The Effects of Genu Varum Deformity on the Pattern and Amount of Electromyography Muscle Activity Lower Extremity during the Stance Phase of Walking

Hosein Tajdini Kakavandi [a*], **Heidar Sadeghi** [a], **Ali Abbasi** [a]

a Department of Sport Biomechanics, Faculty of Physical Education and Sport Sciences, Kharazmi University, Teheran, Iran

Corresponding Author:** Hosein Tajdini Kakavandi. Msc Student in Sport Biomechanics, Kharazmi University, Tehran, Iran. ***Tel: +98 21 22228001; ***E-mail***: h_tajdini@yahoo.com

Submitted: 2017-02-12; **Accepted**: 2017-06-10

Abstract

Introduction: mal-alignment of lower extremity especially at the, aligned with the change of gravity line passing the lower limb joints can cause disorders in neuromuscular control of muscles around the joints and increase the risk of injury during sport activities. Therefore the aim of present study was to evaluate the effects of genu varum deformity on the pattern and amount of Electromyography muscle activity lower extremity during the stance phase of gait respectively. **Materials and Methods:** Thirty active male (two groups of Genu varum and normal) participated in the current semi-experimental study with the age ranged 20-25 years. Utilizing Electromyography data, the amount and the onset time of muscle activity were calculated. Data were analyzed utilizing MANOVA for between-group differences and paired samples t-test for within-group differences at a.05 level of significance. **Results:** The results showed that Gluteus Medius muscle during the loading response phase of walking in the active male with genu varum significantly higher levels of activity than control group in the dominant (P=0.031) and non-dominant limb(*P*=0.004). But the Rectus Femoris and gastrocnemius medialis muscles activity was not significantly different between the two groups in none of the phase walking (*P*>0.05). Also there was no significant difference between the onset of muscle activity (*P*>0.05). Moreover, no significant difference could be observed between dominant and non-dominant limbs in the amount and onset of muscle activity (*P*>0.05). **Discussion:** Based on the results of this study, it is concluded that subjects with Genu Varum deformity are more active than normal subjects in the gluteus medius. This increase in activity can be accompanied with the increase of compressive forces and articular loads which can cause osteoarthritis joint in the long run.

Key words: Electromyography Activation, Genu Varum Deformity, Muscle Activity Timing, Walking

Please cite this paper as: Tajdini Kakavandi H, Sadeghi H, Abbasi A. The effects of genu varum deformity on the pattern and amount of Electromyography muscle activity lower extremity during the stance phase of walking. J Rehab Med. J Clin Physio Res. 2017; 2(3): 110-118.

Introduction

Being able to move is the main factor which fulfills the human burning desire to be an independent creature. One the most prevalent, yet complex human movements is the ability to walk which is considered as the integral part of the daily as well as sport activities. As mentioned previously, human ability to walk is one of the complicated movements since it is a combination of different circumstances which are well organized and scheduled. It is also the result of a complex interaction between the central nerve system and various body muscles enabling an individual to hold standing position and walk without losing balance (1). As a matter of fact, having the constant ability to walk necessitates the coordinated and integrated function of different body organs, it is meant that if lower limb joints fail to work in harmony, a person will face problem in basic movements such as walking (2). It is needless to mention that, the primary responsibility of the lower limb joints is to control the person's ability to walk which have a crucial role in absorbing the forces made when the feet touch the ground, keeping the balance and producing the necessary driving forces to establish the integrated and harmonious pattern of walking (3).

Knee join, as a median part, plays a vital role in supporting the body and transferring its weight when it comes to static and dynamic activities. When the body performs its routines activities it imposes high degree of gravity force on the knee whose stability and protection during the above mentioned activities are provided by the joints and ligaments surrounding the knee with no bone interference that is why this join is known to be one the most vulnerable joints in the body (4). Since the musculoskeletal system is an interwoven system, any change in any part of it will affect the function of other parts, consequently the biomechanical features of movements among people will be influenced respectively (5). One of the common deformity in lower limbs is known as genu varum deformity which causes outward bowing at the knees (6). This type of deformity has several serious consequences which can have direct effect on the function of lower limb muscles among those suffering from genu varum deformity. The negative consequences of this deformity includes; a pelvic, leg and ankle joint deformity, some biomechanical changes in the pelvic, leg and ankle joints, a change in tension line of the muscles, an increase in the imposed gravity force on outward ligament structures of the knee in both static and dynamic positions, stretching and loosening of the outward ligament structures of the knee and finally a change in the signals transferred from their mechanical receptors to the central nervous system (7, 8). The study by Stief *et al.*, demonstrated the maximum quantity of the knee adduction torque during mid-stance and Terminal stance on the frontal plane was %32 among the individuals suffering from genu varum deformity and maximum quantity of the hip abduction torque during loading response phase on Transverse plane was more than people with no deformity (9). It was also shown that there was a noticeable increase in the internal rotational torque of the knee and the external rotational torque of the thigh among those people with deformity, therefore, this conclusion can be drawn that the symptoms and the effects of the genu varum deformity are not exclusively frontal plane oriented.

