DOI: *10.48305/jrrs.2023.31132* *Published by* *Vesnu Publications*

The Effect of Six Weeks of Trampoline Training on Balance and Leg Muscle Strength in Obese and Overweight Women: A Quasi-Experimental Study

Mohammadreza Batavani[1], Neda Boroushak[2], Mahdie Piri[3], Mohsen Ghofrani[4]

Original Article

Abstract

Introduction: Imbalance is one of the common problems in overweight people; disproportionate exercise may increase the risk of injury in these people. Trampoline exercises are one of the highly safe exercises; therefore, the purpose of this research was to investigate the effect of six weeks of trampoline training on balance and leg muscle strength in obese and overweight women.

Materials and Methods: For this semi-experimental pre-post study the target population were all 16-23 years old inactive, obese or overweight women (BMI $\geq$ 27.5 kg/m^2) living in Zahedan city in 1401 among which 20 volunteers met inclusion criteria and were divided into equal experimental and control groups.They were evaluated by static, and dynamic balance and quadriceps strength tests. The experimental group took part in trampoline exercises for 6 weeks, 4 sessions per week. 1.5 hours per session; 48 hours after the last exercise session, a post-test was taken from both groups in the same conditions as the pre-test stage. Statistical analysis was performed using paired t tests, independent t tests and ANCOVA tests at significance level 0.05.

Results: The results showed that there was no significant difference between the pre- and post-test results of the experimental group in static balance ($P = 0.12$), although dynamic balance ($P = 0.04$) and quadriceps muscle strength ($P = 0.03$) significantly improved. Also, between-group comparison revealed no significant difference in static balance ($P = 0.10$); the experimental group showed significantly better values of dynamic balance ($P = 0.03$) and quadriceps muscle strength ($P = 0.04$) v.s. the control group.

Conclusion: It seems that trampoline exercises increased dynamic balance and strength of quadriceps muscles in obese and overweight women.

Keywords: Trampoline; Static balance; Dynamic balance; Quadriceps strength

Citation: Batavani M, Boroushak N, Piri M, Ghofrani M. **The Effect of Six Weeks of Trampoline Training on Balance and Leg Muscle Strength in Obese and Overweight Women: A Quasi-Experimental Study.** J Res Rehabil Sci 2022; 18.

Received date: 02.01.2023 Accept date: 04.02.2023 Published: 06.03.2023

Introduction

Balance refers to the ability to keep the body's center of gravity within the area of support, which is the contact surface between the leg and the ground. Maintaining balance requires minimal movement without losing stability. If the body's center of gravity moves outside of this support area, it results in imbalance (1). Imbalance is particularly common in individuals who are overweight, especially among those who are obese (2). This issue can be aggravated by skeletal problems, such as osteoarthritis, which is prevalent in this population (3). As a result of these imbalances, there is an increased risk of bone fractures, particularly in the hip area, which can lead to serious complications (4). Research shows that obese individuals fall at approximately twice the rate of those with a healthy body weight who experience similar conditions. These falls are a leading cause of injuries

1- Assistant Professor of Sports Sciences, Center of Physical Education, Isfahan University of Technology, Isfahan, Iran
2- Assistant professor of Sports Biomechanics, Department of Sports Biomechanics, Sport Sciences Research Institute, Tehran, Iran
3- MSc of Exercise Physiology, Department of Physical Education and Sport Sciences, Faculty of Educational Sciences, University of Sistan and Baluchestan, Zahedan, Iran
4- Associate Professor, Department of Physical Education and Sport Sciences, Faculty of Physical Education and Sport Sciences, University of Sistan and Baluchestan, Zahedan, Iran
Corresponding Author: Neda Boroushak; Assistant professor of Sports Biomechanics, Department of Sports Biomechanics, Sport Sciences Research Institute, Tehran, Iran; Email: n.boroushak@ssrc.ac.ir

in this group (5).

