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Comparison of lower extremity alignment assessment in traditional and Aston paradigm

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***Abstract*---**The main objective of this study was to compare the lower extremity alignment assessment in traditional and Aston paradigms. In this study, the 13-17 years old students of Gilan participated. A pelvic inclinometer was used to assess the pelvic tilt; a caliper was used to assess the genu varum and genu valgum, and a ruler was used to assess the flatfoot. Also, a photography camera was used to assess the lower extremity alignment using the Aston assessment paradigm. In this study, a nonparametric chi-square test was used to test the variables. The results of the study showed no significant difference between traditional and Aston paradigms in terms of pelvic tilt and flatfoot assessment. However, there was a significant difference between the two methods in terms of genu varum and genu valgum. According to obtained results to assess the pelvic alignment in the frontal plane and the foot, the Ason paradigm can be a replacement for traditional methods. This is because; the method is a simpler method than the traditional assessment models. However, the two methods were significantly different in terms of knee alignment assessment. Further studies are needed according to the novelty of the study and the lack of literature in the field of the Aston paradigm.

***Keywords*---**Aston Paradigm, Traditional Assessment, Lower Extremity, Screen.

Introduction

One of the most important indices of general health is having a suitable physical condition or a suitable erect structure (1, 2, 3). Suitable posture is a situation, in which the least pressure is applied to the joint, and the muscles have the least activity (4). According to the traditional definitions, correct posture is created

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when the gravity of different parts of the body like the head, trunk, pelvis, and the lower extremities are balanced (5). On the4 contrary, incorrect posture refers to the situation, in which pressure is applied to the joints (6). Posture unalignment may be caused by one-side dominance of muscles, asymmetry of soft tissues, and bone contrast resulting from weak mechanical motions (7). Students can be the community exposed to incorrect posture, and as a result, skeletomuscular abnormalities (8). Musculoskeletal abnormalities are the most underlying problems in childhood. Muscular and bone weakness is formed in childhood, and is continued as a result of inattentiveness. At the end of evolution, it causes pain, suffering, and disability of the movement, and brings the inability to do work. Every year, a lot of money is spent on treating patients with complications and diseases caused by abnormalities in the extremities (9). Hence, the prevalence of such abnormalities is serious in the students, which can endanger the health of this powerful generation of the country, and the health of the whole society (10). This can show the significance of assessment and diagnosis of musculoskeletal abnormalities at basic ages to prevent the damages and complications caused by the disorders.

There are two invasive and noninvasive groups of musculoskeletal assessment methods. The invasive methods applied to posture analysis are radiographic methods, bone scan (nuclear imaging), magnetic resonance imaging (MRI), CT scan, and radiography (11). Although the invasive model has high validity and reliability, it is not suitable because of its high costs, unavailability for the ordinary people, being time-consuming, prohibition to use by non-physician people, and more importantly, the dangers caused by using radiation, and the complications of diagnosis and screening a wide range of the people. Hence, the model can be only used in the advanced stages of the abnormality (12).

The noninvasive model has been divided into various methods over the years. The visual methods of posture assessment include checkered plane plump line (the simplest method of abnormality assessment), in which the results can be obtained qualitatively using the New York Test. The disadvantages of this method include needing large space, problems in transportation, high construction costs, visual error, and the inability to record and maintain information on treatments. Other types of visual assessment can be the measurement by imaging, and two-dimensional video analysis (12). Another method is direct assessment, in which movable devices are used by hand or electric devices. For example, a pelvic inclinometer was used to assess the pelvic tilt; a ruler, strip meter, caliper, and goniometer (13) were used to measure knee abnormalities in this method. Also, the flatfoot was assessed using footprint, talc powder, mirror box, and Brody method, which measures the navicular drop (12).

