Comparison of Symmetry of Plantar Pressure Distribution in Adolescent's Female with Selected Knee Abnormalities during Walking on Slope

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Abstract

Introduction: The plantar pressure acts between the foot and the support surface during everyday locomotor activity. Information derived from plantar pressure distribution symmetry is to be important in gait and posture researches for diagnosing lower limb problems, footwear design, injury prevention, and other applications. Hence, this paper aimed to evaluate plantar pressure distribution symmetry in adolescent girls with genu varum, genu valgum, and healthy knees. **Materials and Methods**: In this quasi-experimental study, 45 adolescent females with genu valgum (n=15), genu varum (n=15), and healthy knees (n=15) in the age ranging from 14 to 17 years, who were selected after an invitation and diagnosis by an orthopedic doctor or a specialist, participated. The plantar pressure values were examined in 10 anatomical areas of plantar pressure on 0, and ±10% slopes in the stance phase of gait. Two-way analysis of variance with repeated measures was used for statistical analysis in significance level of 0.05. **Results**: No significant differences were observed in the symmetry variables of plantar pressure distribution among the groups. The maximum plantar pressure on the 1thmetatarsus had better symmetry in the slope of 10% for genu varum, -10% for genu valgum, and level zero for the healthy group. **Conclusion**: The results showed that genu varum and genu valgum abnormalities affect the symmetry indices of plantar pressure distribution in adolescent girls; Also, people with knee deformity had better symmetry at a ±10% slope, which can suggest correcting the deformation of adolescent girls. Therefore, the slope ±10% can suggest improving the plantar pressure distribution pattern in adolescent girls with genu varum and genu valgum knees.

Keywords: Gait; Knee Misalignment; Plantar Pressure Distribution; Slope; Symmetry

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Introduction

Gait on slopes is an inevitable part of daily activities, and it applies rehabilitation exercises with this approach (1). The knee joint is the most important that causes stability and weight endurance, while any abnormality in this joint leads to instability and dysfunction (2, 3). The alignment of the thigh, ankle and foot joints affects the alignment of the knee joint. This interaction results from the location of the knee, which must bear the body's weight. Knee deformity can result from thigh, ankle, and foot malformations, muscle imbalance, or abnormal loads on the knee joint (4). One of the most important and variable structural features of the knee during gait is the increase of valgus and varus knee, which causes deformity in the its skeletal structure named genu varum and genu valgum (5). These anomalies distort the line of gravity relative to the base of support and eventually cause significant changes in individual's balance index. Repeated overuse in genu valgum and genu varum destroys articular cartilage on the medial and lateral of the knee, respectively, and in adulthood, it causes premature osteoarthritis (6). Genu valgum anomalies can also result in the subtalar pronation moment in the stance phase and the subtalar supination moment in the swing phase, as the genu varum causes subtalar pronation moment in both phases. Increasing the pronation and supination moment leads to a change in the gravitational moment and increases the pressure and