Exercise is a widely accepted and popular method for weight management, and many weight control programs incorporate various physical activities (2). However, obesity can be a significant barrier to participating in sports, which can lead to serious physical issues. For instance, recreational sports such as legball and mountain climbing can impose additional pressure on the lower joints of individuals with obesity (3). Physical activities can lead to feeling pain in different areas of the body for individuals with obesity (6). As a result, this population often struggles to lose weight and lower the risks associated with obesity. Additionally, they may experience issues such as decreased muscular strength and balance and are unable to perform any exercises they want. It appears that resistance exercises may be a practical solution for increasing body mass and reducing weight and fat percentage in middle-aged women (3, 6). It was revealed in a simulation study to estimate the amount of balance improvement after muscular reinforcement and weight reduction (7) that both methods can improve balance in people with obesity (2,7).

In Europe and the United States, physical exercises are recently conducted on an unstable surface, leading to improved balance and strength of postural muscles. One example of these types of surfaces is a trampoline board that helps to enhance proprioceptive coordination and stimulation (8). Trampoline exercises involve jumping and postural alternations that can help maintain balance and create contraction and relaxation of various body muscles, associated with numerous benefits for the skeletal-muscular system. Another advantage of trampoline is controlling body posture, which needs to be maintained during the exercise (9). This type of joint exercise is characterized by high energy consumption and is assumed to be effective in training abdominal, leg, hip, and waist muscles (10). Unlike rope skipping, jogging, or walking, jumping exercises are viewed as a new training method, according to the principle of training variety, which possesses the attributes of dynamism and mobility necessary to motivate and interest women, making them preferable to other training methods (8, 10). Moreover, some people avoid participating in regular sports activities, such as walking, which leads to increased inactivity. Therefore, jumping activity using a trampoline board can be viewed as a suitable practice for maintaining physical activity and preventing the consequences of inactivity, as it is a low-risk and safe activity for older adults (9). Additionally, other jumping activities without trampoline such as rope skipping and jogging can lead to joint injuries due to the impact forces upon landing (8). However, the aforementioned method of exercise provides more support for the waist and lower extremities, along with a reduced risk of sports injuries (10), and is therefore more appropriate for people with obesity. It is stated that trampoline training is a practical approach for achieving physical fitness according to American Association of Sport Medicine guidelines for obese and overweight women.

Considering the prevalence of obesity and the irreversible dangers caused by falls in these individuals, which sometimes force them to undergo risky surgeries, improving balance and muscle strength in obese people is of paramount importance. Therefore, given that trampoline is considered an exercise for unstable balance with alternating adduction and abduction of the knee joint, the present research aims to evaluate the effect of a six-week trampoline program on balance and leg muscular strength in obese and overweight women.

Materials and Methods

The present study employed a quasi-experimental research design with a pre-test and post-test, in which variables of interest were evaluated in two experimental and control groups. The statistical population consisted of all obese and overweight women living in Zahedan, Iran, whose Body Mass Index (BMI) was equal to or greater than 27.5 kg/m², and their ages ranged between 16 and 23 years. This study was conducted exclusively on women to control for the confounding effects of gender on research outcomes, considering the differences in anthropometry, physiology, and biometrics between men and women. Through a purposive and convenient sampling method, volunteers were recruited via a written call in cooperation with the Zahedan Sports and Physical Training Office. Since there were no similar studies available, the original sample size was established at 10 participants per group. However, following a statistical evaluation of the 20-subject sample, the size was increased to ensure adequate statistical power ($\beta = 0.80$). Twenty-one women volunteered to participate in the study, from which 20 individuals were selected after administering the Physical Activity Readiness Questionnaire (PAR-Q). The validity and reliability of PAR-Q were determined prior to the present study by Eshaghi et al. (11). The inclusion criteria for the study were as follows: participants had to be female, between the ages of 16 and 23, and have a Body Mass Index (BMI) of 27.5 kg/m² or higher. Additionally, participants were required to demonstrate an absence of regular physical activity in their daily lives and to be in good health, meaning they had no history of heart disease, high blood pressure, diabetes, asthma, rheumatoid arthritis, previous surgeries, neuromuscular diseases, or any inflammatory or painful conditions affecting the ankle joint. Participants also should not be on any medications and had to have a negative history of smoking. Furthermore, they were required to follow the research guidelines and participate in the administered physical program. These criteria were assessed using a self-report health questionnaire, with verification by a physician or an MSc expert in sports physiology. All exercises took place at Ariana Gym in Zhedan, Iran.

