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# The Effect of Selective Plyometric Exercises Using an Unstable Surface on the Movement Performance of Basketball Players

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## ABSTRACT

**Background.** Body adaptations and the high level of achievement in different sporting fields depend on the degree of fitness and training. Hence, it is important for basketball players to have suitable body fitness for tactics and skill performance. **Objectives.** The present study aims to investigate the effect of selective plyometric exercises using an unstable surface on the movement performance of female basketball players. **Methods.** In this pre-/post-designed clinical trial, the subjects were selected from among qualified female basketball players (n=24) having a history of two-year regular specialized training in a team considered as elite. They were randomly assigned into two, experiment (age: 20.25±2.34, training history: 2.55±0.29, and BMI: 23.28±0.93) and control (age: 21.16±2.79, training history: 2.60±0.75, and BMI: 24.80±1.04) groups. The experiment group performed for eight weeks (three sessions each week with a duration of 80 min/session) progressive plyometric exercises on an unstable surface. The assessment of dependent variables was performed using functional movement screening and the star excursion balance test. The results of the control and experiment groups were compared using multivariate covariance and post hoc Bonferroni test, while the pre- and post-test results were compared using the dependent t-test at a significance level of (p<0.05). **Results.** Comparing the results between the groups through the functional movement screening test and dynamic balance showed a significant difference. An improvement was seen in the results of relevant tests for the experiment group (p<0.001). **Conclusion.** The use of progressive plyometric exercise on an unstable surface shows an improvement in the results of the functional movement screening test and movement performance. This, in turn, results in an improvement in exercise performance.

**KEY WORDS:** *Plyometric, Basketball players, Functional Movement Screening, Balance, Star Excursion Balance Test.*

## INTRODUCTION

For efficient prevention of sports-induced injuries, most authorities believe that improvement and maintenance of sports performance plays an important role. Physical fitness training programs, as designed for different sport disciplines, affect the body's adaptation in varied ways. Among multiple

factors, the optimum maintenance of body adaptations is the main concern for sports specialists and researchers (1).

Foot and wrist sprains in basketball players are common due to their quick and sudden sprints to dodge opponents and imbalanced descends during shooting of baskets or executing a

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rebound. During such maneuvers, the player mostly concentrates on the ball or the opponents' movements and less on his/her own performance (2). As Kofotolis et al. (2007) reports, the recovery period of ankle and wrist injuries is lengthy—it results in the injured athlete missing an average of at least seven training sessions per injury episode (3). Another aspect to be considered is the therapeutic expense load that such injuries impose on both the athlete and team. It is obvious that skill is related to the physical capabilities of the player (e.g. muscular strength, endurance, agility, speed, explosive power, flexibility, and balance) in case of basketball (4). Therefore, considering the nature of movement skills, a basketball player should optimally maintain his/her balance and control the body against gravity for achieving optimum performance. In doing so, the player can withstand the forces that tend to disturb his/ her balance. A good balance enhances sports performance and skills; it is an important factor in the prevention of sports injuries (5). In addition, deep sensation plays an important role in maintaining both general body stability and local regional stability (joint functional stability). Thus, the efficiency of deep sensation decreases following joint injuries. Moreover, after the injured athlete's recovery process to the pre-injury level, he/she has to be more aware of joint position and movement, with increased stability as well as dynamic and static balance being important as well (6). Given the key role of improved balance and deep sensation exercises in training schedules, the results of a study by Paterno et al. (2004) concerning the effect of proprioceptive training on the improved stability of single-limb in young female athletes reveal the improvement of injury and stability in the anterior–posterior plane (7). Accordingly, the training regimes for different sports require different postural control strategies; it seems that in terms of improvement objectives, each sporting discipline has to seek its own specific postural control strategies (8). Sports researchers and authorities are continuously designing new and effective training methods to promote the skill performance of athletes. Plyometric training is one such technique often used to promote movement and physical fitness of athletes; it is designed based on a repetitive stretch and

