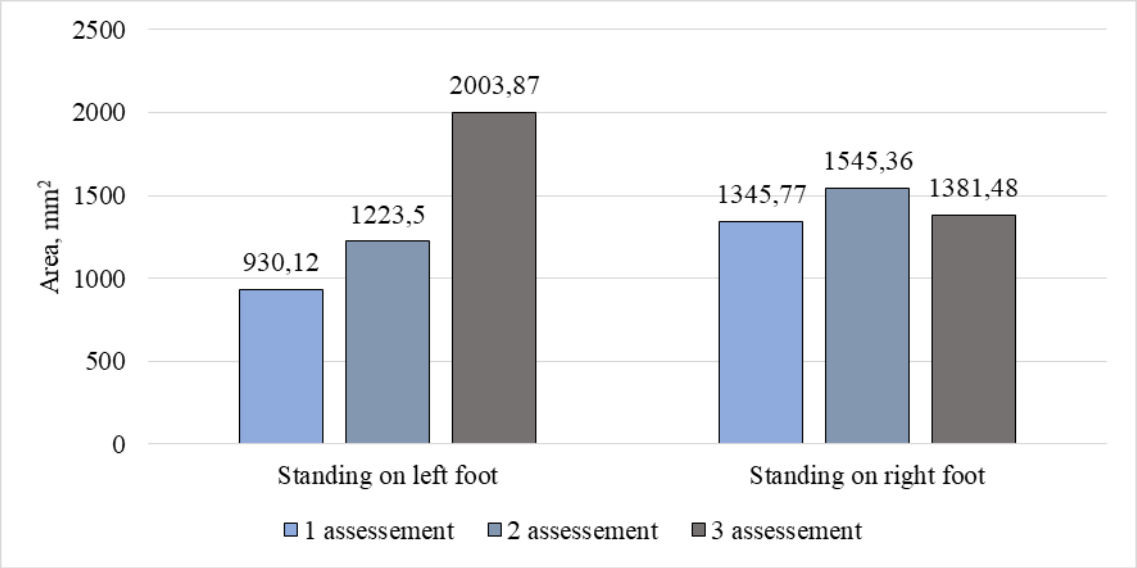

Fig. 12. Balance area standing on left foot and standing on right foot results before, after 6 and 12 weeks of physiotherapy

Walking test. While comparing results of assessment 1 and assessment 2 on the subject's walking speed over 50 seconds we found an improvement of 7 steps (9%). While comparing results of assessment 2 and assessment 3 on the subject's walking speed over 50 seconds we found an improvement of 15 steps (19%). While comparing results of assessment 1 and assessment 3 on the subject's walking speed over 50 seconds we found an improvement of 22 steps (30%) (Fig. 13).