Before the start of the research, all subjects and their parents were informed about the study method and its possible risks and signed a written consent form. At least 10 days before the start of the study, coordination was made with all participants regarding the implementation stages of the training protocol. After being informed about the study process and the type of exercises, they were divided into two equal groups, experimental and control, through matching. Then, the subjects attended a session in the laboratory, and after becoming familiar with the laboratory environment and the instruments used in the study, the physician measured the participants' weight using a TCM analog scale (model TT-, made in China). Each examinee went on the scale with a minimal amount of clothes and without wearing shoes, and her weight was documented using horizontal vision. To maximize the accuracy of documenting physical composition components with this instrument, participants were advised to avoid consuming large amounts of liquids or heavy meals for at least 3 hours before testing. Before the initiation of the training program, participants' heights were measured while they stood steadily for a few seconds with their heels, buttocks, and back of the head touching the wall, looking horizontally, using a Seca stadiometer (made in Germany). Each participant's BMI was calculated by dividing weight in kilograms by height in meters squared (12). To identify individuals at risk of injury, the Functional Movement Screen (FMS) test was used. The FMS test consists of 7 movement tests that measure neuromuscular coordination, trunk assessments, power and central stability, motor asymmetries, and flexibility asymmetries. It includes deep squats, hurdle stepping, lunges, shoulder range-of-motion exercises, active leg raises, trunk stability exercises, and rotational stability exercises. It is capable of identifying limitations and changes in standard movement patterns. A score of less than 14 (out of 21 total points) indicates that the individual is susceptible to injury (13). The procedures for measuring the static and dynamic balance of the dominant leg were initiated next. To identify the dominant leg, each subject was gently pushed from back to front; the leg used to regain balance was classified as the dominant leg (14). Prior to the balance tests, each subject warmed up for 10 minutes, concentrating mainly on their lower limb muscles, and then proceeded to perform the tests.

To measure static balance, the Static Balance Stork Test was used (15). In this test, the subject stands bareleg on a flat surface, places their hands on their hips, and positions the non-dominant leg against the knee of the dominant leg. The subject then lifts the heel, balancing on the ball of the dominant leg. The stopwatch starts when the heel is lifted off the ground, and the duration for which the subject can maintain this position is recorded as their score. The Timed Up and Go (TUG) test was used to evaluate dynamic balance and assess the balance and fall rates of participants during the pre-test. This test measures the time it takes to complete a 3-meter walk. Participants are instructed to rise from a chair with armrests, walk 3 meters, turn around, return to the chair, and sit down (16). It is worth mentioning that each subject performed this test three times with a one-minute rest interval between each repetition, and the average time for them was considered. Then, the participants proceeded to perform the training protocol.

Ethical considerations: This study was approved by the Ethics Committee of the University of Sistan and Baluchestan. (Ethics code: R.USB.REC.1400.028).

During the six-week period between the pre-test and post-test, the control group did not engage in any regular activity or specific exercise; whereas the experimental group performed exercises according to the health protocols, for six weeks, with four sessions per week, each lasting 1.5 hours (a total of 24 sessions). The training protocol consisted of 10 minutes of jumping training followed by 10 minutes of rest, with a 5-minute initial warm-up and final cool-down to prevent any potential injuries under the supervision of a trainer.

In the first session, the participants were introduced to the exercises, and an expert instructor then taught them basic preparatory exercises to help them develop spatial awareness, spatial orientation, and body control. These activities included jumping on a trampoline, and later, the participants were instructed to perform the movements independently during practice sessions in the following weeks (17). During the first and second weeks, training focused on hand and leg placement, proper body posture on the trampoline, as well as jumping, standing, and bouncing techniques to prevent injury. From the third to the sixth week, the training progressed to include high jumps with proper landing, bouncing in various directions, and clapping hands above the head while jumping on the trampoline. The trainer implemented the principle of overload by adjusting the number of jumps in each training session, ensuring that, according to the Borg index, participants began with fewer jumps that were considered to have mild difficulty based on their perceived exertion. Each week, the subjects aimed to not only maintain but also increase both the quantity and height of their jumps in each set, thereby progressively enhancing the level of difficulty (18). The control group carried out all their regular daily activities. Two days after the training concluded, a post-test was administered under conditions similar to those during the pre-test phase, between 8:00 AM and 12:00 PM. It's important to note that during the training period, only one case of an acute injury was reported, which did not result in the participant's withdrawal from the program.