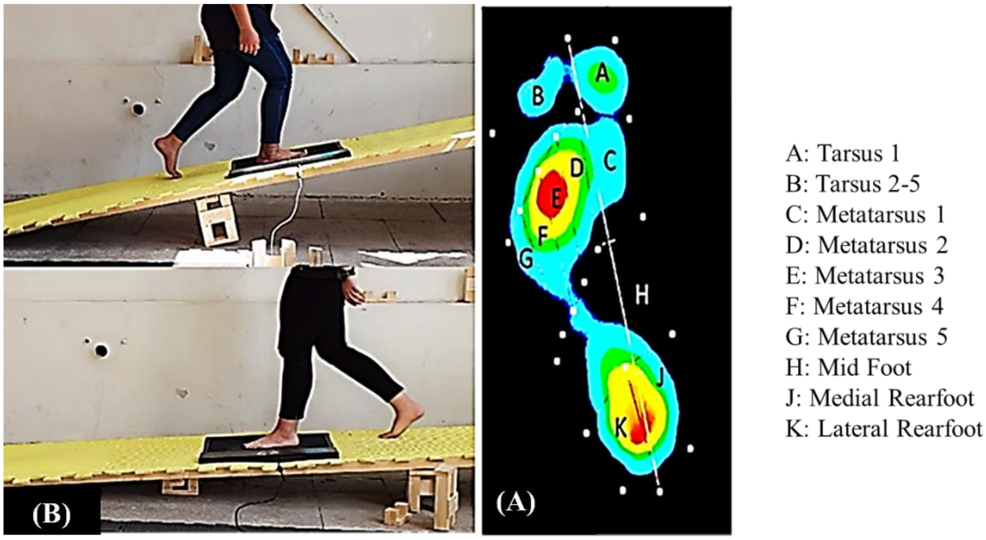


Figure 1. *A*) Division of plantar pressure points; *B*) Evaluate the plantar pressure while gait on a positive and negative slope

mechanical load due to weight endurance and displacement activities (6, 7). This condition may result in excessive muscle energy consumption, fatigue, loss of posture stability when standing on two feet, and disrupting the optimal locomotor pattern in dynamic postures such as gait, thereby leading to long-term injuries (8).

Recently, one area that has attracted the attention of various researchers in medical and sports studies is the symmetry and analysis of the plantar pressure distribution used in quantitative and common method to study the structural and functional anomalies of the foot(4, 9, 10). Symmetry is to be consider as a perfect match between two halves of a shape or object that any deviation from this ideal profile shows asymmetry and may cause deformity, increased stress, non-distribution, absorption of plantar pressures, muscles dysfunction of the lower limbs, and decreased ankle joint stability (11, 12). To our knowledge, no study has evaluated the asymmetry of the plantar pressure distribution in people with knee deformities in slope. However, this issue had addressed in studies of plantar pressure distribution in individuals with lower limb deformities and healthy individuals during gait. Studies have shown that among the plantar pressure parameters, the maximum load on different areas of the foot is measured during the walking and running (13-16). Any changes in the plantar pressure pattern can damage the tissues of the lower limbs and may increase pain in the ankle and knee (13-16). Some studies have demonstrated that the balance function and pressure distribution in the human foot when standing varies according to various factors. For normal people, there is usually more pressure on the forefoot, followed by the rearfoot and then midfoot. So, the highest peak and mean plantar pressure is distributed at the 2nd and 3rd metatarsal in healthy individuals (17, 18), while the asymmetry of the plantar pressure distribution of these individuals in the 3rd tarsal is observed in the lateral rearfoot and midfoot (19-21). In people with genu varum, this asymmetry of the plantar pressure distribution of lateral rear foot and lateral forefoot was accompanied by an increase in the level of pressure and force, while in people with genu valgum, this asymmetry of the plantar pressure distribution was in the lateral forefoot during gait (19, 20).

Considering the importance of the onset of puberty in the adolescence period and the occurrence of musculoskeletal anomalies in this age group, gait on the slope of the path can reduce gait stability and change the variety and complexity of gait, and this is more obvious in descending because some previous studies have shown that this is biomechanically more challenging than surface gait and imposes more needs on the musculoskeletal system to increase the risk of slipping, change the mechanism of force absorption, and reduce the softness of the gait pattern (9-20). Given that non-invasive methods for correcting the knees alignment of children and adolescent are recommended to reduce the load imposed on the knee parts, in the meantime, recommended walking on slopes is a non-invasive solution for people with knee deformities and is considered a preventive agent against premature arthritis in adults. However, the purpose of the present study was to compare the symmetry of plantar pressure distribution in adolescent girls with genu varum, genu valgum, and healthy girls during gait on the slope.