As the world is moving toward doing things in a fast and easy way with the least equipment use, posture assessment also needs modern screening methods because of population growth, lack of sufficient equipment, decreased costs, and increased speed. The traditional assessment also includes some advantages and disadvantages. This method has high validity, reliability, and high accuracy. However, this test is time-consuming because needed equipment such as a checkered plane, pelvic clinometer, strip meter, collis, and ruler, need a special place, and being relied on the expertise and experience of the examiner. Also, errors are possible in measurements because of non-calibrated measuring instruments, and examiner's error.

Aston paradigm is one of the modern methods with the least need for equipment, and high speed of assessment, which can provide good information for the specialist to diagnose the abnormalities of the patients. Aston paradigm has been designed by Judith Aston, who graduated in the physical training field from Los Angeles University. In the Aston paradigm, the images of the client are recorded from four sides for alignment assessment. Then, the body is segmented to none parts to find out how much the segments can affect each other. Then, the nine segments are separated in form of a circle to outline the ball body as an innovation made by Aston to assess body alignment in 3-D form. Finally, the extremity alignment is assessed using the symbols encoded by Aston to show segments exposed to shift, tilt, rotation or the segment tolerated the highest pressure (4).

Various studies have been done till now on the traditional methods of assessment of extremity alignment and musculoskeletal abnormalities. However, it is essential to make an assessment method needless of many types of equipment, with low costs, and more importantly, a simple method taking students screening in wide range faster than traditional methods. Therefore, this study has compared the lower extremity alignment assessment between two traditional and Aston paradigms.

Methodology

This study compared the lower extremity alignment assessment between two traditional and Aston paradigms. This is descriptive-comparative research, in which the data are collected using the field method and the measurements are done using qualitative and quantitative methods. The statistical sample in this study consists of 60 male students in the age range of 13-17 years old. The sampling method was convenience sampling based on inclusion and exclusion criteria. The exclusion criteria are dissatisfaction of participants, families, and authorities; inadequate cooperation of the participants, unwillingness to continue the study; experience of surgery, and suffering from a type of disease. Are steps of the study were completed in the Gym Plus complex located in the city of Rasht. The assessment time for each person was 10 minutes.

In this study, the centimeter and balance scale were respectively used to measure the height and weight of the subjects. Also, a pelvic inclinometer was used to measure lateral pelvic tilt, and high measurement accuracy was reported for that (14, 15). For this purpose, the subjects were asked to wear clothing that allows the examiner to measure comfortably. Also, they were asked to stand with bare feet in a direct line with a distance of 10-12cm between the feet. Then, they had to stare at the point in front of them on the wall from a distance of 175cm. Afterward, the examiner measured the sign points, which are the upper anterior iliac spine on both sides of the body by touching the points. The examiner put the inclinometer on these points, measured the lateral pelvic tilt, and recorded it in the special form (16, 18). The Collis was used to measure genu varum and genu valgum, the measurement accuracy of which is reported at one-tenth of mm. For genu varum, collis was used in the mode where knees were completely extended, the ankles were stuck together, and the distance between two inner thigh condyles (above the inner thigh) was measured and recorded. For the genu valgum, the subjects were stood in front of the examiner comfortably with bare feet in the mode that their knees, thighs, and legs were visible. Their thigh muscles should not be exposed to abnormal contraction and unusual tension. Then, the distance between ankles was measured using collis while the knees were tangent to each other (18, 19). To test the flatfoot, the navicular drop test was used with high reliability reported (20). For the measurement purpose, the subjects sat on the chair. The thigh and knee were in 90° flexion mode, the foot sole was on the ground, and the subtalar joint was in neutral mode with no weight tolerance. The examiner touched and marked the navicular bone protrusion, and measured then the distance from the ground with a ruler. Then, the subjects were asked to stand on their feet, take the legs shoulder-width apart, and make equal weight on each leg (weight tolerance). The distance of navicular bone from the ground was then measured again. The difference between the two postures was recorded as the navicular drop level per mm (21).