Based on the evidence collected if any musculoskeletal disorder is developed in one of the joint of the body, the muscles and ligaments on the concave side will become shorter, on the other hand, the muscles and ligaments on the convex side will become stretched; consequently, it seems reasonable that every single biomechanical change in lower limbs will affect the muscles activities which will finally result in a change in their function and a decrease in their efficiency (10). It is believed that many walking disorders observed among people are the result of the gradual muscular weakness, in this case, some other muscles start compensatory procedure which might result in altering the proportion of muscular forces and changes in movement patterns (11). Undoubtedly, it is vitally important to study the amount and the pattern of muscular activities among athletes. It is worth mentioning that improper or a delay in the function of muscles around the joint can negatively affect its stability and increase the risk of joint damage so that neuromuscular system plays a really important role in muscles activation and damage protection. To have the muscles activated, neuromuscular system employs two types of mechanisms known as; feed forward and feedback. On the one hand, in the feed forward mechanism neuromuscular system activates the muscles before any stimulus comes into operation, that is, neuromuscular system based on its previous experiences gained activates the muscles to prevent the balance loss and damage (12). It is really important to activate the muscles on time in order to establish the muscular stability (13). Preparatory muscular activity results in the Anticipatory postural Adjustments (13). It is with the help of these adjustments that body can keep the balance when stronger forces are imposed. Anticipatory postural Adjustments creates the proximal stability initiating distal movement; thus, muscular activities control the imposed forces to the joint by producing reaction torque (14). Muscular activity should be triggered on time and harmonically through the process of combining necessary forces effectively (13). Neuromuscular recruitment patterns are mainly liable for forming the joint firmness as well as its dynamic stability during the movement (15). Taking this into account, a joint stability disorder in three-phase motor plates during the lower limbs and body kinetic chain caused by deficiency in Dynamic Neuromuscular control, Timing or improper and unnatural Recruitment in the muscles of knee during exercise are considered as the main reasons for the ligament damage of the knee joint (16).

A comprehensive review of the literature revealed that while there were many studies conducted to examine the function of the muscles in people with genu varum deformity, where changes in structure and function of the Quadriceps were solely surveyed, there were few studies which focused on either other muscles or timing of the muscular activity so that the gap spotted contributed to carrying out the current study (17). There is also an ambiguity in the comparison of leg dominance during walking. Due to the fact that raising awareness of muscular imbalance between dominant and non-dominant leg as a dangerous and damaging factor among the athletes who rely on both legs equally in performing some physical activities is a crucial issue and due to the prevalence of genu varum deformity and lack of enough studies about the Electromyography genu varum deformity, coming to a basic understanding of its effects on Electromyography variable during the walking process is to be taken into consideration. As a result, the current study was conducted to find out if genu varum deformity has any influence on the pattern and the amount of the muscular activity of the dominant and non-dominant leg of the active men during the stance phase.

Materials and Methods

All active male students studying at Kharazmi University comprised the sample of this semi-experimental study. They were in the 20-25 age range who had been following a regular sport schedule. Their schedule consisted of 3 sessions of physical activity, each lasted 90 minutes during a week. Thirty available participants were equally distributed into two groups of genu varum and normal in accordance with their knee status to perfume reformative movements in biomechanical laboratory. Some personal factors, including their height, weight, age as well as their physical activity features such as the amount, the type and the time they allocated to do exercise were quite similar. They took part in a wide range of physical activities, mainly known as, jogging, exercise movements, weight lifting to keep fit and healthy. The exclusion criteria determined were; suffering functional instability in ankle, experiencing the ankle sprain two years before the participation, having joint fractures or surgical record in lower limb, suffering ligament damages or Knee meniscus, having Mechanical knee instability, following a rehabilitation schedule relating to the lower limb during the six months before the participation, being diagnosed with chronic diseases such as rheumatism or diabetes and having Vestibular disorders.