Table1. Mean (SD) of descriptive measures of demographic parameters of the individuals in the study

Group	Age (Year)	High (cm)	Weight (kg)	Distance medial knee & ankle (cm)
Genu varum	16.31 (0.70)	162.93 (5.23)	51.12 (8.97)	4.31(0.71)
Genu valgum	16.23 (0.72)	160.46 (6.14)	61.60 (5.56)	3.90 (0.44)
Healthy	16.40 (0.63)	163.73 (6.08)	58.33(9.23)	0.84 (0.18)
Sig	0.212	0.316	0.339	0.000*

**sig P≤0.05*

Table 2. Mean (SD) of plantar pressure distribution (kg.cm2) and intergroup results of Genu varum, Genu valgum, and healthy knees at levels (0, ±10)

SLOPE GAIT (%)	**0**	**+10**	**-10**							
Variables	**Group**	**Mean (SD)**	**F**	**Sig**	**Mean (SD)**	**F**	**Sig**	**Mean (SD)**	**F**	**Sig**
Symmetry of Tars 1	Genu varum	128.58 (0.03)	2.55	0.092	105.43 (0.26)	1.99	0.151	106.50 (0.22)	1.17	0.321
	Genu valgum	76.67 (0.19)			67.11 (0.06)			69.28 (0.17)		
	Healthy	119.83 (0.24)			98.48 (0.16)			92.41 (0.20)		
Symmetry of Tars 2-5	Genu varum	111.85 (0.29)	2.54	0.092	82.97 (0.26)	0.87	0.427	82.00 (0.08)	0.66	0.520
	Genu valgum	96.53 (0.14)			59.11 (0.01)			64.75 (0.02)		
	Healthy	73.56 (0.02)			79.71 (0.03)			64.84 (0.08)		
Symmetry of Metatarsal 1	Genu varum	80.51 (0.19)	0.31	0.731	103.09 (0.15)	2.36	0.108	90.52 (0.18)	0.65	0.528
	Genu valgum	91.97 (0.27)			64.62 (0.06)			113.47 (0.12)		
	Healthy	100.63 (0.06)			87.36 (0.07)			90.30 (0.17)		
Symmetry of Metatarsal 2	Genu varum	53.55 (0.26)	0.43	0.648	43.79 (0.10)	0.38	0.682	55.73 (0.24)	1.25	0.297
	Genu valgum	39.30 (0.14)			40.36 (0.15)			65.97 (0.06)		
	Healthy	48.76 (0.14)			34.52 (0.09)			44.22 (0.29)		
Symmetry of Metatarsal 3	Genu varum	47.93 (0.32)	2.11	0.135	23.56 (0.09)	0.36	0.697	38.04 (0.27)	0.01	0.987
	Genu valgum	57.94 (0.15)			26.14 (0.28)			39.24 (0.08)		
	Healthy	31.54 (0.25)			31.70 (0.06)			37.44 (0.35)		
Symmetry of Metatarsal 4	Genu varum	43.94 (0.20)	1.91	0.161	48.19 (0.05)	0.25	0.779	43.38 (0.30)	0.61	0.548
	Genu valgum	67.50 (0.15)			48.04 (0.03)			57.91 (0.02)		
	Healthy	40.28 (0.21)			56.78 (0.01)			48.59 (0.24)		
Symmetry of Metatarsal 5	Genu varum	84.85 (0.18)	0.44	0.646	95.38 (0.13)	0.01	0.986	63.61 (0.09)	1.91	0.162
	Genu valgum	98.32 (0.16)			99.09 (0.19)			89.13 (0.29)		
	Healthy	104.32 (0.16)			97.88 (0.22)			108.45 (0.36)		
Symmetry of Midfoot	Genu varum	32.29 (0.44)	1.72	0.193	47.87 (0.01)	0.02	0.978	45.01 (0.03)	0.04	0.955
	Genu valgum	59.57 (0.16)			51.27 (0.08)			47.40 (0.14)		
	Healthy	47.96 (0.12)			51.14 (0.25)			43.48 (0.37)		
Symmetry of Medial Rear foot	Genu varum	84.33 (0.29)	0.16	0.852	59.57 (0.01)	0.77	0.467	78.57 (0.01)	0.41	0.661
	Genu valgum	76.19 (0.03)			62.31 (0.13)			71.24 (0.05)		
	Healthy	74.02 (0.22)			83.12 (0.09)			91.51 (0.37)		
Symmetry of Lateral Rear foot	Genu varum	38.18 (0.08)	1.37	0.267	39.12 (0.05)	0.91	0.408	47.83 (0.06)	0.48	0.619
	Genu valgum	46.91 (0.05)			48.52 (0.10)			47.65 (0.27)		
	Healthy	28.43 (0.04)			103.32 (0.27)			35.58 (0.19)		