For the measurement using the Aston paradigm, photography was done from the subjects from four views including anterior, posterior, right side, and left side using a camera from a distance of 1.5meter. The subjects had to wear suitable clothing with no unusual contraction and tension in muscles and look at the point in front of them. Then, the photos of the subjects were printed, so that the examiner could trace the ball body to do the musculoskeletal assessment. In this paradigm, the examiner divided the body into nine segments from all dimensions.
The nine segments are 1- head 2- neck 3- upper chest 4- lower chest 5- abdominal area 6- pelvis 7- upper leg 8- lower leg 9- foot sole. However, as this study tends to assess lower extremity alignment, four out of nine balls were needed: 1- pelvis 2- upper leg 3- lower leg, and 4- foot sole. The assessment steps using the Aston paradigm: step 1: changing the image of the subject into ball body segments in 4 views: 1- landmark reference 2- outlined segments 3- nine body balls

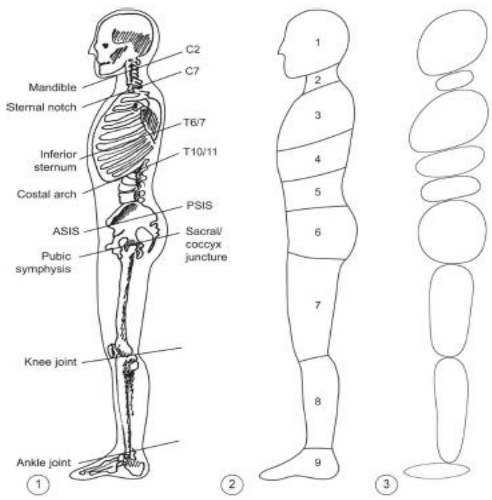

Figure 1. Landmark reference, outlined segment, ball body

Step 2: After changing the image into the ball body, the symbols presented by Aston were added to the ball body to diagnose the musculoskeletal abnormalities. The symbols included: 1- using symbol X to determine landmark reference 2- outlining vertical line 3- determining the center of each segment and connecting these points 4- outlining horizontal arrows to appoint the position of anterior and posterior segments from the vertical line. However, it should be noted that the length of arrows is outlined based on the displacement of each segment from the upper segment (when starting from the lower segment) or lower segment (when starting from the upper part) 5- outlining to show the place tolerating the highest weight 6- outlining horizontal line on the determined points to diagnose the body tilts 7- outlining to show the rotation of extremities (2).
An example of the Aston paradigm:

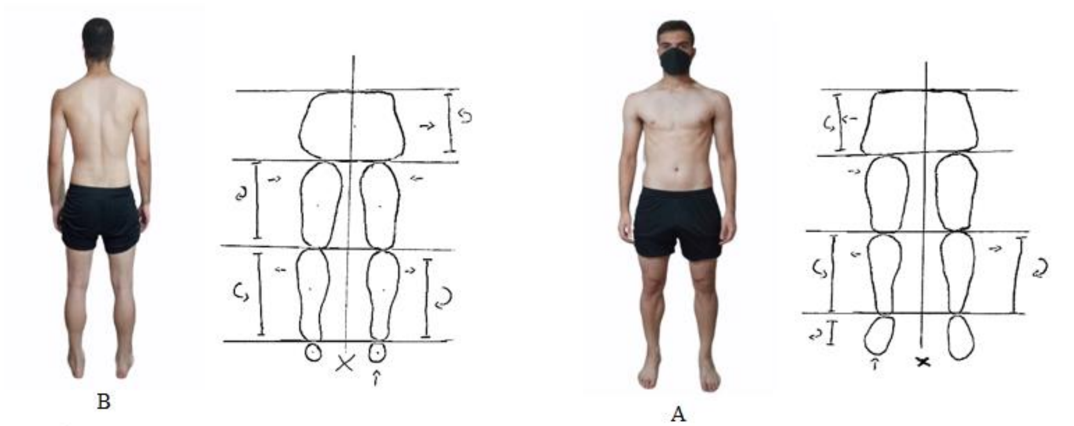

Figure 2. A) anterior view B) posterior view

Statistical method

The data analysis was done using descriptive and inferential statistics, and according to the main research questions. Mean value and standard deviation were used for the descriptive data analysis, and the chi-square test was used as a nonparametric test for the inferential data analysis and nominal data.

