How to Cite:

Majelan, A. S., & Habibi, J. (2022). The effect of dual-task on tuck jump performance in volleyball players with dynamic knee valgus. *International Journal of Health Sciences*, 6(S7), 6517-6526. Retrieved from https://sciencescholar.us/journal/index.php/ijhs/article/view/13636

The effect of dual-task on tuck jump performance in volleyball players with dynamic knee valgus

Ali Shamsi Majelan

Assistant Professor, Department of Corrective Exercise and Sport Injuries Faculty of P. E & Sport Sciences University of Guilan.

Javad Habibi

MSc Student of Corrective Exercises, Faculty of Physical Education and Sport Sciences, University of Guilan, Rasht, Iran

> Abstract --- Objective: This study aimed to investigate the effect of dual-task on tuck jump performance in athletes with dynamic knee valgus. Methods: The statistical population of this study consisted of adolescent volleyball players. The statistical sample consisted of 24 volleyball teenagers with an average age of 10 to 17 years old who were purposefully selected from the Rasht Municipality Cultural and Sports Club and then randomly classified into two groups of 12 with dynamic knee healthy and healthy. The subjects' performance before and after the dual task was evaluated using the tuck jump. Parametric tests of analysis of variance were used to compare differences between groups, and paired t-test was used to compare within groups. In order to analyze the comparison hypothesis, a oneway analysis of variance and Tukey post hoc test was used. Also, hypothesis testing was performed at a 95% significance level with alpha less than or equal to 0.05. Results: The results of the analysis of covariance showed that after controlling the effect of the pre-test (curvature), there was a significant difference in the number of jumping results in the post-test between the control and experimental groups (P≥0.05), so the score The performance of tuck jump in the experimental group was weaker after applying the dual task (P = 0.00). The ounce square ounce of 0.58 indicates the large effect size of the difference in tuck jump score between the two groups. On the other hand, the correlated t-test shows that after applying the cognitive task, in both groups with and without the cognitive task, a significant difference was observed in the tuck jump performance score and the tuck jump score was weaker (= 0.00 P).Conclusion: The results of the present study show the negative effect of dual-task on tuck jump and some performance. In other words, athletes with dynamic knee valgus suffer from functional impairment. Also, doing cognitive homework

International Journal of Health Sciences ISSN 2550-6978 E-ISSN 2550-696X © 2022.

Manuscript submitted: 9 May 2022, Manuscript revised: 18 July 2022, Accepted for publication: 27 August 2022

reduces performance. Therefore, by designing exercises based on dualtask methods, especially exercises based on the ability to change attention, cognitive abilities and proper division of attention to these tasks can be improved and by improving these abilities, the risk of injury in this segment of society can be reduced.

Keywords---dual task, tuck jump, Dynamic knee valgus.

Introduction

Dynamic knee valgus (DKV) is a common risk factor for acute injuries and lower limb overuse. In the bigger picture, excessive knee movement in the frontal plane during sports activities is a known factor for many acute and chronic knee injuries (1). As such, researchers have recognized dynamic knee valgus as a risk factor for lower limb injuries, including patellofemoral pain syndrome and ACL tear, to the extent that reducing knee valgus by maintaining proper alignment during activity has been frequently cited as an effective factor in preventing noncollision ACL injuries and the patellofemoral pain syndrome (2). Dynamic knee valgus is a movement pattern of the lower limb, potentially comprised of a combination of adduction and internal rotation of the femur, abduction of the knee, anterior tibial translation, external tibial rotation and ankle eversion during jump landing or squat maneuvers, which can be further affected by the proximal and distal joints of the knee, including body, thigh, and ankle (3). Ligament dominance or excessive dynamic valgus is one of the most common neuromuscular defects that occur when the mechanism of neuromuscular control is not able to provide the necessary dynamic stability for the knee joint, as a result of which, the knee ligaments absorb a greater-than-average share of ground reaction force during sport-intensive activities. This causes the knee to be valgus in jump-landing maneuvers (4). Jump-landing is a highly prevalent maneuver in many sporting activities of professional athletes, for which the highest rate of ankle and knee injuries have been reported in sports. Evidence suggests that most knee-related injuries are reported in athletes with dynamic knee valgus (5). Gray and colleagues (1985) argued that 58% of all injuries of female basketball players pertain to landing after jumping (6).