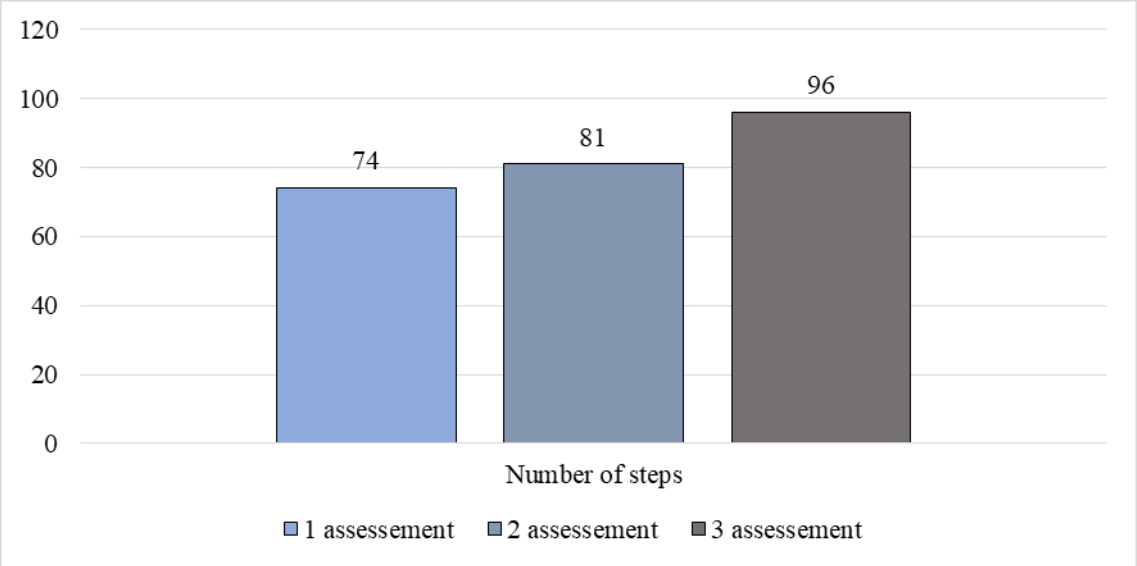

Fig. 13. Number of steps results before, after 6 and 12 weeks of physiotherapy

Limits to stability. While comparing results of assessment 1 and assessment 2 on the subject's maximum amplitude of stability limits in 8 directions we found an improvement of 2102.13 mm (2%). While comparing results of assessment 2 and assessment 3 on the subject's maximum amplitude of stability limits in 8 directions we found an improvement 8985.66 mm (9%). While comparing results of assessment 1 and assessment 3 on the subject's maximum amplitude of stability limits in 8 directions we found an improvement 11087.79 mm (11%) (Fig. 14).

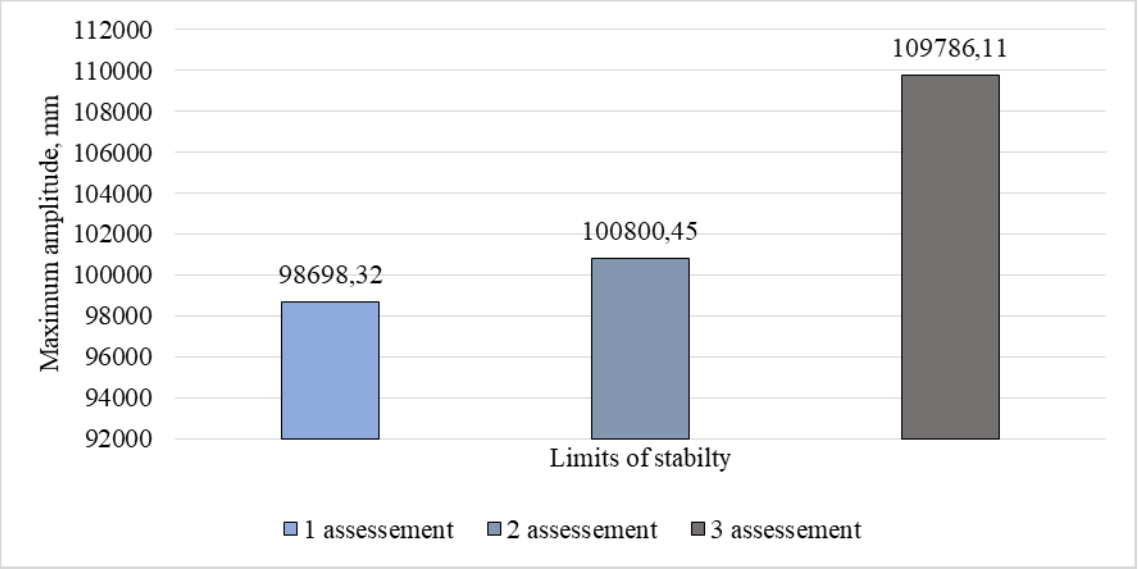

Fig. 14. Limits of stability results before, after 6 and 12 weeks of physiotherapy

Discussion

The aim of this study was to evaluate the effect of a balance training program on balance, muscle strength and foot reaction time of a kickboxing athlete with chronic ankle joint instability. After the study we found that a 12-week balance training program improved the subject's dynamic and static balance, lower limb muscle strength, foot reaction time, coordination of an ankle.

Increased muscle strength also has an effect on static balance. When muscles, surrounding the ankle joint become stronger and more coordinated, they can stabilize ankle joint better, thus static balance while standing on one leg also improves. When there is better muscle response, ankle posture changes also, there are less unnecessary movements, joint stays stable inspite of internal or external stimulus.

Reaction time improves also when muscle strength and balance increase. While performing exercises on unstable surfaces, afferent and efferent impulses between CNS and lower limb increases, thus reaction time shortens. That allows to maintain optimal ankle joint stability and coordination. When muscles surrounding ankle joint become stronger, they not only stabilize the joint better, but also can contract faster and effectively adjust position necessary for movements.