Ethical considerations

To conduct this study, an ethical code was received from the Institute of Physical Education and Sports Sciences, and all ethical criteria were observed under the Morality Act in the Institute of Physical Education and Sports Sciences.

Results

The statistical description of samples:
Table 1 has presented the demographic information of the participants.

Table 1
Demographic information of the students

Variable	Number	Average	Standard deviation
Age	60	14.10	1.32
Height	60	163.33	13.3
Weight	60	51.93	11.88

The traditional and Aston assessment paradigms were compared in terms of variables including lateral pelvic tilt, genu varum, genu valgum, and flatfoot. As the existing data were nominal, a nonparametric chi-square was used for the data analysis.

As at least one of the table rows included a frequency lower than the expected level, the significance level of the Fisher test was used. According to the results in table 2, there was no significant difference between the two traditional and Aston groups in terms of lateral pelvic tilt and flatfoot assessment. The significance level in the genu valgum was equal to 0.05, and it was lower than 0.05 in the genu varum. Hence, there was a significant difference between the two groups in terms of knee alignment assessment.

Table 2
The results of the chi-square test to compare pelvic, knee, foot alignment between two traditional and Aston assessment paradigms

Variable	Classes	Group		Chi-square	P
		Aston	Traditional		
Lateral pelvic tilt	Yes	43	53	0.82	0.39
	No	17	7		
Genu valgum	Yes	12	5	5.45	0.05
	No	48	55		
Genu varum	Yes	30	51	6.40	0.02
	No	30	9		
Flatfoot	Yes	13	23	0.42	0.53
	No	47	37		

Discussion and conclusion

The main objective of this study was to compare the lower extremity alignment assessment between two traditional and Aston assessment paradigms. The study examined the pelvic, knee, and flatfoot alignment variables. According to obtained results in Table 2, there was no significant difference between traditional and Aston assessment methods. Hence, the Aston paradigm can be used instead of the traditional model for musculoskeletal screening for purpose of pelvic and foot alignment assessment. However, there was a significant difference between traditional and Aston models in terms of valgum and varum knee assessment. Hence, the Aston paradigm can't be used instead of the traditional model for knee alignment assessment. Many studies have been done on types of traditional methods. One of the methods has been radiography, reminded as the golden standard for pelvic alignment assessment by Crowile et al., (1994 (22). In this regard, Yung et al., (2000) mentioned that the computed tomography method is the most used because of measurement accuracy equal to 1mm, and with less radiation than other methods (14). For the knee alignment assessment, Kalbach et al., (2009), Chang, Angel, and Heis, et al., used the radiography method in their studies and reported the method as the best option for lower extremity alignment assessment (21). For the foot alignment assessment, Menz (1998) introduced the radiography technique as the golden standard for the assessment of foot skeleton posture in static mode (23). Also, the findings of Razeghi et al., (2002), Chen et al., (2006), Mall et al., (2007), and Williams et al., (2000) were consistent with the findings of Menz et al., (998), who used this method (24-28). However, Murley et al., (2009) mentioned in a study that excessive use of this method is not appropriate because of potential risks and high costs of the method (27). In this field, Vincent (2010) has mentioned that the impracticality of the radiography method, high costs, and long-time damages of knee radiography prevent large-scale investigations, and can be used periodically in clinical evaluations. Hence, the authors always tend to replace noninvasive methods for body alignment assessment (21). In this regard, Bussey (2010) used the electromagnetic method for pelvic assessment in a study. As this is the only study using this method for pelvic assessment, there is not sufficient information about the details of this method and its measurement accuracy (17). Rafael et al., (2008), Khamis and Yizhar (2007), and Al-Eisa et al., (2006) used a motion analysis device, which is mostly used for dynamic measurements. The high costs of this device have made it difficult to use that in field studies (30-32). The pelvic inclinometer is the only device, which is more applicable than the others and has high measurement accuracy. According to Crovile et al., (1994), its error is reported at 1 compared to radiography (22). High measurement accuracy, movability, cost-effectiveness, and low risk of the device have changed it into an applied device for pelvic tilt assessment. The device has been used in some recent studies conducted by Yung et al., (2000), Jull et al., (2004), and Gannat et al., (2009) (15-17). However, the palm caliper is a device similar to a pelvic inclinometer, and the only difference between the two devices can be the arrow shape of the palm caliper to show the degree. Regardless of the difference, the two devices are the same in terms of measurement accuracy (16).