The strength of the quadriceps muscles was evaluated using a dynamometer. To measure quadriceps strength, the patient was instructed to bend their knees and then straighten them to pull the handle. The tests were conducted twice: once with a short chain and once with a long chain, and the average of the two measurements was recorded (19).

In the descriptive analysis, the mean and standard deviation were used to summarize the statistical samples. For inferential analysis, the Shapiro-Wilk test assessed the normality of the data distribution. Given that the data were normally distributed, paired t-tests were used to examine within-group differences, independent t-tests were employed to compare pre-test anthropometric values between groups, and an analysis of covariance (ANCOVA) was conducted to compare post-test values between groups. These statistical analyses were performed using SPSS software (version 21, IBM Corporation, Armonk, NY), with a significance level set at $p < 0.05$. Power analysis was conducted using G*Power software (version 3.1.9.7, University of Düsseldorf, Germany). Since no participants dropped out during the study, an Intention-to-Treat (ITT) analysis was not conducted.

Results

In this study, all participants completed every stage of the survey, resulting in a zero dropout rate for both the individual groups and the overall study. The demographic variables of the participants are summarized in table 1.

The results from the Independent t-test indicated no significant differences in the pre-test values ($P > 0.5$). The results indicated that there was no significant difference between the pre-test and post-test stages for both the experimental and control groups in the static balance test. Furthermore, an Independent t-test comparing the post-test values of the control and experimental groups revealed no significant difference in the static balance variable ($P = 0.10$). The results obtained in the dynamic balance test showed a significant difference between the pre-test and post-test stages of the experimental group. In contrast, no significant difference was observed in the control group. The results of the independent t-test comparing the post-test dynamic balance values between the control and experimental groups revealed a significant difference ($P = 0.03$). The results of the paired t-test revealed a statistically significant difference in quadriceps muscle strength between pre-test and post-test scores within the experimental group ($P = 0.03$). Conversely, no significant difference was observed in the control group ($P = 0.09$). Additionally, the results of the independent t-test comparing post-test quadriceps muscle strength between the control and experimental groups demonstrated a significant difference ($P = 0.04$) (Table 2). Power analysis indicated that the statistical power of the present study was high ($\beta = 0.90$). Therefore, the absence of a significant difference in static balance between the two groups cannot be attributed to a small sample size.

Discussion

The present study aimed to investigate the effect of six weeks of trampoline training on balance and leg muscle strength in obese and overweight women.

Table 1. Comparison of demographic data between the experimental and control groups (10 participants in each group)

Variable	Group	Mean ± Standard deviation	t-statistic	P value
Age (year)	Experimental	20.80 ± 2.61	0.20	0.12
	Control	20.90 ± 1.79		
Height (cm)	Experimental	159.90 ± 2.02	012	0.26
	Control	159.10 ± 1.37		
Weight (kg)	Experimental	74.50 ± 2.12	0.14	0.21
	Control	74.30 ± 4.00		

Table 2. Intra-group and inter-group comparison of pre-test and post-test values of static, dynamic balance, and quadriceps strength in the experimental and control groups

Variable	Group	Pre-test value (Mean ± SD)	Post-test value (Mean ± SD)	Intra-group comparison (Paired t)	Inter-group comparison (Independent t)
Static balance (seconds)	Experimental	2.61 ± 0.46	2.80 ± 0.61	t = 2.12 (P = 0.12)	t= 0.78, P > 0.10
	Control	2.27 ± 0.67	2.75 ± 0.79	t = 2.80 (P = 0.09)	
Dynamic balance (seconds)	Experimental	6.70 ± 0.44	5.90 ± 0.36	t = 0.12 (P = 0.04)†	t = 1.12, P = 0.03*
	Control	6.53 ± 0.30	6.43 ± 0.37	t = 0.80 (P = 0.13)	
Quadriceps Muscle Strength (kilogram-force)	Experimental	28.90 ± 2.02	32.34 ± 1.09	t = 2.30 (P = 0.03)†	t = 1.12, P = 0.04*
	Control	29.10 ± 1.37	30.38 ± 0.85	t = 3.80 (P = 0.09)	