**significant differences (P≤0.05)*

Method and Materials

The present study was quasi-experimental. The sample size was calculated 12 people for each group using G-Power software for each group, taking into account the power of 0.80, the significance level of 0.05, and the average effect size of 0.6 (22). Since some individuals may not continue cooperating during performing the study, more sample size (10% to 20%) was considered. The statistical population of the study consisted of adolescent girls in Tehran that 45 people with an age range of 14 to 17 (15 genu varum, 15 genu valgum, and 15 healthy knee as a sample available in the summer of 1400 according to the inclusion criteria included Having genu varum for the genu varum group and genu valgum for the genu valgum group in both feet and no knee injury. Also, a history of lower limb fractures, neuromuscular problems, and no discrepency in in length of lower limbs more than 1 cmwere considered as exclusion criteria. The healthy group also had a normal posture in all parts of their body, and the distance between the two medial epicondyles of the thigh was less than 1 cm. This research had an ethics code No. (IR.SSRI.REC.1400.1182) from the *Institute of Physical Education and Sports Sciences*. All ethical considerations were observed in accordance with the *Helsinki Declaration*.

Table 3. Result spost hoc test of Genu varum, Genu valgum, and healthy knees at levels (0, ±10)

slope			0		+10%		-10%	
Variables	**Group (2)**	**Group (2)**	**Mean (SD)**	**Sig**	**Mean (SD)**	**Sig**	**Mean (SD)**	**Sig**
symmetry of Tars 1	Healthy	Genu varum	8.75 (24.20)	0.931	6.93 (19.87)	0.935	14.08 (23.20)	0.817
		Genu valgum	43.15 (23.68)	0.176	31.36 (19.87)	0.267	23.13 (23.71)	0.597
	Genu varum	Genu valgum	51.90 (25.01)	0.109	38.30 (20.57)	0.164	37.22 (24.51)	0.294
symmetry of Tars 2-5	Healthy	Genu varum	38.28 (17.23)	0.081	3.25 (19.07)	0.984	17.15 (16.73)	0.566
		Genu valgum	22.96 (16.86)	0.371	20.59 (19.07)	0.532	0.09 (17.10)	1.000
	Genu varum	Genu valgum	15.31 (17.81)	0.669	23.85 (19.74)	0.456	17.24 (17.68)	0.597
symmetry of Metatarsal 1	Healthy	Genu varum	20.10 (25.29)	0.708	15.72 (17.18)	0.634	0.22 (22.21)	1.000
		Genu valgum	8.64 (24.75)	0.935	22.74 (17.18)	0.391	22.94 (22.70)	0.569
	Genu varum	Genu valgum	11.46 (26.14)	0.900	38.46 (17.79)	0.091	22.94 (23.46)	0.595
symmetry of Metatarsal 2	Healthy	Genu varum	4.79 (15.08)	0.946	9.27 (10.72)	0.666	11.51 (13.49)	0.673
		Genu valgum	9.46 (14.75)	0.799	5.83 (10.72)	0.850	21.74 (13.79)	0.269
	Genu varum	Genu valgum	14.25 (15.58)	0.635	3.43 (11.10)	0.949	10.23 (14.25)	0.755