Goniometer can be an applied device for knee alignment assessment. Paggy et al., (2005) used a goniometer in a study for knee alignment assessment and reported high validity for the device (33). Also, ReGrasso et al., (1998) reported sufficient content validity for the goniometer in a study to assess varum and valgum knee alignment (34). In this field, Bayraktar et al., (2004) used the same instrument in a study and reported a measurement accuracy of 0.1 degrees for that (35). Collis is also an applicable and common instrument compared to other instruments for knee alignment assessment, especially in field studies. Abdollahpour et al., (2018) used deformed universal industrial collis made by Japanese LTD Co for genu varum assessment, and a measurement accuracy of 0.1degree was reported for that (36). In this regard, Bayraktar et al., (2004) used the same instrument in a study for knee alignment assessment and reported a measurement accuracy of 1.1degree for that (35). Also, there are other types of collis made by other companies, which are used in other studies. For example, Barzegar (2012) used

Verni Collis made in China for knee alignment assessment, the measurement accuracy of which was reported at a tenth of 1 mm (10).

Waist-to-height ratio (WTHR) is one of the noninvasive methods to assess foot alignment. In a study conducted by Williams et al., (2000), the WTHR with repeatability of 0.811-0.848 and validity of 0.844-0.851 obtained the highest validity and repetition among other methods (28). Also, Mc Poil et al., (2008) reported repeatability of 0.98, and validity of 0.929 for the WTHR (37). Another noninvasive method is using footprint. Azma et al., (2012) confirmed the validity and reliability of using a footprint device (38). Another noninvasive method for foot alignment assessment is a measurement of rearfoot angle by a goniometer. Many studies have used this method to measure the rearfoot angle to the date, and have reported a reliability of ICC=0.69 for that (39). In the end, one of the best and the most common methods of foot alignment measurement is navicular drop measurement, which obtained high reliability in the study conducted by Schultz (2005) (21). In this regard, Smitt et al (1997) reported a reliability of ICC=82% for this method (40). Also, Williams et al., (2000) reported average to good validity and reliability for this method (27). In another study conducted by sell et al., (1994), internal and external repeatability (0.73-0.83) for the radiography image (41). In the study conducted by Hannigan et al., (2000) the validity (0.61-0.89) was reported for radiography images (42).

Despite the traditional assessment model, on which many studies have been conducted, no study has been conducted on the Aston paradigm, and this method has been used clinically by those educated personally by Judith Aston, or those who studied his book. Aston believes that visual references are useful for therapists and clients. The advantages of this method for the therapists are: 1- recording posture images of four views at the beginning of treatment as the reference point 2- comparing changes in clients in distance between the sessions 3- the treatment results can be documented at the end of treatment phase 4- the next step specifies the tendency of different parts of the body created by treatment. This is because; it may show the point that is neglected. The advantages of this method for the clients are: 1- the spirit of participants is improved during the sessions 2- some people have never seen themselves from the posterior view. This is an experience, which shows the different views of their body.