Similarly, Goodwin-Gerberich et al. (1982) also stated that 63% of ankle and knee injuries in volleyball competitions are owing to jumping errors (7). Inefficient landing in sports activities is often one of the common mechanisms in lower limb injuries, which corresponds to the scenario in which the athlete does not have proper control over the lower limb (8), in turn leading to rotation or angulation of the knee or spraining of the ankles to very serious consequences for the athletes (9). The effect of injury can be compounded if the jump-landing is performed with intensity and speed. Any defect and disorder that causes a person to face difficulties in maintaining dynamic stability can lead to distortions to the center of gravity, difficulties in balance-keeping, and a heightened risk of falling and injury (10). Many parameters are thought to be involved in a person's ability to maintain and restore postural stability, including defects in the nervous system, inefficiency of optic nerve sensors in the retina, mental pressure, activities requiring high concentration, vestibular mechanism, and fatigue (11).

6518

On the other hand, researchers have stated that, contrary to previous beliefs, pastural activities such as jump-landings are not voluntary. That is, organizing information received from sensory inputs and then producing appropriate motor responses requires the activity of the cognitive system and hence attention. As such, information processing capacity for each person is shown by research to be limited, with every distinct task pre-occupying a share of the very same processing capacity. A sensory-motor task (such as jump-landing) and a cognitive task performed simultaneously may exceed the total processing capacity, leading to interference in the performance of the individual and hence impairing either or both of the tasks. Factors such as the difficulty of the cognitive task and the difficulty of the pastural task can affect the level of interference resulting from the dual-task performance (12). The discussion above indicates the effect and significant role of cognitive tasks in athletes' sports performance; as in many sports, volleyball is no exception, and many cognitive activities and tasks are performed. This sport is staggeringly prevalent in lower limb injuries (e.g., dynamic knee valgus, ACL tear, frequent ankle sprains, and muscle and ligament strains). As such, the purpose of the current study was to determine whether the cognitive task affects the performance of the tuck jump test in volleyball players with and without knee dynamic valgus.