SD: Standard deviation

The results showed that six weeks of trampoline training led to a significant increase in dynamic balance and quadriceps muscle strength in obese and overweight women but did not have a significant effect on improving static balance. A literature search conducted revealed no studies that specifically examined the effects of trampoline training on balance and leg muscle strength in obese women. However, in a similar survey, Mashaal and colleagues concluded that six months of whole-body vibration training using a vibration device, combined with exercises on a trampoline and treadmill, led to improved balance in obese children (19). Additionally, Saleh and Afroundeh's study results showed that eight weeks of anaerobic gymnastics exercises improved the dynamic balance of obese children (20). Afsharmand and colleagues demonstrated the positive impact of a four-week unstable-surface training program on dynamic balance and muscle strength (21). In the present study, one reason for the increase in dynamic balance in obese individuals after six weeks of trampoline exercises is likely that the brain is forced to perform bilaterally during jumping, allowing both sides of the brain to work together to maintain body coordination. This leads to the activation of both sides of the body's limbs and an improvement in balance (22). During trampoline exercises, the body works to maintain its posture, activating core muscles such as the gluteus, erector spinae, and abdominal muscles, which help support body posture while jumping (23), thereby improving the individual's balance.

When using a trampoline, a sensation of weightlessness is experienced at the highest point of the jump, and upon landing on the jumping surface and jumping back up, the body is subjected to forces up to three times the force of Earth's gravity (22). In these two states, the muscles alternate between contraction and relaxation, which unconsciously leads to increased muscle endurance and strength (23). Another reason for the improvement in dynamic balance resulting from trampoline exercises in the present study may be the increased strength of the lower limb muscles of the participants and the enhanced stability of the foot structures after participating in the training program.

Research results have shown that trampoline exercises can lead to an increase in the maximum center of pressure (CoP) of the foot (24). Plantar pressure provides helpful information regarding the structure and function of the foot and, in addition, serves as an indicator for assessing balance. One of the primary functions of the foot is to absorb shock during activities such as running, jumping, and walking (25).

In trampoline exercises, due to continuous jumping movements and increased shock absorption in the foot structure area, the plantar pressure pattern in participants is likely to change, leading to improved balance in these individuals. It appears that this physiological and biomechanical principle has not substantially improved static balance performance in the experimental group, as there is no plantar contact with the ground during the static balance test.

Training in unstable conditions stimulates deep sensory receptors, providing feedback for maintaining balance and body awareness (26). Therefore, repeated jumps in trampoline exercises cause the body to move in various directions and angles. This dynamic movement challenges the brain to process information quickly and accurately. With consistent practice, the brain improves its ability to understand spatial relationships between the body, the trampoline, and the surrounding environment. This repeated engagement in spatial movements on the trampoline helps strengthen proprioception, or body awareness in space. Consequently, another reason for the improvement in dynamic balance observed in this study could be the enhancement of proprioception in obese girls. However, further research is needed to gain more insight into this area.

The recent use of training on various unstable surfaces has led to significant advancements in rehabilitation. Based on the findings of this study, trampoline exercises can serve as an effective method to improve balance and muscle strength, enhance overall health, and support injury recovery in training programs and rehabilitation processes.

The results of this study indicate that six weeks of trampoline exercises had no significant impact on the static balance of obese girls. An individual's balance is determined by the position of the body's center of mass relative to their base of support, which is the area of contact between the individual and the ground. Static balance is maintained when a person can keep their center of mass within this base of support. Various factors influence static balance, including the height of the center of gravity, the size of the base of support, and the positioning of the gravitational force's line of action. One possible reason for the lack of effectiveness of trampoline exercises on static balance in this study is that these exercises are inherently dynamic, involving jumping and hopping. As a result, they do not significantly impact the factors that govern static balance; rather, they enhance balance in dynamic situations (27). To better explore this topic, it is recommended that future studies focus on specific exercises designed to improve static balance in obese women.