The therapists using Aston paradigm said: 1- it facilitates diagnosis by prioritization and sequence in treatment 2- it provides a system to improve assessment skill by recognizing and complying the relations between one part of the body with another one 3- it suggests information about the areas of the body underused or overused during exercise 4- it helps providing integration among concepts by learning various techniques 5- it helps the therapist in the field of treatment, and training effective patterns in functional actions affecting prevention of pain relapse 6- it helps designing practical programs to provide sufficient support in the body to take special task (e.g. making suitable support base to facilitate access for standing) 7- appliable for all people from professional athletes to physical and mental patients 8- it promotes the ability of practicing treatments to analyze the body pattern of the client, and the cooperation of the paradigm with unalignment symptoms for more effective interference 9- it provides sufficient support by using treatment period to train the client to optimal use of the body regarding the existing limitations 10- it allows the therapists see the whole body in a frame, and find out that every part of the body shows the effect of interactions of the body organs. This helps them diagnose and treat shortcomings, which cause unpleasant feelings in the people in daily life. 11- it helps them diagnose areas with excessive compression, contraction, reduction of dimensions, hypermobility or hypomobility in the musculoskeletal system 12- it helps them shoe the way of cooperation of the body pattern with tiredness, hypertension syndrome, and pain 13- helping better understanding and removing the limit between soft tissue and body alignment 14- helping the coaches to see that in which area the client needs increasing or decreasing tonicity to improve the alignment and stability in good posture by increasing the power and improving the performance 15- it helps designing exercises based on a special structural paradigm for every person and reducing the risk of injuries 16- finally, it helps to increase the ability of visual assessment in different body patterns. Also, it helps the client achieve the most optimal mode by observing individual patterns before the pretest session, while practicing, and then, changing in pattern after the practical session (4).

Accordingly, this study has applied a pelvic inclinometer for pelvic alignment assessment; collis was used to measure knee alignment, and a ruler was used to measure navicular drop to assess foot alignment. Each instrument was introduced as the most common and reliable instrument to assess musculoskeletal abnormalities based on the traditional paradigm used in the literature. Hence, this study used the method, so that the Aston paradigm can be compared with the traditional model using the best instrument. According to obtained results, and based on the relevant literature, it seems that there is no significant difference between traditional and Aston paradigms in terms of pelvic alignment assessment in the frontal plane, and foot alignment assessment. Hence, the Aston paradigm can be used instead of traditional assessment in screening with large populations to enhance the measurement speed. Also, other advantages of this method can be easy working according to no need to present subjects for a long-time in the test place, and no need for special laboratory instruments. However, there was a significant difference between traditional and Aston paradigms in terms of knee alignment assessment. According to the novelty of the method, and the lack of literature in this field based on the Aston paradigm, further studies are needed.

The message of the study

According to the high speed of measurement by the Aston paradigm, the method can be used in screening projects with a large population with the aim of assessment of pelvic alignment and foot alignment.