Research Methodology

The current research is a quasi-experimental study that employs a pre-test/posttest. The statistical population of this research consisted of all teenage volleyball players. The statistical sample included 24 volleyball teenagers aged 10 to 17 years selected from Reza Khodaparast Academy in Rasht using purposive sampling, randomly assigned to experimental (dual cognitive task) and control groups, each with 12 participants. The subjects exercised regularly three days a week and had at least 1 year of experience in sports training. The groups were normalized in age, height, weight, and preferred leg. After receiving their verbal consent, their parents were asked to fill out written consent forms. At first, the participants were provided information regarding the purpose of the study, after which they were required to fill in the personal information questionnaires. Then the researchers measured various parameters for every participant, including height and weight, determined by tape measure and clinical scale, respectively, and finally, their preferred foot was determined. At first, the necessary explanations on how to perform the task were provided to all subjects. Afterward, the subjects warmed up their bodies with stretching and flexing movements. The single-leg squat exercise was administered to identify subjects with dynamic knee valgus, such that any participant whose knees went towards valgus during squats was considered an individual with DKV. The results from the squat test were used to divide subjects into two experimental and control groups to perform the jump tuck test, requiring the VO2max threshold performance of the athlete. In this test, the athletes were required to stand with their feet shoulder-width apart, jump vertically and raise their knees as high as possible. At maximum height, the thighs must be parallel to the ground, and after landing, the athlete must perform the next jump immediately. This test lasted 10 seconds, during which the subject performed this action repeatedly (13). On the other hand, the cognitive task was also administered as a part of the dual-tasking routine for the experimental and control groups while performing tuck jumps. The cognitive task in this test was to read a series of 5-digit numbers randomly displayed on the screen at intervals of 2 seconds. To improve the measurement accuracy, two video cameras were used, and the cameras were adjusted to the height of the subjects in the parabolic and transverse planes, and after performing the test, the position of the lower limbs during landing was checked in the aforementioned planes (13). This test is scored on a 10-error scale given the position of the thigh and knee, the foot position during landing and plyometric movement, such that for each error, the person received one score. That is, the participant who scored 4 on the test had fewer errors than the one who scored 8. The errors of the tuck jump are as follows: In the thigh and knee area: 1- Knee valgus during landing; 2- Thighs not being parallel at the maximum height of the jump; 3- Thighs not being parallel during the jump; Position of the feet during landing: 1- The feet are not shoulder width apart when landing; 2- The feet not being parallel; 3- The feet not hitting the ground at the same time; 4- The feet producing a striking sound with the ground at the moment of contact; 5- Not landing at a specific point; Plyometric movement: 1- Missing the rhythm of the technique in 10 seconds 2- Having a break during the jump. This test can be used to detect if the subject has ligament dominance, which is one of the most common neuromuscular defects. Two characteristics of ligament dominance are 1- Landing with knee valgus. 2. The distance between two feet being more or less than the required shoulder-width apart during landing (13). As previously stated, all the steps were recorded by 2 cameras located in the front and at the side, the outputs from which were examined using Kinovea (14). The Shapiro-Wilk test was used to check the normality of data distribution. The parametric tests of covariance analysis were used to compare the differences between groups, and the paired t-test was used to compare the within-groups findings. The hypotheses were tested on a 95% confidence interval with alpha less than or equal to 0.05. SPSS v. 24 was used to analyze the data.

Findings

The individual characteristics of each group, including age, weight, height, and body mass index (BMI), were measured before the test, summarized in Table 1. *Table 1: Descriptive statistics of research variables*

Variable	Group	Frequency	Mean ± S.D.				
Age (years)	Control	12	13.91 ± 2.46				
	Experiment	12	13.95 ± 2.20				
Height (cm)	Control	12	1.62 ± 0.175				
8 ()	Experiment	12	1.66 ± 0.158				
Weight (kg)	Control	12	55.50 ± 2.52				
	Experiment	12	56.32 ±?				
BMI	Control	12	23.20 ± 1.41				
(kg/m ²)	Experiment	12	22.66 ± 1.75				

The findings of this study were presented in two stages. The first stage pertains to the results of the analysis of the covariance test, which is presented in Table 3 after checking the homogeneity of variances (Table 2), after which the pre-test/post-test results in both control and experimental groups are reviewed in Table 4.

Table 2: Results of Levene's test for equality of variances

F	First DOF	Second DOF	Sig. level
0.330	1	22	0.571

Table	3:	The	results	of	covariance	analysis	of	the	effect	of	cognitive	task	and
predic	tor	on ti	ıck jump	pc	st-test								

Variable		Stage	Group	Mean*	F	Df	Р	Eta squared
Tuck ju score	mp	Post-test	Control	4.83	30.01	1	0.000**	0.588
		Post-test	Experiment	5.91				

*Adjusted based on the values of pre-test

**Significant at p<0.01 level

The results of the analysis of the covariance test showed that after controlling the effect of the pre-test (sphericity), there is a significant increase in the score of tuck jump results (and thus a significant decrease in performance) in the post-test between the two control and experimental groups ($p \le 0.05$). The Eta squared value of 0.588 indicates the large effect size of the difference in the jump score between the two groups. The paired t-test was conducted to examine the difference in pretest and post-test in two groups separately, which is reported in Table 4.