At the beginning, the participants were briefed on the purpose and the process of the test, then the written consent beside all their personal information including; age, training history, the number of training sessions during a week and their diseases and damages records were obtained. To have the genu varum deformity determined among the participants, the distance between two internal ankles of the femoral bone at its prominence was measured and recorded by modified Industrial caliper enjoying the accuracy of 1/1 mm manufactured by LLD Company in Japan. The applicants were asked to stand barefoot in front of the examiner at their ease with no muscular contractions in their lower limb (18). They were also instructed to lean against the wall and while their head, spinal cord, hip and heel touched the wall, they were required to keep their legs paired. The participants were placed into the group with genu varum deformity if three- centimeter distance was recognized between two internal ankles of the femoral bone. Next, the leg dominance among the subjects was identified by a simple test in which they were asked to shoot a ball. The participants were given five minutes to get themselves prepared to start the test and to perform the intended movement. To set totally natural conditions and to prevent any change in the walking patterns of the subjects they were requested to walk barefoot with their preferable speed along the direction, it helped them familiarize themselves with the test conditions. A speedometer was also used to control the potential effect of the speed of walking which was to be ±5% (19).

Two force plates with three axes, BERTEC model, made in the USA, were used to identify the first time that the foot touched the ground; additionally, Electromyography with eight channels, MIE model, made in England was employed to examine the pattern and the amount of the muscular activity. It was synchronized with two force plates mentioned above. Later on, the data relating to Electromyography were collected with the frequency of 1024 HZ, then they were all filtered through the Butterworth filter with Cut of frequency of 13 to 430 HZ (20). Signals were measured by Disposable Electrodes one cm in diameter, SKINTACT model, made in Australia. After having the skin shaved and cleansed by a pad and alcohol, the electrodes were fixed upon the projected muscle of the dominant and non-dominant legs. The electrodes were placed on the muscles in accordance with bipolar method and twenty mm center to center distance was considered. The European protocol called SENIAM was adapted to determine the place of electrodes on Gluteus medius muscle, Rectus femoris muscle, gastrocnemius medialis muscle. The earth electrode was also placed in suitable distance from the muscle on the bony area. The RMS index was considered to measure the amount of the Electromyography activity of the muscles during the Loading response phase (%15 at the beginning of the stance phase) and mid-stance/Propulsion phase (%45 at the end of the stance phase). After that, the obtained data relating to RMS index were normalized and divided by Maximum voluntary isometric contraction to be compared among the participants. To have the onsetof muscular activity at stance stage measured, the Rectify waves and triple the standard deviation of the amount of electrical activity of the muscles were taken into account. Arbitrarily, when the muscular activity reaches its threshold and remains on the threshold for minimum 25 Milliseconds, this will be considered as the onset of the activity (20). The onset of the activity of every muscle was evaluated when

Table 1. Mean and standard deviation of two groups

Group	Age (year)	Weight (Kilogram)	Height (Cm)	Distance between knee medial epicondyles (cm)
Normal	22.53±1.59	74.66±6.76	176.13±5.35	0.78±0.65
genu varum	22.80±1.56	72.73±6.52	178.26±4.75	5.68±0.78
***P*-value**	0.657	0.433	0.259	0.000

Table 2. The results of the MANOVA test to compare the amount and the starting pint of muscular activity

Variable	Wilks' λ	F	Sig	Partial Eta Squared
Amount of activity	0.161	7.373	0.000	0.839
Onsetof activity	0.693	1.697	0.167	0.307

the heel touched the ground, in case that the muscle got activated earlier than the time when the heel touched the ground, the starting time was illustrated by minus sign and if the muscular activity initiated after the time when the heel touched the ground, the onsetwas demonstrated by plus sign.

Several statistical procedures were then adopted to analyze the data obtained by the SPSS software version 23. Mean and standard deviation were employed to describe the variables, Kolmogorov–Smirnov test was used to determine the normal distribution of data, Levene test was performed to check the homogeneity of the data Variance, independent T-test was used to survey the difference in the physical features of two groups, dependent T-test was performed to study the intra difference and finally MANOVA, $P>0.5$, was employed to compare the amount and the onset of muscular activity between two groups of participants.

Results

All personal characteristics of the participants in both normal and genu varum groups including, age, weight, height and the distance between two knee medial epicondyle are presented in the table 1.

Table 2 illustrates the results of the MANOVA test performed to examine the amount and the onset of muscular activity between two groups of participants. As can be clearly seen, there was a significant difference between two groups regarding the amount of the muscular activity; however, as regards to the onset of the activity ($P=0.000$), the data did not show any significant difference between two groups $P>0.05$.