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References

1. Shahrokhi H, Daneshmandi H, Javaheri Hashemi Ali A. The study of upper Extremity and trunk anatomical Alignment concerning anthropometric characteristics of athletes, J Sports med number.2011; 6: 73-89. (Persian)
2. Gallyamova ZV, Batyukova VE, Malakhova VY, Fomenko EV. Health care system in the USSR (through the example of the Kirov region). J. Adv. Pharm. Edu. Res. 2019;9(4):70-5.
3. Moghadas Tabrizi Yousef*, Ghafoori Hamid, Mansouri Mohammad Hani, Minoonejad Hooman. The Comparison Angles Of Forward Head, Kyphosis And Lordosis Between Table Tennis Players And Normal Range Of Iranian Non-Athlete Subjects. J Res sport rehabil. 2019, 7,13 ; 67-76.
4. Aston JU. Aston Postural Assessment. 2nd ed. United Kingdom: Handspring Publishing; 2019.
5. Noll M, Candotti CT, Vieira A. Escola de educação postural: revisão sistemática dos program asdesenvolvidos para escolares no Brasil. Movimento Porto Alegre. 2012; 18(4): 265-91.
6. Abdoli Armaki M. Body mechanics and workstation design principles (ergonomics). 1nd ed. Iran: Omid Majd Publishers; 2008. (Persian)
7. Cuartas E, Rasouli A, O'Brien M, Shufflebarger HL. Use of All-pedicle-screw Constructs in the Treatment of Adolescent Idiopathic Scoliosis. J Am Acad Orthop Surg. 2009; 17(9): 550-61.
8. Dehghan menshadi F, Khalkhali zavieh M, Mehrabi yad elah. Prevalence of Scoliosis and Trunk Disorders in High School Students, Tehran. J rafsan uni med sci health serv. 2003; 2(3-4): 143-150. (Persian)
9. Khiavi Noazar Rasoul (2019) quoted from Frahbod et al (2015), Evaluation of the causes and prevalence of genu varum and genu valgum in primary school students in Meshkinshahr. (Persian)
10. Barzegar KF, Siahkohian M, Aghayari A. Survey the Relationship between Lower Body Abnormalities with Muscle Power in10 and 11 Aged Girl Students in Ardabil. J Phys Educ. 2013; 2(1): 39-47. (Persian)
11. Herma.Mun Cheung lau A, Thomas Tai Wing Chiu A, Tai-Hing Lam.Clinical measurement of craniovertebral angle by electronic head posture instrument: A test of reliability and validity. Man Ther. 2009; 14: 363-368.
12. letafatkar A, Daneshmandi H, Hadadnezhad M, Abdolvahabi Z. Advanced corrective exercises. 6th ed. Iran: Avaye zohor Publishers;2021. (Persian)
13. Alizadeh Mohammad Hossein, Raese Jalili, Elham Shirzad, Laleh Bagheri, Comparison of standing balance between athletes and non-athletes with pes planus and normal foot under altered sensory condition. J Hum mo sci. 2008; 2: 115-122. (Persian)
14. Young RS, Andrew PD, Cummings GS. Effect of simulating leg length inequality on pelvic torsion and trunk mobility. Gait Posture. 2000; 11)3):217–23.
15. Henry Juhl J, Tonya M. Ippolito Cremin, DO, Russell G, DC. Prevalence of frontal plane Pelvic Postural Asymmetry. J Osteopath Assoc. 2004; 104(10): 411-21.
16. Rafat GN, Saulicz ED, Maciej BI, Patryk KT. Does Pelvic Asymmetry always mean Pathology? Analysis of Mechanical Factors Leading to the Asymmetry, J Hum kinet. 2009; 21: 23-35.