shortening in the tendon-muscle complex to increase the excitability of neuromuscular system. It is believed that the efficacy of plyometric training is a result of the neuromuscular adaptations in either the recruitment of motor units, frequency release of neurotransmitter, or alteration in the elastic properties of the muscle (9). Arazi et al. (2011) have studied the effect of aquatic and land plyometric training on balance in young basketball players. They report that training in both water and land has an effective role on the studied variables: Plyometric training in water played a more effective role in improving the strength and speed of running (10). Asadi et al. (2015) have studied the effect of neuromuscular plyometric training on postural control among basketball players. Their study shows that plyometric training improves postural control (11). Furthermore, Verma et al. (2015) have studied the positive effect of plyometric training on vertical jumping in secondary school basketball players (12). Moreover, McCormick et al. (2016) have shown a significant improvement in the motor performance of basketball players in frontal and sagittal movement planes (13). Based on the findings of different studies, it is observed that the use of an unstable surface develops muscular power and strength owing to the concomitant increment of muscle cross-sectional area and improvement in neuromuscular coordination. Thus, it is believed that the use of different training plans on unstable surfaces can provide effective training adaptations via clear neural adaptations during the primary stages of training protocol. Employing unstable training environments can optimize the performance of movement through increased activation of the core (trunk muscles) and stability muscles. Therefore, the application of unstable training seems more efficient than other applied methods. Based on the training specificity concept, training on unstable or imbalanced surfaces may provide a sort of instability that is better adapted to daily living activities and training environments; it may provide an effective learning transition through training adaptations (14).

In summary, given the structural importance of deep sensation in postural control and its significance in basketball, and also given the contradiction among related studies (11-13), the present work aims to study the concomitant use of

selective plyometric training on an unstable surface and the routine sport activities for female basketball players with an emphasis on the effect of such training on their functional balance.

## MATERIALS AND METHODS

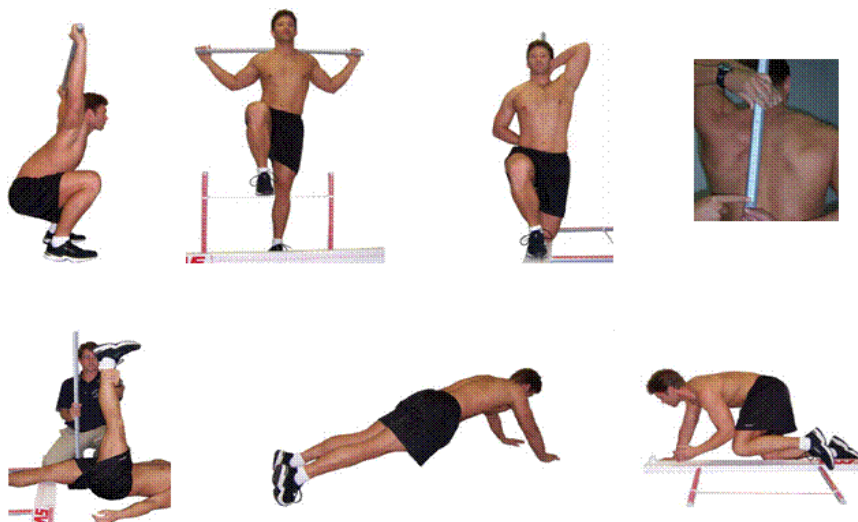
**Design.** This study is a clinical trial pre-post design with an eight-week-long intervention period. The study has been approved by the Research Ethics Committee of Kashan University of Medical Sciences (code: IR.KAUMS.REC.1396.59) and registered in the Iranian Registry for Clinical Trials (IRCT20160815029373N2). The informed consent forms were signed by all participants. The participants were allowed to withdraw in case of disinclination in continuing the study. In addition, the sample size was determined based on previous studies (power: 80%,  $\alpha$ : 0.05%, and the effect size: 30%) using the G-power software.

**Participants.** After primary and general posture assessment, 24 out of a total 38 female basketball players (age range: 17–23 year) from local sports clubs (Qom province, Iran) volunteered to participate in this study. The experiment group progressively performed an eight-week-long plyometric training program on an unstable surface (the control group performed their routine training). Dynamic balance and functional movement screening tests were performed for all participants both before and after eight weeks.

The inclusion criteria were: having a history of regular sport activity (three times per week) and at least two years of professional activity at the club level, a history of injury in the past six months, history of surgery, a score less than 14 in the functional movement screening test, and hypermobility *joint* syndrome using the Beighton method (1973)(15). None of the subjects had misalignment or pain in either upper or lower limbs, back pain, spinal cord anomaly, dislocation of patella, knee surgery, or any severe trauma in lower limbs. The tests were done five minutes after the warm-up session. Prior to measurements, the aim and method of each test was clearly explained to the subjects and consent forms were signed. The participants were randomly assigned into experiment or control groups.