According to the authors of the balance training program that was used in our study, a 4-week balance training program consisting of exercises with progressive difficulty on a BOSU ball improved strength of the muscles surrounding the ankle joint [3]. In our study we found that the balance training program improved strength of muscles involved in plantarflexion, dorsiflexion and eversion. In comparison of the strength of the muscles surrounding the ankle joint from Cuğ and co-authors' (2016) study showed that 4 weeks of balance training program improved strength of the muscles involved in plantarflexion, dorsiflexion, eversion and inversion ($p<0.05$). Meanwhile, Deussen and co-authors (2018) conducted a study on the effect of exercises on a wobble balance board and soft surfaces on athletes who sustained ankle sprains [4]. The study results showed an increase in the strength of the athletes' muscles involved in eversion and inversion and found that a 6-week program showed a more significant increase in muscle strength than a 10-week program. The authors suggest that sensorimotor training on unstable surfaces may have contributed to the prolonged neuromuscular adaptation leading to the increase in the strength of the muscles surrounding the ankle joint.

A systematic review and meta-analysis conducted by Plangtaisong and co-authors (2021) showed that the reflexive response to external stimuli is worse in individuals with chronic ankle instability. Because of lower reflexive response the adaptivity to sudden and changing movements is weakened and it is more difficult to avoid ankle sprains. In a selected study investigating the effects of balance, neuromuscular and proprioception training on the response time of the core muscles showed that neuromuscular and proprioceptive training improves hamstring muscle reaction time and thus reduces the risk of injury [8]. Balance training improves the athlete's reaction time and lower limb stability control while standing on the ground. It also enhances the signals sent by the proprioceptors, which results in a feedback loop which trains the athlete's balance and improves body positioning awareness in changing conditions [9]. In our study the subject's lower limb reaction time of the subject's left and right

leg was reduced. For kickboxing athletes, muscle strength and reaction time are important components to achieve excellence in competition. Kickboxing mainly consists of dynamic and short actions performed in a very short period of time, therefore lower limb muscle strength and reaction time are important during training and competition [12]. In comparison with the authors of the balance program our study showed an improvement of dynamic balance. In the original study a moderate improvement was found in dynamic balance in the anterior direction, but even more significant increase was found in posteromedial and posterolateral directions. Meanwhile, in a study done by Schaefer and co-authors (2012), an identical balance training program and dynamic balance assessment was used and it was found that individuals with chronic ankle instability showed a greater improvement of dynamic balance in anterior direction [10]. A study conducted by Benis and co-authors (2016) investigated the changes of dynamic balance in professional basketball players following a neuromuscular exercise program and found that neuromuscular and plyometric exercises improved dynamic balance in posteromedial and posterolateral directions as well as the composite outcomes in both limbs [1].

In our study we found an improvement of the subject's static balance as the number of errors made with the left leg decreased by 5 errors and the number of errors made with the right leg decreased by 4 errors. Tanir and co-authors (2018) conducted an 8-week study investigating static and dynamic balance in soccer players aged 10-12 years. The program used in the study consisted of exercises on a BOSU ball, gymnastics ball and balance board, plyometric and spinal stabilization exercises [13]. The study showed an improvement in static balance.

The results obtained in this study may have been limited by several aspects. Firstly, the subject was involved in 8 hours of standing physical work followed by an assessment. The fatigue caused by the physical work could have negatively affected the results. Secondly, the subject contracted COVID-19 before assessment 2 and the subject still continued the exercise program. Also, after his recovery the subject immediately started intensive training for kickboxing competitions. At that time, the intensity and number of training sessions was increased to 5 times per week and 2 times per day. During the competition, the subject sustained several right leg ankle ligament sprains. Also, the outcome of the competition was affected by breathing difficulties caused by COVID-19. These causes may have affected the subject's results of 2nd assessment.

In over all, despite several study limitations, we got a significant increase in ankle joint functions and physical parameters focusing only on ankle joint. Thus, future researchers should consider including evaluation of knee and hip joint functions when performing these exercesis, analyze how changes in these regions change results of ankle function and vice versa. Also we would recommend to include assessment and exercises of core region as it has big influence to overall balance.

Conclusions

Chronic ankle joint instability is a condition that affects the ankle joint, that causes loss of muscle strength, pain and disturbance of proprioception and balance. An effective rehabilitation program consisting of muscle strength and balance training exercises on unstable surfaces is important in the case of chronic ankle joint instability. A 12-week balance training program on the BOSU ball improved the subject's dynamic and static balance, increased the strength of the muscles involved in flexion, extension, inversion and eversion of the foot, increased the reaction time of the lower limbs and reduced ankle joint pain. While comparing the changes before and after balance training program we found that balance, muscle strength of the muscles surrounding the ankle joint and lower extremity reaction time improved after the physiotherapy program.

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