Limitations

The present study was limited to a female population, and the number of participants was selected based on volunteers. Additionally, the age range of these individuals was restricted to 16 to 23 years.

Recommendations

It is recommended to investigate the effect of trampoline exercises on balance assessment indicators such as CoP displacement and the vestibular system to obtain more precise information about this type of exercise.

Conclusion

It seems that trampoline exercises can lead to an increase in dynamic balance and quadriceps muscle strength in obese and overweight women, reducing the risks associated with imbalance during other physical exercises in these individuals.

Acknowledgments

This research is based on a master's thesis (ID number 400 02 01) and has the ethics code IR.USB.REC.1400.028, approved by the University of Sistan and Baluchestan. The authors express their gratitude to all participants.

Authors' Contribution

Design and conceptualization: Neda Boroushak, Mohammadreza Batavani
Funding for project implementation: Neda Boroushak, Mahdie Piri, Mohammadreza Batavani, Mohsen Ghofrani
Project support, executive, and scientific services: Mohammadreza Batavani, Neda Boroushak, Mohsen Ghofrani, Mahdie Piri
Instruments and Sampling: Mahdie Piri, Mohammadreza Batavani
Data Collection: Neda Boroushak, Mahdie Piri
Data Analysis: Neda Boroushak, Mohammadreza Batavani, Mohsen Ghofrani, Mahdie Piri
Statistical analysis: Neda Boroushak, Mohammadreza Batavani
Manuscript preparation: Neda Boroushak, Mohammadreza Batavani, Mahdie Piri, Mohsen Ghofrani
Scientific revising of the manuscript: Mohammadreza Batavani, Mohsen Ghofrani, Neda Boroushak, Mahdie Piri
Approval of the final manuscript for submission to the journal office: Mohammadreza Batavani, Mohsen Ghofrani, Neda Boroushak, Mahdie Piri

Funding

The present study is based on the analysis of part of the data extracted from a master's thesis with the number 400 02 01, approved by the University of Sistan and Baluchestan, and was conducted without financial support. The University of Sistan and Baluchestan had no involvement in data collection, analysis, reporting, manuscript preparation, or final approval of the article for publication.

Conflict of Interest

Authors have no conflict of interests to declare.

References

1. Emery CA. Is there a clinical standing balance measurement appropriate for use in sports medicine? A review of the literature. J Sci Med Sport 2003; 6(4): 492-504.
2. Saleh V, Afroundeh R. Effects of 8-week anaerobic gymnastics training on weight loss and related growth factors in obese children: A clinical trial. J Pediatr Rev 2022; 10(3): 257-66.
3. Messier SP. Obesity and osteoarthritis: disease genesis and nonpharmacologic weight management. Rheum Dis Clin North Am 2008; 34(3): 713-29.