Table 4: The difference in the mean score of the tuck jump in the subjects before and after applying the cognitive task

Group	Control			Experimental								
	Pre-test		Post-test		Т	Р	Pre-test		Post-test		Т	Р
Tuck	3.25	±	4.83	±	-	0.00	3.75	±	5.91	±	-8.00	0.000
jump	1.35		1.33		6.91		1.13		1.24			

The paired sample t-test (Table 4) indicates that the cognitive task significantly decreased the jump performance score in both groups.

Discussion and conclusion

Dynamic knee valgus is a major injury concern for many athletes, and despite numerous studies on finding key risk factors for injuries, the effect of cognitive tasks on the performance of athletes remains elusive. That is, research is yet to examine whether the activities that require high cognitive demands by athletes and require a prolonged duration of attention can undermine the function of the lower extremities or not. This study showed that cognitive task significantly affects athletes with dynamic knee valgus; with the increase in the level of cognitive task, the tuck jump score of volleyball athletes decreases. In Kahneman theory of attention, it is suggested that attention is limited and has a fixed central source that cannot be changed, and all activities compete for this source. According to this model, also known as the theory of the central source of attention, when performing two tasks simultaneously, attention demands exceed this central capacity. For this reason, one of the tasks or both is either halted or disrupted. The dual-task method is developed using the notions of Kahneman's theory, in which the attentional needs of an action or a part of a task are assessed (15). The level of interference in a special task (primary) is evaluated when the person simultaneously executes another task (secondary). The results often reveal that (1) the processing of different tasks is different and (2) the simultaneous execution of tasks can cause an overload on the limited capacity of the attention system (16). In a special type of dual-task, the exploration method is also popular. If the exploring phase of the main task is perceived to require the total capacity for attention, the response to the secondary task will be longer than when the person has to only respond to the secondary task. This method has been long used to determine the attention needs of sports skills (17). For instance, Castiello et al. (1988) employed dual-tasking to identify the temporal differences in attention in several sports tasks, including receiving a volleyball serve, 100-meter run, 110-meter hurdle run, and receiving a tennis serve, the results of which revealed that in tennis and volleyball serve, all stages require attention, but not in equal proportions. That is, the receiver required less attention when the opponent was serving and when the ball was above the net, and as the time of receiving the ball approached, the amount of attention increased linearly. They also found that in the 100m sprint and 110m hurdles, exploration at the beginning and end of both events occurred slower than during the event and concluded that the attentional load in these two events has a non-linear pattern (17). Rose and Christina (1990) examined attention demands of precision pistol shooting as a function of skill level and reported that the reaction time to an auditory reduction task increases linearly, such that the greatest demand for attention pertains to the final part (18). Tuck jumping is one of the main components of most daily activities and is very similar to the motor patterns of volleyball, and is also an important indicator of sports performance and the level of balance of athletes (5). However, no research was found to examine the effect of cognitive tasks on the changes in the tuck jump score. nevertheless, several studies have investigated the effect of muscle fatigue on balance control. Among other things, Coutinho et al. (2018) explored the effects of mental and muscular fatigue on soccer players' performance, and their results showed that following mental fatigue and dualtask, physical performance such as soccer-specific running ability, speed and accuracy of decision-making, as well as accuracy in activities that require coordination all decrease (19). Bruno et al. (2011) also reported in their research