The results of the intra group tests depicted that there was a significant difference between two groups regarding the amount of the Gluteus medius muscle activity during loading position in the dominant leg ($P=0.031$) in comparison with non-dominant leg ($P>0.004$), in other word, the participants in the genu varum group demonstrated the larger amount of activity. Considering the amount of the Rectus femoris muscle and gastrocnemius muscle activity, there was no significant difference between two groups ($P>0.05$).

Tables 3 and 4 shows the results of the dependent T-test indicating that concerning the amount of the activity of a particular muscle, there was no significant difference between the dominant and non-dominant legs ($P>0.05$).

As shown in the table 5, regarding the onsetof the muscular activity there was no significant difference between the dominant and non-dominant leg ($P>0.05$)

Discussion

The purpose of the current study was to examine the effect of the genu varum deformity on the pattern and the amount of the Electromyography muscular activity of the lower limb during the stance phase among active female subjects. According to the results achieved, there was no significant difference between two normal and genu varum groups regarding the onset of the activity of the Gluteus medius, Rectus femoris and gastrocnemius medialis in the dominant and non-dominant leg. Neuromuscular activation patterns are one important area of research when it comes to injury. Neuromuscular control, known as muscular activation adjustment, are defined based on the nervous system and the factors relating to the performance of the physical activity (21). It is absolutely necessary for the Dynamic firmness of muscles to be predicted, some reactions to the forces imposed on the joints during the movement should be produced (15). It should be mentioned that efficient Neuromuscular control which is the result of the proper timing and proper production of force is really important to bring the protective stability about; as a result, any factor resulting in the delay or functional inhibition of the joints stabilizing factors will initially lead to joint instability and later on it will cause other

Table 3. Amount of muscular activity and intra-group differences

Variable	Organ	Muscle	Group	Mean±SD	Df	F	Sig	Partial Eta Squared
Amount of activity at loading response phase	**Dominant**	Gastrocnemius	Normal	19.09±6.34	1	1.270	0.269	0.043
			Genu Varum	16.67±5.38				
		Rectus Femoris	Normal	21.69±7.13	1	1.862	0.183	0.062
			Genu Varum	18.26±6.60				
		Gluteus Medius	Normal	38.93±10.48	1	5.152	0.031	0.155
			Genu Varum	47.27±9.62				
	Non-dominant	Gastrocnemius	Normal	16.92±5.57	1	0.516	0.478	0.018
			Genu Varum	15.58±4.61				
		Rectus Femoris	Normal	23.03±8.02	1	1.140	0.295	0.039
			Genu Varum	20.05±7.19				
		Gluteus Medius	Normal	38.87±9.06	1	9.808	0.004	0.259
			Genu Varum	48.10±6.92				
Amount of activity at mid-stance/Propulsion phase	**Dominant**	Gastrocnemius	Normal	38.78±9.23	1	1.365	0.253	0.046
			Genu Varum	34.73±10.14				
		Rectus Femoris	Normal	8.76±3.70	1	0.113	0.739	0.004
			Genu Varum	8.30±3.89				
		Gluteus Medius	Normal	18.46±6.65	1	3.802	0.061	0.120
			Genu Varum	23.05±6.23				
	Non-dominant	Gastrocnemius	Normal	39.47±10.32	1	0.368	0.549	0.013
			Genu Varum	37.26±9.57				
		Rectus Femoris	Normal	9.01±3.94	1	0.127	0.724	0.005
			Genu Varum	8.49±4.04				
		Gluteus Medius	Normal	17.19±7.41	1	2.081	0.160	0.069
			Genu Varum	20.84±6.40				

Table 4. Results of the dependent T-test to compare the muscular activity in dominant and non-dominant organs