symmetry of Metatarsal 3	Healthy	Genu varum	16.39 (13.32)	0.443	8.13 (9.81)	0.688	0.60 (11.00)	0.998
		Genu valgum	24.40 (13.03)	0.120	5.56 (9.81)	0.839	1.79 (11.24)	0.986
	Genu varum	Genu valgum	10.00 (13.77)	0.749	2.57 (10.16)	0.965	1.19 (11.62)	0.994
symmetry of Metatarsal 4	Healthy	Genu varum	3.65 (15.10)	0.968	8.58 (14.26)	0.820	5.20 (12.57)	0.910
		Genu valgum	27.22 (14.77)	0.170	8.74 (14.26)	0.814	9.31 (12.84)	0.750
	Genu varum	Genu valgum	23.56 (15.61)	0.298	0.15 (14.77)	1.000	14.52 (13.28)	0.524
symmetry of Metatarsal 5	Healthy	Genu varum	19.46 (20.95)	0.626	2.50 (21.97)	0.993	44.84 (22.93)	0.138
		Genu valgum	5.99 (20.50)	0.954	1.20 (21.97)	0.998	19.32 (23.48)	0.690
	Genu varum	Genu valgum	13.47 (21.66)	0.809	3.71 (22.74)	0.985	25.52 (24.22)	0.549
symmetry of Midfoot	Healthy	Genu varum	15.56 (14.19)	0.522	3.27 (17.92)	0.982	1.52 (12.64)	0.992
		Genu valgum	11.60 (13.89)	0.683	0.12 (17.92)	1.000	3.91 (12.91)	0.951
	Genu varum	Genu valgum	27.17 (14.67)	0.167	3.39 (18.55)	0.982	2.39 (13.35)	0.982
symmetry of Medial Rear foot	Healthy	Genu varum	10.30 (18.83)	0.848	23.54 (20.88)	0.503	12.94 (22.20)	0.830
		Genu valgum	2.16 (18.42)	0.992	20.80 (20.88)	0.584	20.27 (22.69)	0.648
	Genu varum	Genu valgum	8.13 (19.46)	0.908	2.73 ((21.61)	0.991	7.33 (23.45)	0.948
symmetry of Lateral Rear foot	Healthy	Genu varum	9.74 (11.43)	0.673	16.41 (12.13)	0.375	12.25 (14.32)	0.671
		Genu valgum	18.48 (11.90)	0.237	7.01 (12.13)	0.833	12.07 (14.63)	0.690
	Genu varum	Genu valgum	8.73 (11.82)	0.742	9.39 (12.55)	0.736	0.17 (15.13)	1.000

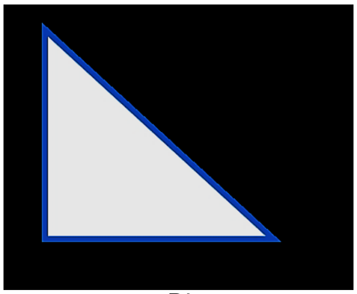
**significant differences (P≤0/05)*

A caliper (CA46150, Alton, China) was used to measure varus and valgus of the knee. For this purpose, participants were asked to stand in an anatomical posture. Then, the distance between the two medial epicondyles of the thigh and the two medial ankles was measured using a caliper, respectively(17). Then, participants with genu varum and genu valgum with a distance of 2 to 5 cm were included in the study (17).

At first, the subjects' height was measured by a stature meter (26 SM) with an accuracy of 0.1 cm and their weight using a digital calibrated scale (Bs101) with 0.5-kilogram accuracy. Then, a plantar pressure scanner (*model PT-Scan4452F100, made in Iran by Payafnavaran Mashhad Co.*) was utilized with accurately pressure measured of 10% with 2288 sensors in the matrix of 52×44 and a sampling frequency of 200 to 400 Hz. The device consists of a plate with a metal frame mounted on the ground and aligned with the surface, where the information of the plantar pressure distribution is recorded by the system using stepping in a dynamic state.