on football players that the muscle fatigue caused by intense functional activity can make it difficult to shift the center of pressure in the anterior-posterior direction, leading to high levels of instability therein (20). Hosseini Mehr et al. (2020) argued further that the difficulty level of the task is a moderating factor in the performance loss in athletes attempting dual-task routines (21). The findings of Ranjana et al. (2019) are consistent with those of the current study, as they reported that mental fatigue affects increasing physical fatigue (22). Martin et al. (2018) stated that following mental fatigue (i.e., cognitive task), the heightened levels of adenosine in the brain lead to increased resistance to effort, feeling and understanding of fatigue, and hence perceived lack of energy (23). According to systems theory, the function of the sensory system in controlling balance and performance depends on the purpose and environmental conditions, and each sensory system can be more important under certain conditions; That is, the superior sensory system at any moment outputs more accurate information about the current environmental situation (24). Research indicates that cognitive interference had a negative effect on the tuck jump performance of athletes. In this regard, Stins et al. (2009) performed a dual task study to investigate the effect of expertise, cognition and vision on the attentional involvement postural control in two groups of ballerinas and non-ballerinas and reported that postural sways in the standing position with eyes closed was significantly higher than those with open eyes (25). The need for attentional resources increases when people are placed in a difficult postural position. According to the postural prioritization mechanism, individuals are perceived to prioritize maintaining stability in the standing position over other simultaneous tasks in dual-tasking scenarios. The higher levels of attentional involvement in the postural control hinder the integrity of the cognitive task, leading to its disruption (26). As a such, cognitive function, when coupled with fatigue, plays a role in the function of the cerebellum for optimal performance and hence, postural control. Another assumption is that in case of mental fatigue as a result of the cognitive task, the effect of the motor commands sent to the muscle, and thus, the tension or force of the muscles involved in posture control is reduced, in turn degrading the individual's performance (26). On the other hand, improper function of the muscles around the knee joint can affect its dynamic stability and put it at risk of injury. Dynamic valgus of the lower extremity is a risk factor associated with improper muscle function for many acute and chronic lower limb injuries, none more pronounced than knee injuries (27, 28). Valgus defect (i.e., ligament dominance) is among the more prevalent neuromuscular defects that occur when the joint is not provided with the necessary dynamic stability by neuromuscular control strategies. This leads to the absorption of a large reaction force by the knee ligaments during sports activities, forcing the knee into a valgus position (29). The results of the studies imply that the increase in valgus of the knee leads to a change in the function of the lower limb in the frontal plane (30), which may be caused by changes in the contraction patterns of the trunk muscles, thigh adductors and abductors, as well as knee flexor muscles, primarily hamstrings and gastrocnemius (31). In anatomic literature, the exclusive mechanical behavior of the proximal and distal joints of the middle joint of the lower limb movement chain is perceived to determine whether the forces imposed on the musculoskeletal system of this joint are properly distributed (32, 33). Accordingly, the athlete's ability to maintain the correct dynamic alignment of the lower limb segments in the movement planes is deemed pivotal to the prevalence of knee

injuries in sports (34). In this regard, Mauntel et al. (2013) stated the effect of abnormal neuromuscular control of the knee muscles on knee valgus, and hence the increased risk of ACL damage (35). Imposing loads on the valgus increases the relative pressure applied to the anterior cruciate ligament, leading to ligament laxity at high loads (36). Other studies have also revealed that people with increased valgus are more susceptible to anterior cruciate ligament injuries when performing dynamic activities (30, 37, 38). As such, one of the effective ways to reduce the incidence of anterior cruciate ligament injuries is to reduce valgus loads.

Overall, the results of the present study have indicated the negative effect of dual tasking on the performance of the tuck jump exercise. Therefore, it can be concluded that performing a dual task can intensify the effects of dynamic knee valgus defect on an athlete's performance. Therefore, designing exercises based on cognitive task methods, cognitive abilities and proper distribution thereof can result in improved performance levels, thereby reducing the risk of injuries in similar scenarios.