Variable	Stage	Muscle	Group	Organ	Mean±SD	t	Sig
Amount of muscular activity	**Loading position**	Gastrocnemius	Normal	Dominant	19.09±6.34	1.909	0.077
				Non-dominant	16.92±5.57		
			Genu Varum	Dominant	16.67±5.38	0.896	0.385
				Non-dominant	15.58±4.61		
		Rectus Femoris	Normal	Dominant	21.69±7.13	-1.740	0.104
				Non-dominant	23.3±8.02		
			Genu Varum	Dominant	18.26±6.60	-1.540	0.146
				Non-dominant	20.05±7.19		
		Gluteus medius	Normal	Dominant	38.93±10.48	0.049	0.962
				Non-dominant	38.87±9.06		
			Genu Varum	Dominant	47.27±9.62	-0.540	0.598
				Non-dominant	48.10±6.92		
	Mid-stance and Propulsion	Gastrocnemius	Normal	Dominant	38.78±9.23	-0.613	0.549
				Non-dominant	39.47±10.32		
			Genu Varum	Dominant	34.73±10.14	-2.007	0.065
				Non-dominant	37.26±9.57		
		Rectus Femoris	Normal	Dominant	8.76±3.70	0.390	0.702
				Non-dominant	9.01±3.94		
			Genu Varum	Dominant	8.30±3.89	-0.215	0.833
				Non-dominant	8.49±4.04		
		Gluteus medius	Normal	Dominant	18.46±6.65	1.429	0.175
				Non-dominant	17.19±7.41		
			Genu Varum	Dominant	23.5±6.23	1.631	0.125
				Non-dominant	20.84±6.40		

Table 5. results of the dependent T-test to compare the onset of activity in dominant and non-dominant organs

Variable	Muscle	Group	Organ	Mean±SD	t	Sig
Onset of activity	Gastrocnemius	Normal	Dominant	73.93±44.22	-0.365	0.721
			Non-dominant	78.86±28.75		
		Genu Varum	Dominant	66.46±35.56	0.225	0.825
			Non-dominant	63.93±30.50		
	Rectus Femoris	Normal	Dominant	-116.80±49.20	0.751	0.465
			Non-dominant	-105.13±38.28		
		Genu Varum	Dominant	-133.00±29.76	1.861	0.084
			Non-dominant	-118.60±42.65		
	Gluteus medius	Normal	Dominant	-150.33±34.75	0.681	0.507
			Non-dominant	-140.40±44.16		
		Genu Varum	Dominant	-126.80±43.81	0.720	0.483
			Non-dominant	-117.40±37.94		

damages (15). As a matter of fact, the manner and the time of the muscular activation enable the joints to optimize their firmness and to absorb and ward off the forces effectively, that will prevent the potential damages. The first negative consequence of the improper timing with regard to activity of the muscles surrounding the joints is considered to be the joints dynamic stability. On the other hand, proper timing employs the suitable feed forward patterns to control the movement and joint status in damaging situations. In case of improper timing of muscular activity, the joint will be exposed to damage. Additionally, to have the control over the Varvs and Valgvs during the physical activity, feed forward patterns are required to take the proper measures on time.

Patrek *et al.* reported no change in Kinematiclanding after the thigh abductor muscles experienced fatigue, but longer delay in Gluteus medius muscle (22). They also stated that, the longer delay in Gluteus medius muscle was equal to Predictive activity of this muscle. A decrease in the Predictive activity or in the power of the thigh abductor muscles result in a decrease in hip stiffness، on the frontal plate. Besides, a decrease in the Predictive activity means a decrease in the Joint torque and in the external thigh adductor torque. Russell *et al.* said that the activity time of the Gluteus medius muscle is more important than its amount of activity. Based on the literature review, there was no study conducted to examine the onset of the muscular activity during walking and among the people suffering from genu varum deformity (23). The majority of the studies related to the time of muscular activity mostly focused on the possible knee damages such as, Arthritis and Reconstruction of the anterior cruciate ligament, based on these studies knee damages can change the time of the muscular activation (24, 25). According to one similar study carried out by Park *et al.* in which they compared the onsetof the muscular activity of Vastus medialis and vastus lateralis among people with genu varum deformity, there was no difference between the normal and among people with genu varum group regarding the onsetof the muscular activity (20, 26). The results of that study by Park *et al.* are compatible with the results of the current study (26). In another research done by Javdaneh *et al.*, the timing of the activity of the corresponding and apposite muscles to the function of anterior cruciate ligament among male athletes with ankle pronation during the Single-leg landing was surveyed, considering the gastrocnemius and Gluteus medius muscles, its results which match the results of the present study did not support the evidence of any significant difference between two groups (27, 28).

Another comparable study was conducted by Beckman in which the internal rotation of ankle, the onset of the Gluteus medius muscle activity among those who had extreme range of motion were measured. The results of the study proved that there was a delay in the Gluteus medius muscle activation among people with extreme range of motion. There are several factors that can clearly explain the incompatibility of the results of that study with the present study, for example; Classification anomalies, range age of 31 (29), (older age range changes the employment of muscular activity patterns), type of the research, the physical activity level of the participants who were normal individuals (employment of muscle might be different between normal subjects and athletes) (28). Since there was no significant difference between participants in normal and genu varum groups regarding the muscular activation pattern, it might be concluded that genu varum deformity is not an important factor causing the increase in the onset of muscular activity during the stance phase of walking; consequently, Kinetics and Kinematic factors should be carefully examined to explain the main reasons of damage among those with genu varum deformity.