**Dynamic Balance test:** In this test, the subjects had to maintain their balance on one leg and move the other leg as far as possible over a distance in eight different directions at the 45-degree angle. Before the test, the actual length of the leg (distance from anterior superior iliac spine to internal ankle) was normalized, and the dominant leg of each subject was determined. In case of right dominant leg, the test was performed counterclockwise and vice versa. To calculate the reaching distance as a percentage of the leg length, the ratio of the mean reaching distance to the leg length was normalized and then multiplied by 100. The high reliability and validity of the test for assessing dynamic balance (0.67–0.87) was reported by Kinzey (1998) and Ganesh (2015) (16, 17). Besides assessing the dynamic balance, the star excursion balance test can be used for testing the performance of these athletes' core regions (18).

**Functional movement screening.** This battery was designed for the concomitant assessment of mobility and stability using seven movement tests (19). During the test performance, two experimenters objectively determined the score for functional movement screening tests in anterior and lateral planes. The performance of each subject was tested on an individual basis of seven functional movements (deep squat, hurdle step, in line lunge, shoulder mobility, active straight leg raise, trunk stability pushup, and rotary stability) (Figure 1). The scoring system was based on Cook's study (2006) (19). A total of five out of the seven tests (hurdle step, in line lunge, shoulder mobility, active straight leg raise, and rotary stability) were scored depending on whether it was the left or right side of the body. Due to the neuromuscular asymmetry between these sides, the scoring system for functional movement screening was based on asymmetry and assigned the lowest score (score range: 0–21), (19). The total score was calculated as the sum of the separate test scores. A score less than 14 was considered a predictive criterion for injury (19). According to Saki et al., the battery has higher validity and reliability (88%–95%) for the assessment of movement performance in basketball players (20).



**Figure 1.** Functional movement screening tests

**Exercise protocol.** The selected plyometric training in the two first week was conducted without an unstable surface. Later in the following six weeks, only the first five exercises were conducted on an unstable surface (6 cm foam mattress). The overload principle of strength training was considered in which an increasing and progressive number of repetitions is employed during the training period. The plyometric training consisted of squat jumps, ring square jumps, high-knee jumps, side and forward hopscotch, jumping along rings, pair jumping on steps, side pair jumping on steps, and zig-zag jumps (21, 22). The duration of the principal exercises in the training sessions was 60 min.

**Table 1. Timing plan for progressive plyometric training**

| Weeks   | 1-2 | 3-4 | 5-6 | 7-8 |
|---------|-----|-----|-----|-----|
| Sets    | 2   | 2   | 2   | 3   |
| Repeats | 10  | 12  | 15  | 12  |

**Statistical Analysis.** Firstly, the distribution normality and the homogeneity of the variances

were tested and verified using the Shapiro–Wilk and Levene tests, respectively. The multivariate covariance, Bonferroni test, and paired-samples t-test were used to compare the difference in pre/post-tests. A significance level of  $P < 0.05$  was considered for all analyses. Statistical analysis was performed using SPSS V.16.

## RESULTS

The distribution normality and the homogeneity of the variances were tested and verified using the Shapiro–Wilk and Levene tests, respectively. There was a normal distribution for age, height, weight, BMI, performance score of body's core region, and dynamic balance.

The results of multivariate covariance analysis revealed a significant difference for functional movement screening and dynamic balance in dominant and non-dominant foot after a course of plyometric training on an unstable surface in terms of the control and experiment groups ( $p < 0.05$ ), (Table 2).

**Table 2. The demographic characteristic (age, height and weight) of the participants in control and experiment group. Mean(SD).**

| Groups     | Age (y)     | Training history(y) | BMI ( $\text{kg}/\text{m}^2$ ) | Height (cm)  | Weight(kg)  |
|------------|-------------|---------------------|--------------------------------|--------------|-------------|
| Experiment | 20.25(2.34) | 2.55(0.29)          | 23.28(0.93)                    | 164.00(2.41) | 63.33(3.28) |
| Control    | 21.16(2.79) | 2.60(0.75)          | 24.80(1.04)                    | 164.91(4.18) | 68.25(5.51) |

Notes: y, BMI ( $\text{kg}/\text{m}^2$ ), cm, and kg stand for year, body mass index, centimeter, and kilogram, respectively.

**DISCUSSION**

The results of the present study showed that eight weeks of plyometric training on an unstable surface had a significant difference on the results of dynamic balance tests in both legs and the

movement function screening of the female basketball players. In other words, the training improved the results of dynamic balance tests and the movement function screening scores of the mentioned players.