4. Sadeghi H, Hemati Nezhad MA, Baghban M. The effect of endurance training on a few kinematics parameters ingait of non-active elderly people. Salmand Iran J Ageing 2009; 4(1): 62-9. [In Persian].
5. Lockhart TE, Frames CW, Soangra R, Lieberman A. Effects of obesity and fall risk on gait and posture of community-dwelling older adults. Int J Progn Health Manag 2019; 10(1): 019.
6. Okifuji A, Hare BD. The association between chronic pain and obesity. J Pain Res 2015; 8: 399-408.
7. Moradi H, Aslani M, Fazel Khakhoran J. Effect of virtual reality-based balance exercise on static, dynamic and functional balance in elderly. Journal of Geriatric Nursing 2018; 4(2): 93-102. [In Persian].
8. Aragao FA, Karamanidis K, Vaz MA, Arampatzis A. Mini-trampoline exercise related to mechanisms of dynamic stability improves the ability to regain balance in elderly. J Electromyogr Kinesiol 2011; 21(3): 512-8.
9. Tay ZM, Lin WH, Kee YH, Kong PW. Trampoline versus resistance training in young adults: effects on knee muscles strength and balance. Res Q Exerc Sport 2019; 90(4): 452-60.
10. Karakollukcu M, Aslan CS, Paoli A, Bianco A, Sahin FN. Effects of mini trampoline exercise on male gymnasts' physiological parameters: A pilot study. J Sports Med Phys Fitness 2015; 55(7-8): 730-4.
11. Eshaghi S, Taheri M, Irandoust K. The effect of a period of targeted sports and food interventions on attention capacity, reaction speed and information processing in elderly women with sleep disorders. Journal of Sports and Motor Development and Learning 2022; 13(4): 427-41. [In Persian].
12. Zahabi G, Barari A, Ahmadi M. Effect of concurrent training on paraoxonase activity levels and some of the lipid plasma markers in the blood of women without exercise activity. Journal of Paramedical Sciences and Rehabilitation 2015; 4(1): 15-23. [In Persian].
13. Chorba RS, Chorba DJ, Bouillon LE, Overmyer CA, Landis JA. Use of a functional movement screening tool to determine injury risk in female collegiate athletes. N Am J Sports Phys Ther 2010; 5(2): 47-54.
14. Khaje Nemat K, Sadeghi H, Sahebzamani M. The effect of 8 weeks of strength training on static and dynamic balance in healthy men. Sport Sciences and Health Research 2014; 6(1): 45-55. [In Persian].
15. Saleh V. The relationship between floor exercise landing deduction, anthropometric characteristics and balance in 6 to 8 year old gymnasts. Science of Gymnastics Journal 2015; 7(2): 25-32.
16. Farsi A, Ashayeri H, Mohammadzadeh S. The effect of six weeks balance training program on kinematic of walking in women elderly people. Salmand Iran J Ageing 2015; 9(4): 278-87. [In Persian].
17. Aalizadeh B, Mohammadzadeh H, Khazani A, Dadras A. Effect of a trampoline exercise on the anthropometric measures and motor performance of adolescent students. Int J Prev Med 2016; 7: 91.
18. Piri M, Batavani MR, Ghofrani M, Mohammaddoost O. Effect of Trampoline rebound exercises on cardiovascular indices, body mass index, and lipid profile of obese and overweight women. Yafte 2022; 24(1): 24-37. [In Persian].
19. Mashaal AH, El-Negmy EH, Al-Talawy HA, Helal SI, Kandil W, Abd ElHady HS. Effect of vestibular stimulation on balance in obese children. International Journal of Pharmaceutical and Phytopharmacological Research 2018; 8(1): 27-32.
20. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods 2007; 39(2): 175-91.
21. Afsharmand Z, Akoochakian M, Daneshmandi H, Sokhanguei Y. The effect of training on stable and unstable surfaces on static balance in healthy elderly. Physical Treatments 2018; 8(3): 143-52.
22. Surgent OJ, Dadalko OI, Pickett KA, Travers BG. Balance and the brain: A review of structural brain correlates of postural balance and balance training in humans. Gait Posture 2019; 71: 245-52.
23. Karakaya MG, RutbIl H, Akpinar E, Yildirim A, Karakaya IC. Effect of ankle proprioceptive training on static body balance. J Phys Ther Sci 2015; 27(10): 3299-302.
24. Esmaeili H, Ghasemi MH, Anbarian M, Ghavimi A. Comparison of plantar pressure distribution in runners with different foot structures. Iranian Journal of Rehabilitation Research 2018; 5(1): 8-18. [In Persian].
25. Abdi E, Eslami M, Taghi Pou M. Identifying the best indicator of assessing the athletes balance in the sudden perturbation test. J Sport Biomech 2016; 2(1): 57-66. [In Persian].
26. Lee Y. The influence of unstable modified wall squat exercises on the posture of female university students. J Phys Ther Sci 2015; 27(8): 2477-80.
27. Eslami M, Damavandi M. Principles of biomechanics and movement analysis. Tehran, Iran: Sport Sciences Research Institute of Iran; 2012. [In Persian].