Moreover, according to the results of this study there was a significant difference between the subjects distributed in two normal and genu varum groups considering the activity of the Gluteus medius muscle at the stage of loading position in both dominant and non-dominant organs, the activity of the gastrocnemius and Rectus femoris muscles was not significantly different in two groups of participants, though. The electrical activity of these two types of muscles among the subjects in the genu varum group was less than those in the normal group. The above mentioned results are consistent with the findings of studies conducted by Barati, Musavi, Anbarin *et al.*, Heiden *et al.* and Tsakoniti *et al.* on the one hand, and they were not compatible with the results of the research done by Mahaki *et al.* and Musavi *et al.*, on the other hand (30-34). This incompatibility can be related to the difference in the pattern of foot contact with the ground during walking and landing circle as well as the difference in the pattern of muscle employment and absorption of the shock. Gluteus medius muscle is responsible for the stability of pelvis and thigh abduction, its activity increases depending on the task difficulty. The body gravity turns into the supporting surface during walking and imposing the weight on one leg and the body weight creates an external and adductive torque which is a Disruptive force to the stability. This force puts the thigh in adduction position, the pelvis in downward position and the knee in Valgus position. As there is an interval between the electrical activity of the muscle and the creation of the force, abductor should take action prior to the Disruptive force to the stability in order to have effective function. To achieve this purpose, central nervous system predicts the time when Disruptive force to the stability starts to be active and makes the muscles contracted with the help of some muscular strategies (35). In accordance with the results of the current study, the activity of the Gluteus medius muscle among individuals with genu varum deformity is more than healthy subjects (1). One possible explanation for the obtained results can be the fact that Coxa Valga is common among the people suffering from genu varum deformity. Since in Coxa Valga there is a decrease in the Torque arm of the abductor muscles in thigh joint, to compensate the lack of mechanical advantage, the activity of these muscles increases in order to keep the pelvis in horizontal position when it has to bear the body weight (1). Due to the increase in the muscular activity, compressive forces in the thigh bone head increase which promotes the tendency to thigh Osteoarthritis. In case that a muscle is weak, central nervous system compensates this weakness by increasing the Neural Drive through which it can create similar force to increase the muscular activity (36). Although there was no significant difference between the applicants in both normal and genu varum groups with regard to the activity of gastrocnemius and Rectus femoris muscles, subjects in genu varum group recorded less activity in these muscles. Decrease in the activity of the Rectus femoris muscle can be related to the change in the Tension line and in the direction of the Quadriceps tendon as well as the force transition to inner side of the muscle on the sagittal plane (37). Tsakoniti *et al.* did not report any significant difference between normal and genu varum groups regarding the Rectus femoris, a reasonable explanation for this finding is that Rectus femoris which kelps the thigh bend has two joints (38). The decrease in the gastrocnemius muscle activity among those who suffered from genu varum deformity can be also explained by taking this fact into consideration that this deformity causes some secondary changes in lower limb which result in an internal rotation in Tibia and a change in the ankle position when it has to tolerate the body weight. As previously mentioned, there was no significant difference between normal and genu varum groups as regards to the amount and onset of the muscular activity of the gastrocnemius, Rectus femoris and Gluteus medius in dominant and non-dominant legs. It seems that there is no difference between the muscular function of the dominant and non-dominant legs among people who rely on both legs while doing physical activities. More significant difference might be observed among those athletes who have to depend on one leg more to perform the intended physical activity (39). When it comes to walking, a foot touches the ground and the produced shock is transferred to the lower limb, in case of knee varus, this shock will result in improper force imposition. If there is no suitable contraction in the amount and the time of activity, Ground reaction force will impose a lot of pressure on different parts on all planes which can increase the compressive forces in Compartments and joint, this, in the end will cause many damages; therefore, all biomechanical changes caused by knee varus or compensatory disorders such as; ankle pronation, Coxa valga can affect the a, mechanical efficiency of muscles, sensory feedback and navigation. These effects will respectively bring about some changes in muscular function which will have destructive effects in the future, so the difference observed in the activity of the Gluteus medius muscle can be considered as a response to these changes.