**Table 3. The comparison of mean for dependent pre-/post-test variables in control and experiment groups.**

| Variable                                   | Mean (SD)        |                |               |                |
|--|------------------|----------------|---------------|----------------|
|  | Experiment(n=12) |                | Control(n=12) |                |
|  | Pre-test         | Post-test Mean | Pre-test Mean | Post-test Mean |
| <b>FMS score</b>                           | 18.08(0.08)      | 19.66(0.65)    | 18.33(1.15)   | 18.16(1.33)    |
| <b>t</b>                                   |                  | -8.204         |               | 0.001          |
| <b>sig</b>                                 |                  | 0.001*         |               | 0.615          |
| <b>Dynamic Balance (dominant foot)</b>     | 78.68(4.27)      | 84.58(6.59)    | 75.82(4.32)   | 75.25(4.95)    |
| <b>t</b>                                   |                  | -3.298         |               | 0.472          |
| <b>sig</b>                                 |                  | 0.007*         |               | 0.646          |
| <b>Dynamic Balance (Non dominant foot)</b> | 75.10(5.29)      | 78.25(6.00)    | 74.49(4.64)   | 73.91(4.79)    |
| <b>t</b>                                   |                  | -2.773         |               | 0.573          |
| <b>sig</b>                                 |                  | 0.018*         |               | 0.578          |

Notes: FMS, y, BMI (kg/m<sup>2</sup>), cm, and kg stand for Functional movement screening, year, body mass index, centimeter, and kilogram, respectively. \*Significance level for dependent t-test.

**Table 4. The results for multivariate covariance and Bonferroni analysis of mean for variable scores in control and experiment groups.**

| Variable                                   | Wilks        | f      | sig    | partial             |
|--|--------------|--------|--------|---------------------|
| <b>Between Variable</b>                    | 0.034        | 36.767 | 0.001* | 0.966               |
| Variable                                   | Squared Mean | f      | sig    | Partial Eta Squared |
| <b>FMS score</b>                           | 8.114        | 37.263 | 0.001* | 0.713               |
| <b>Dynamic Balance (dominant foot)</b>     | 120.405      | 4.862  | 0.043* | 0.245               |
| <b>Dynamic Balance (Non dominant foot)</b> | 59.922       | 5.765  | 0.030* | 0.278               |

\*Significance level for multivariate covariance test.

One reason for the improved plyometric training-induced balance on an unstable surface is related to deep sensory receptors in the lower limbs. From this view, the alteration in joint receptor feedback may result in a central nervous system reorganization, sensory-motor integration, and finally altered motor response (23). In addition, the unstable surface used in similar studies activated deep sensory receptors in muscles and joints to increase the coordination and integrity of motor units, coactivation of synergic muscles, inactivation of antagonistic muscles, and activation of balance-improving mechanisms, which finally resulted in improved performance (24, 25).

Moreover, the training-induced tension affects the coactivation through facilitation and synchronization of large and fast-twitch motor units (26), stimulation of muscle spindles, decreasing the auto-inhibitory effect of Golgi tendon organs, and increased coordination of involved muscles. Through stimulation of muscle spindles, the muscular contraction causes the increased activation of spindle gamma efferents, thus increasing the sensitivity of spindles for improved joint position sense and control (27). Since balance training involves the effective use of neuromuscular control mechanisms for maintaining balance during movement (28),

whereas training on unstable surfaces involves using deep sensory receptor integration and muscle coordination in cocontraction activities(24), the output of such a combination of mechanisms can benefit the athlete and contribute to enhancing his/her performance. The results of this present study that show an improvement in dynamic balance is in line with findings of Arazi et al. (2012) who reports positive impact of plyometric training, when combined with high intensity, on dynamic balance (29); Wilkerson et al. (2004) who reports improved dynamic balance under the effect of plyometric plans in jump training (30) and the findings of Mahieu et al. (2006) who also indicates an improvement of dynamic balance (31). However, the findings of the present study were in disagreement with the findings of Schlicht et al. (2001) who reported no significant differences in the results of dynamic balance under the effect of plyometric training (32). The reason for these agreements or disagreement may be due to the similarity or dissimilarity in type, intensity, and duration of the training, the training surface (unstable surface), and the specific characteristics of the subjects (14, 23). In addition, according to Chimera et al. (2004), the improvement of muscular performance based on plyometric training is more related to increased neural adaptation than morphologic changes in muscle tissue (33). From this perspective, the main reason for implementing plyometric training is because of the need for quicker activation of more motor units for improved neuromuscular adaptations (34). Collectively, researchers believe that with plyometric training, the improved feedback potential or alteration in elastic characteristics of the muscles and connective tissue occur via neuromuscular adaptations in recruiting the motor units or through the frequency release of neurotransmitters (9).