References

- 1- Sigward SM, Ota S, Powers CM. Predictors of frontal plane knee excursion during a drop land in young female soccer players. J Orthop Sports Phys Ther. 2008; 38(11):661-7.
- 2- Bell DR, Padua DA, Clark MA. Muscle strength and flexibility characteristics of people displaying excessive medial knee displacement. Arch Phys Med Rehabil. 2008; 89(7):1323-8.
- 3- Barrios JA, Heitkamp CA, Smith BP, Sturgeon MM, Suckow DW, Sutton CR. Three-dimensional hip and knee kinematics during walking, running, and single-limb drop landing in females with and without genu valgum. Clin Biomech. 2016; 31:7-11
- 4- Hewett T, Ford KR, Hoogenboom BJ, Myer GD. Understanding and preventing ACL injuries: Current biomechanical and epidemiologic considerations- update 2010. N Am J Sports Phys Ther. 2010; 5(4):234-51.
- 5- Herrington L, Myer GD, Munro A. Intra and inter-tester reliability of the tuck jump assessment. Physical Therapy in Sport. 2013;14(3):152-5.
- 6- Gray, J.; J.E. Taunton; D.C. McKenzie; D.B. Clement; J.P. McKonkey; R.G. Davidson (1985). "A survey of injuries to the anterior cruciate ligament of knee in female basketball players". Int J Sports Med. 6:314-316.
- 7- Goodwin-Gerberich, S.G.; S. Luhmann; C. Finkle; G.D. Periest; B.J. Beard (1982). "Analysis of sever injuries associated with volleyball activities". Phys Sports Med. 15(8):75-79. 10.
- 8- Louw, Q., Grimmer, K., Vaughan, K. (2003). Knee injury patterns among young South African basketball players. South African Journal of Sports Medicine.
- 9- Jones, D., Louw, Q., Grimmer, K. (2000). Recreational and sporting injury to the adolescent knee and ankle: Prevalence and causes. Australian Journal of Physiotherapy. 46:179-88.
- 10- Giansanti D, Dozza M, Chiari L, Maccioni G, Cappello A. Energetic assessment of trunk postural modifications induced by a wearable audio-biofeedback system. Medical Engineering & Physics, 2009; 31:48–54.

6524

- 11- Guskiewicz K, Perrin D. Research and clinical applications of assessing balance. Sport Rehabilitation, 1996; 5:45-63.
- 12- Marcora SM, Staiano W, Manning V. Mental fatigue impairs physical performance in humans. Journal of applied physiology. 2009;106(3):857-64.
- 13- Myer, G.D., et al., Real-time assessment and neuromuscular training feedback techniques to prevent ACL injury in female athletes. Strength and conditioning journal, 2011. 33(3): p. 21.
- 14- Negahban H, Hadian M R, salavati M, Mazaheri M, Talebian S, Jafari AM, et al. The effects of dual-tasking on postural control in people with unilatral anterior cruciate ligament injury. J Gait&Posture,2009;30:477-481
- 15- Abernethy, B. (1988). Dual-task methodology and motor skills research some applications and methodological constraints .Journal of Human Movement Studies, 14, 101-132
- 16- Kahneman, D. (1973). Attention and effort. New Jersey: Englewood Cliffs.
- 17- Castiello, U., & Umilta, C. (1988). Temporal dimensions of mental effort in different sports. International Journal of Sport Psychology, 19, 199-210.
- 18- Rose, D. J., & Christina, R. W. (1990). Attention demands of precision pistol shooting as a function of skill level. Research Quarterly for Exercise and Sport, 61, 111-113.
- 19- Coutinho D, Gonçalves B, Wong DP, Travassos B, Coutts AJ, Sampaio J. Exploring the effects of mental and muscular fatigue in soccer players' performance. Human movement science. 2018;58:287-96.
- 20- Bruno M, Matheus JW, Generosi AR, Marco AV, Junior CP. Effect of muscle fatigue on posture control in soccer Players during the short-pass movement. Revista Brasiliera Cineantropometria and Desempenho Humano, 2011; 13(5): 348-53.
- 21- Hosseinimehr SH, Daneshmandi H, Norasteh AA. The effects of activity related fatigue on static and dynamic postural control in college athletes. Journal of Brazilian Biomotoricity, 2020; 4 (2): 148-55.
- 22- Baumeister J, Reinecke K, Schubert M, Schade J, Weiss M. Effects of induced fatigue on brain activity during sensorimotor control. European journal of applied physiology. 2019 Ju 1;112(7):2475-82.
- 23- Martin K, Meeusen R, Kevin G, Thompson, Keegan R, Rattray B. Mental Fatigue Impairs Endurance Performance: A Physiological Explanation. Sports Medicine. 2018 Sep 9; 48(11): 2041-2051
- 24- Pate DS, Margolin DI, Friedrich FJ, Bently E.E., Decision- making and attentional processes in ageing and in dementia of the Alzheimer's type, Cognitive Neuropsychology, 1994; 11(3): 321-335
- 25- Stins, J. F., Michielsen, M. E., Roerdink, M., & Beek, P. J. (2009). Sway regularity reflects attentional involvement in postural control: Effects of expertise, vision and cognition. Gait & posture, 30(1), 106-109.
- 26- Tixier, M., Rousset, S., Barraud, P. A., & Cian, C. (2021). Postural responses to specific types of long-term memory during visually induced roll self-motion. PloS one, 16(12), e0261266.
- 27- Gage BE, McIlvain NM, Collins CL, Fields SK, Dawn Comstock R. Epidemiology of 6.6 million knee injuries presenting to United States emergency departments from 1999 through 2008. Academic emergency medicine. 2012;19(4):378-85.
- 28- Blokker AM. Development and Assessment of a Micro-CT Based System for Quantifying Loaded Knee Joint Kinematics and Tissue Mechanics: University of Western Ontario; 2018.