Conclusion

By taking the results of the current study into account it can be concluded that Gluteus medius muscle is more active among individuals with genu varum deformity. Considering the fact that the operating angle of Gluteus medius muscle anatomically is located on the frontal plane, people with genu varum deformity maintain the stability on frontal plane to keep the center of gravity around the supporting surface by increasing the Gluteus medius muscle through an adduction torque. This increasing activity can be the reason for some joint related diseases like thigh Osteoarthritis in a long turn due to the increase in the compressive forces and articular loads; consequently it is highly recommended that people with genu varum deformity perform reformative exercises to decrease the activity of the Gluteus medius muscle which will result in the improvement in the muscular function and damage prevention. Additionally, to be able to generalize the findings of the current study to a wider range of groups, the present study can be conducted on larger sample with wider age range.

Acknowledgments:
The current article is based on the parts of the thesis written by Hossein Tajdini Kakavandi under the supervision of Dr. Sadeghi in biomechanical department of Kharazmi university. Hereby, we would like to thank all those who help us in conducting this study.

Conflict of interest:
None

Funding support:
This project had no external funding, and no financial or other relationships pose a conflict of interest

Authors' contributions:
All authors made substantial contributions to conception, design, acquisition, analysis and interpretation of data.

References

1. Neumann DA. Kinesiology of the musculoskeletal system: foundations for rehabilitation: Elsevier Health Sciences; 2013.
2. Sneyers CJL, Lysens R, Feys H, Andries R. Influence of malalignment of feet on the plantar pressure pattern in running. Foot & ankle international. 1995;16(10):624-32.
3. Lusardi MM, Jorge M, Jorge M, CC N. Orthotics and prosthetics in rehabilitation: Elsevier Health Sciences;; 2012.
4. Levangie PK, Norkin CC. Joint structure and function: a comprehensive analysis: FA Davis; 2011.
5. Twomey D, McIntosh A, Simon J, Lowe K, Wolf S. Kinematic differences between normal and low arched feet in children using the Heidelberg foot measurement method. Gait & posture. 2010;32(1):1-5.
6. Neely FG. Biomechanical risk factors for exercise-related lower limb injuries. Sports medicine. 1998;26(6):395-413.
7. Van Gheluwe B, Kirby KA, Hagman F. Effects of simulated genu valgum and genu varum on ground reaction forces and subtalar joint function during gait. Journal of the American Podiatric Medical Association. 2005;95(6):531-41.
8. Marks R, Percy J, Semple J, Kumar S. Quadriceps femoris activation changes in genu varum: a possible biomechanical factor in the pathogenesis of osteoarthrosis. Journal of theoretical biology. 1994;170(3):283-9.
9. Stief F, Böhm H, Schwirtz A, Dussa CU, Döderlein L. Dynamic loading of the knee and hip joint and compensatory strategies in children and adolescents with varus malalignment. Gait & posture. 2011;33(3):490-5.
10. Ramsey DK, Snyder-Mackler L, Lewek M, Newcomb W, Rudolph KS. Effect of anatomic realignment on muscle function during gait in patients with medial compartment knee osteoarthritis. Arthritis Care & Research. 2007;57(3):389-97.
11. Goldberg EJ, Neptune RR. Compensatory strategies during normal walking in response to muscle weakness and increased hip joint stiffness. Gait & posture. 2007;25(3):360-7.
12. Silvers HJ, Mandelbaum BR. ACL injury prevention in the athlete. Sport-Orthopädie-Sport-Traumatologie-Sports Orthopaedics and Traumatology. 2011;27(1):18-26.
13. Borghuis J, Hof AL, Lemmink KA. The importance of sensory-motor control in providing core stability. Sports medicine. 2008;38(11):893-916.
14. Kibler WB, Press J, Sciascia A. The role of core stability in athletic function. Sports medicine. 2006;36(3):189-98.
15. Baratta R, Solomonow M, Zhou B, Letson D, Chuinard R, D'ambrosia R. Muscular coactivation: the role of the antagonist musculature in maintaining knee stability. The American journal of sports medicine. 1988;16(2):113-22.
16. Hewett T, Zazulak B, Myer G, Ford K. A review of electromyographic activation levels, timing differences, and increased anterior cruciate ligament injury incidence in female athletes. British journal of sports medicine. 2005;39(6):347-50.
17. Namavarian N, Rezasoltani A, Rekabizadeh M. A study on the function of the knee muscles in genu varum and genu valgum. Journal of Modern Rehabilitation. 2014;8(3):1-9.
18. Palastanga N, Field D, Soames R. Anatomy and human movement: structure and function: Elsevier Health Sciences; 2006.
19. Murley GS, Landorf KB, Menz HB, Bird AR. Effect of foot posture, foot orthoses and footwear on lower limb muscle activity during walking and running: a systematic review. Gait & posture. 2009;29(2):172-87.
20. Park S, Chung J-S, Kong Y-S, Ko Y-M, Park J-W. Differences in onset time between the vastus medialis and lateralis during stair stepping in individuals with genu varum or valgum. Journal of physical therapy science. 2015;27(9):2727-30.