Thus, considering neuromuscular adaptations, plyometric training is preferred to other training

(35). In recent years, system hypothesis is commonly used by researchers as a basis for the study of balance. According to this hypothesis, the ability for controlling posture in space is related to the complex and mutual effects of neural and musculoskeletal systems. For maintaining postural orientation in space and directing its movement thereby, the postural control system requires the incorporation and integration of sensory information to apply suitable force and determination of body orientation along with musculoskeletal ability. So, depending on the objective of the movement and the ambient condition, the gain of each system would be variable. In this regard, some researchers believe that in achieving the optimum neuromuscular adaptation, the role of sports discipline (36) and training protocol (14, 37) may be effective.

## CONCLUSION

Implementing suitable training methods is a routine and effective strategy used to enhance the performance of competitive athletes. In line with this strategy, the researchers were interested in application of special training (e.g. plyometric training) as a suitable tool to promote movement and physical fitness of athletes. Here the strategy of the concomitant use of plyometric training on an unstable surface had a dual advantage.

## APPLICABLE REMARKS

- Using the advantages of selected plyometric training on an unstable surface, as presented in this study, sports coaches and corrective exercise specialists can improve the sports performance, movement pattern, and the performance of basketball players.

## REFERENCES

1. Agel J, Olson DE, Dick R, Arendt EA, Marshall SW, Sikka RS. Descriptive epidemiology of collegiate women's basketball injuries: National Collegiate Athletic Association Injury Surveillance System, 1988–1989 through 2003–2004. *Journal of athletic training*. 2007;42(2):202.
2. McKay GD, Goldie P, Payne WR, Oakes B. Ankle injuries in basketball: injury rate and risk factors. *British journal of sports medicine*. 2001;35(2):103-8.
3. Kofotolis N, Kellis E. Ankle sprain injuries: a 2-year prospective cohort study in female Greek professional basketball players. *Journal of athletic training*. 2007;42(3):388.