- 29- Myer GD, Brent JL, Ford KR, Hewett TE. Real-time assessment and neuromuscular training feedback techniques to prevent ACL injury in female athletes. Strength and conditioning journal. 2011;33(3):21.
- 30- Kianifar R, Lee A, Raina S, Kulić D. Automated assessment of dynamic knee valgus and risk of knee injury during the single leg squat. IEEE journal of translational engineering in health and medicine. 2017;5:1-13.
- 31- Ireland ML, Bolgla LA, Noehren B. Gender differences in core strength and lower extremity function during static and dynamic single-leg squat tests. ACL Injuries in the Female Athlete: Springer; 2018. p. 239-57.
- 32- Shultz SJ, Schmitz RJ, Benjaminse A, Collins M, Ford K, Kulas AS. ACL Research Retreat VII: an update on anterior cruciate ligament injury risk factor identification, screening, and prevention: March 19–21, 2015; Greensboro, NC. Journal of athletic training. 2015;50(10):1076-93.
- 33- Chuter VH, de Jonge XAJ. Proximal and distal contributions to lower extremity injury: a review of the literature. Gait & posture. 2012;36(1):7-15.
- 34- Ford KR, Myer GD, Hewett TE. Valgus knee motion during landing in high school female and male basketball players. Medicine & Science in Sports & Exercise. 2003;35(10):1745-50.
- 35- Mauntel TC, Begalle RL, Cram TR, Frank BS, Hirth CJ, Blackburn T, et al. The effects of lower extremity muscle activation and passive range of motion on single leg squat performance. The Journal of Strength & Conditioning Research. 2013;27(7):1813-23.
- 36- Myer GD, Ford KR, Brent JL, Hewett TE. Differential neuromuscular training effects onACL injury risk factors in" high-risk" versus" low-risk" athletes. BMC musculoskeletal disorders. 2007;8(1):39.
- 37- Schilaty ND, Bates NA, Krych AJ, Hewett TE. Frontal plane loading characteristics of medial collateral ligament strain concurrent with anterior cruciate ligament failure. The American Journal of Sports Medicine. 2019;47(9):.50-2143
- 38- Ludwig O, Simon S, Piret J, Becker S, Marschall F. Differences in the dominant and non-dominant knee valgus angle in junior elite and amateur soccer players after unilateral landing. Sports. 2017;5(1):14.