21. Riemann BL, Lephart SM. The sensorimotor system, part I: the physiologic basis of functional joint stability. Journal of athletic training. 2002;37(1):71.
22. Patrek MF, Kernozek TW, Willson JD, Wright GA, Doberstein ST. Hip-abductor fatigue and single-leg landing mechanics in women athletes. Journal of athletic training. 2011;46(1):31-42.
23. Russell KA, Palmieri RM, Zinder SM, Ingersoll CD. Sex differences in valgus knee angle during a single-leg drop jump. Journal of athletic training. 2006;41(2):166.
24. Cowan SM, Bennell KL, Hodges PW, Crossley KM, McConnell J. Delayed onset of electromyographic activity of vastus medialis obliquus relative to vastus lateralis in subjects with patellofemoral pain syndrome. Archives of Physical Medicine and Rehabilitation. 2001;82(2):183-9.
25. Hinman RS, Bennell KL, Metcalf BR, Crossley KM. Delayed onset of quadriceps activity and altered knee joint kinematics during stair stepping in individuals with knee osteoarthritis. Archives of Physical Medicine and Rehabilitation. 2002;83(8):1080-6.
26. Park S, Kong Y-S, Ko Y-M, Jang G-U, Park J-W. Differences in onset timing between the vastus medialis and lateralis during concentric knee contraction in individuals with genu varum or valgum. Journal of physical therapy science. 2015;27(4):1207-10.
27. Javdaneh N, Minoonejad H, Shirzad E, Javdaneh N. The investigation of the muscle timing of anterior cruciate ligament agonist and antagonist muscles in athletes with hyper pronated feet. 2016.
28. Beckman SM, Buchanan TS. Ankle inversion injury and hypermobility: effect on hip and ankle muscle electromyography onset latency. Archives of Physical Medicine and Rehabilitation. 1995;76(12):1138-43.
29. Arjunan SP, Kumar DK. Age-associated changes in muscle activity during isometric contraction. Muscle & nerve. 2013;47(4):545-9.
30. Barati AH. The Effect of Various Standing Positions in Muscles Activity between Healthy Young Men and those with Genu Varum. Journal of Sport Biomechanics. 2015;1(1):53-61.
31. . Anbarian M, Esmailie H, Hosseini Nejhad SE, Rabiei M, Binabaji H, et al. Comparison of knee joint muscles' activity in subjects with genu varum and the controls during walking and running. Journal of Research in Rehabilitation Sciences. 2012;1(1):298-309.
32. Heiden TL, Lloyd DG, Ackland TR. Knee joint kinematics, kinetics and muscle co-contraction in knee osteoarthritis patient gait. Clinical Biomechanics. 2009;24(10):833-41.
33. Mahaki M, Shojaedin S, Memar R, Khaleghinazeji M. Comparison of electromyography activity of leg muscles and maximum vertical ground reaction forces in the single leg landing between patients with genu varum and normal men. Sport Medicine. 2013;4(9):87-106.
34. Musavi SK, Shojaedin SS, R M. Comparison of maximum vertical ground reaction forces and electromyography activity of leg muscles in the single leg landing between patients with genu varum and normal men of different heights. Sport Medicine. 2012;2(6):167-86.
35. Jacobs CA, Uhl TL, Mattacola CG, Shapiro R, Rayens WS. Hip abductor function and lower extremity landing kinematics: sex differences. Journal of athletic training. 2007;42(1):76.
36. Sims K, Richardson C, Brauer S. Investigation of hip abductor activation in subjects with clinical unilateral hip osteoarthritis. Annals of the rheumatic diseases. 2002;61(8):687-92.
37. Junge A, Dvorak J. Soccer injuries. Sports medicine. 2004;34(13):929-38.
38. Tsakoniti AE, Stoupis CA, Athanasopoulos SI. Quadriceps cross-sectional area changes in young healthy men with different magnitude of Q angle. Journal of applied physiology. 2008;105(3):800-4.
39. Mann RA, A H. Biomechanics of the foot and ankle. Surgery of the foot and ankle. 6 ed: Louis: Mosby; 1993.