4. Adams T, Worley D, Throgmartin D. An investigation of selected plyometric training exercises on muscular leg strength and power. *Track and Field Quarterly Review*. 1984;84(4):36-40.
5. Snyder-Mackler L. Scientific rationale and physiological basis for the use of closed kinetic chain exercise in the lower extremity. *Journal of Sport Rehabilitation*. 1996;5(1):2-12.
6. Olmsted LC, Hertel J. Influence of foot type and orthotics on static and dynamic postural control. *Journal of Sport Rehabilitation*. 2004;13(1):54-66.
7. Paterno MV, Myer GD, Ford KR, Hewett TE. Neuromuscular training improves single-limb stability in young female athletes. *Journal of Orthopaedic & Sports Physical Therapy*. 2004;34(6):305-16.
8. Bressel E, Yonker JC, Kras J, Heath EM. Comparison of static and dynamic balance in female collegiate soccer, basketball, and gymnastics athletes. *Journal of athletic training*. 2007;42(1):42.
9. Vissing K, Brink M, Lønbro S, Sørensen H, Overgaard K, Danborg K, et al. Muscle adaptations to plyometric vs. resistance training in untrained young men. *The Journal of Strength & Conditioning Research*. 2008;22(6):1799-810.
10. Arazi H, Asadi A. The effect of aquatic and land plyometric training on strength, sprint, and balance in young basketball players. *Journal of Human Sport and Exercise*. 2011;6(1).
11. Asadi A, de Villarreal ES, Arazi H. The effects of plyometric type neuromuscular training on postural control performance of male team basketball players. *The Journal of Strength & Conditioning Research*. 2015;29(7):1870-5.
12. Verma C, Subramaniam L, Krishnan V. Effect of plyometric training on vertical jump height in high school basketball players&58; randomised control trial. *International Journal of Medical Research and Health Sciences*. 2015;4(1):7-12.
13. McCormick BT, Hannon JC, Newton M, Shultz B, Detling N, Young WB. The effects of frontal-and sagittal-plane plyometrics on change-of-direction speed and power in adolescent female basketball players. *International Journal of Sports Physiology and Performance*. 2016;11(1):102-7.
14. Sedaghati P, Daneshmandi H, Karimi N, Barati A-H. A selective corrective exercise to decrease falling and improve functional balance in idiopathic Parkinson's disease. *Trauma monthly*. 2016;21(1).
15. Beighton P, Solomon L, Soskolne C. Articular mobility in an African population. *Annals of the rheumatic diseases*. 1973;32(5):413.
16. Kinzey SJ, Armstrong CW. The reliability of the star-excursion test in assessing dynamic balance. *Journal of orthopaedic & sports physical therapy*. 1998;27(5):356-60.
17. Ganesh GS, Chhabra D, Mrityunjay K. Efficacy of the star excursion balance test in detecting reach deficits in subjects with chronic low back pain. *Physiotherapy Research International*. 2015;20(1):9-15.
18. Layne M. *Water Exercise: Human Kinetics*; 2015.
19. Cook G, Burton L, Hoogenboom B. Pre-participation screening: The use of fundamental movements as an assessment of function–Part 2. *North American journal of sports physical therapy: NAJSPT*. 2006;1(3):132.
20. Saki F. Functional Movement Screen in Elite Boy Basketball Players: A Reliability Study. *Physical Treatments-Specific Physical Therapy Journal*. 2017;6(4):211-6.
21. Chu DA, Faigenbaum AD, Falkel JE. *Progressive plyometrics for kids: Healthy Learning* Monterey, CA; 2006.
22. Plyometric C. *Practical Guidelines for Plyometric Intensity*. *Plyometrics*. 2007:12.
23. Young WK, Metzl JD. Strength training for the young athlete. *Pediatric annals*. 2010;39(5):293-9.
24. Marsh DW, Richard LA, Williams LA, Lynch KJ. The relationship between balance and pitching error in college baseball pitchers. *Journal of strength and conditioning research*. 2004;18(3):441-6.
25. McKeon PO, Hertel J. Systematic review of postural control and lateral ankle instability, part II: is balance training clinically effective? *Journal of athletic training*. 2008;43(3):305-15.
26. Trowbridge C, Ricard M, Knight K, Hopkins J, Draper D, Hilton S. The effects of strength and plyometric training on joint position and joint moments of the female knee. *Journal of Orthopaedic & Sports Physical*. 2007;37(2):A25.
27. Docherty CL, Moore JH, Arnold BL. Effects of strength training on strength development and joint position sense in functionally unstable ankles. *Journal of athletic training*. 1998;33(4):310.
28. Zech A, Hübscher M, Vogt L, Banzer W, Hänsel F, Pfeifer K. Balance training for neuromuscular control and performance enhancement: a systematic review. *Journal of athletic training*. 2010;45(4):392-403.
29. Arazi H. Effects of high-intensity plyometric training on dynamic balance, agility, vertical jump and sprint performance in young male basketball players. *Journal of Sport and Health Research*. 2012;4(1):35-44.
30. Wilkerson GB, Colston MA, Short NI, Neal KL, Hoewischer PE, Pixley JJ. Neuromuscular changes in female collegiate athletes resulting from a plyometric jump-training program. *Journal of Athletic Training*. 2004;39(1):17.
31. Mahieu NN, Witvrouw E, Van de Voorde D, Michilsens D, Arbyn V, Van den Broecke W. Improving strength and postural control in young skiers: whole-body vibration versus equivalent resistance training. *Journal of athletic training*. 2006;41(3):286.

32. Schlicht J, Camaione DN, Owen SV. Effect of intense strength training on standing balance, walking speed, and sit-to-stand performance in older adults. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*. 2001;56(5):M281-M6.
33. Chimera NJ, Swanik KA, Swanik CB, Straub SJ. Effects of plyometric training on muscle-activation strategies and performance in female athletes. *Journal of athletic training*. 2004;39(1):24.
34. Bompa T, Buzzichelli C. *Periodization Training for Sports*, 3E: Human kinetics; 2015.
35. Åstrand P-O. *Textbook of work physiology: physiological bases of exercise: Human Kinetics*; 2003.
36. Norasteh A, Mohebbi H, Shahheydari S. Comparison of static and dynamic balance in different athletes. *Sport medicine* 2012;2(2):5-22[Article in Farsi].
37. Mansfield A, Peters AL, Liu BA, Maki BE. Effect of a perturbation-based balance training program on compensatory stepping and grasping reactions in older adults: a randomized controlled trial. *Physical therapy*. 2010;90(4):476-91.