17. Bussey, D, Melanie, Does the demand for asymmetric functional lower body postures in lateral sports relate to the structural asymmetry of the pelvis? J Sci Med Sport. 2010; 13(3): 360-4.
18. Hadadnezhad M, Letafatkar A. The Relationship Between Genu Varum Abnormality and Lower Extremity's Performance and Strength in Teenage Footballers. J res rehabil sci. 2012; 7(2): 188-196. (Persian)
19. Pereira R, Machado M, Santos M, Pereira L N, Sampaio-Jorge F, Muscleactivation sequence compromises vertical jump performance, Serbian JSports Sci. 2008; 2(1-4): 85-90.
20. Shultz Sandra J. Development of an Anatomical Landmark Proto-col for Constructing Segment Axes for Lower Extremity Kinematic Analysis. 1nd ed. UNCG: Thesis Publishing; 2005.
21. Vincent SM. Flexible flatfoot in children and adolescents, J Child Orthop. 2010; 4: 107–12.
22. Krahl H, Michaelis U, Pieper H, Quack G, Montag M. Stimulation of bone growth through sports. A radiologic investigation of the upper extremities in professional tennis players. J Sports Med. 1994; 22(6): 751-7.
23. Menz H. Alternative techniques for the clinical assessment of foot pronation. J Am Podiatr Med Assoc. 1998; 88(3):119-29.
24. Razeghi M, Batt ME. Foot type classification: a critical review of current methods. Gait & posture. 2002; 15(3): 282-91.
25. Chen C-H, Huang M-H, Chen T-W, Weng M-C, Lee C-L, Wang G-J. The correlation between selected measurements from footprint and radiograph of flatfoot. Arch Phys med rehabil.2006; 87(2): 235-40.
26. Mall NA, Hardaker WM, Nunley JA, Queen RM. The reliability and reproducibility of foot type measurements using a mirrored foot photo box and digital photography compared to caliper measurements. J Biomech. 2007; 40(5): 1171-6.
27. Williams D, McClay I. Measurements used to characterize the foot and the medial longitudinal arch: reliability and validity. Phys Ther j. 2000; 80(9): 864−71.
28. Menz HB, Munteanu SE. Validity of 3 clinical techniques for the measurement of static foot posture in older people. J Orthop Sports Phys Ther. 2005; 35(8): 479-86.
29. Murley GS, Menz HB, Landorf KB. A protocol for classifying normal-and flat-arched foot posture for research studies using clinical and radiographic measurements. J foot ankle Res. 2009; 2(1):1-13.
30. Rafael Z.A. Pinto Thales R. Souza, Renato G. Trede, Renata N. Kirkwood, Elyonara M.
31. Figueiredo, Se´ rgio T. Fonsec. Bilateral and unilateral increases in calcaneal eversion affect pelvic alignment in standing position. J Man Ther. 2008; 13: 513–519.
32. Khamis S, Yizhar Z. Effect of feet hyper pronation on pelvic alignment in a standing position. Gait and Posture. 2007; 25(1):127–34.
33. Al-Eisa E, Egan D, Deluzio K, Wassersug R. Effects of pelvic asymmetry and low back pain on trunk kinematics during sitting: a comparison withstanding. J Spine. 2006; 31: E135-43.
34. Paggy H A. Therapeutic exercise for musculoskeletal injury. 4th ed. United States: J hum kinet. 2005; 700-718.

35. ReGrasso R, Bianchi L, Lacquaniti F. Motor Patterns for Human Gait, Backward Versus Forward Locomotion. J Neurophysiol. 1998; 12: 223-227.
36. Bayraktar B, Yucesir I. Ozturk A, Cakmak, AK, (2004). Change of quadriceps angle values with age and activity. Saudi Med J. 2004; 25(6):756-60.
37. Darvishani Abdollahpour M, Barghamadi Mohsen, Kiani A. The effect of comparison Kinesio taping and corrective exercise on genu varum and knee kinematics in adolescent soccer players. J sport biomes.2018; 4(2): 59-69. (Persian)
38. McPoil T, Cornwall M, Vicenzino B, Teyhen D, Molloy J, Christie D, et al. Effect of using truncated versus total foot length to calculate the arch height ratio. Foot. 2008;18(4) :220−7.
39. Azma K, Mahnama A, Tamaddon A. Design and Manufacturing Podographometer Device and Scientific Principles Used in It. J Anal mil health sci res. 2012; 10(4): 285-292. (Persian)
40. Farzaneh H, Ilbigi S, Anbarian M. The Comparison of Two Models of Rear Foot Angle Measuring in A Static Position and Correlation With The Dynamic Position In Pronate Foot Subject During The Stance Phase Of Walking. J res sport rehabil. 2015; 2(4); 57-65. (Persian)
41. SmithJ Szczerba JE, Arnold BL, Perrin DH, Martin DE. Role of hyper pronation as a possible risk factor for anterior cruciate ligament injuries. J Athl Train. 1997; 32(1): 25-8.
42. Sell KE, Verity TM, Worrell TW, Pease BJ. Wigglesworth J. Two measurement techniques for assessing subtalar joint position: a reliability study. J Orthop Sports Phys Ther. 1994; 19(3): 162-7.
43. Hannigan-Downs K, Harter R, Smith G. Radiographic validation and reliability of selected clinical measures of pronation and biomechanical analysis of tarsal navicular displacement under statics and dynamic loading conditions. J Oregon state uni. 2004; 35: 12-30.