The slope was determined as a percentage based on the ramp slope formula (Formula 1) (23), which was movingly prepared with a length of 3 meters, and the foot pressure device was placed in the center of this slope. It was used positively (ascending) and negatively (descending) to record the plantar pressure distribution in the individuals, once with the right foot and once with the left foot with three repetitions on a flat surface and a slope (10%). At first, the person was asked to perform a 5-meter route with a self-selected speed backward and forward with three repetitions to get acquainted with the foot pressure scanner on a flat surface. For inclined surfaces, we first placed the device in the center of the inclined surface. The person was then asked to practice the 3-meter slope 5 times up and down at her chosen speed (Figure 1B). Finally, the test was performed at zero and ±10% once with the right foot and once with the left foot with 3 repetitions. During the tests, the participant should not makeany other movements, such as talking or looking at the ground, since this may cause errors in recording data and tests. Then, the plantar pressure rate in ten anatomically sensitive areas including the tarsal of the second to fifth toes (Tarsal 2-5), the first to fifth metatarsals (1-5), midfoot and the medial rear foot, and latera rearfoot was examined (Figure 1A). Gait asymmetry index (SI), which is created by comparing the locomotor characteristics of

Formula 1. Calculating the slope percentage:



$$\text{Slope} = \frac{\text{Rise}}{\text{Run}} \times 100$$

Formula 2. Symmetry evaluation between two Legs:

$$\text{SI} = \frac{|X_L - X_R|}{0.5.(X_L - X_R)} .100\%$$

right and left limbs, was calculated from the following equation (Formula 2). The SI factor is a method to assess the percentage difference between kinematic and kinetic parameters for both lower limbs during gait (24). The value of SI=0 indicates perfect symmetry, while SI ≥ 100% indicates its asymmetry.

Mean and Deviation was used to describe the data. Shapiro-Wilk test was utilized to examine the normal distribution of data. The differences in measured variables during gait between the three groups of genu varum, genu valgum, and healthy knees were examined using repeated two-way analysis of variance. If there was a difference, Tukey post hoc test was used to compare the variables within each factor. These analyzes were used with SPSS software version 16 with a significance level of $P<0.05$.

Results

Based on the demographic characteristics, the participants were homogeneous in height, weight and age, and there was a significant difference in all three groups only in the distance between the two medial epicondyles of the knee and the medial ankle of foot (Table 1).

Based on the results of analysis of variance test to compare the symmetry indices of ten areas during gait between three healthy, genu varum and genu valgum groups, no significant difference was observed among groups in the symmetry variables of plantar pressure distribution in 0, ±10 slopes (Table 2).

According to Table 3, no significant differences were seen among the groups on different slopes.

Discussion

The purpose of the current study was to investigate the symmetry of plantar pressure distribution of adolescent girls with genu varum, genu valgum, and healthy knees while walking on a slope. The results indicated no significant difference among groups in the symmetry variables of the plantar pressure distribution in the zero, ±10 slopes. Also, the results showed that the asymmetry in the right and left legs of the individuals can affect causing knee abnormalities. The genu varum group had more asymmetry in all three levels in the medial part of the forefoot and Genu valgum group in the 5th tarsus in 0 and +10% slope and the 1st metatarsus in -10% slope, and in metatarsus 1 at -10% slope, they had high asymmetry. Also, the healthy showed better symmetry in the 2nd and 3rd metatarsals and the lateral part of the heel in all three slope levels, but the 1st tarsal and the 5th metatarsal had high asymmetry.

A review of studies conducted by some researchers in plantar pressure distribution symmetry shows that the posture in certain conditions, *e.g.* The occurrence of anomalies, muscle weakness, neuromuscular disorders, and length differences in the longitudinal structure of the bone has a systematic tendency towards a specific limb, and this may cause asymmetry and secondary problems in other parts of the body (3, 15, 25). Farjad Pezeshk *et.al* (15) after examining the symmetry of plantar pressure distribution and vertical ground reaction force in dominant and non-dominant limbs of healthy individual, found that there was no significant difference in the pattern of dominant and non-dominant plantar pressure distribution which is consistent with the results of the present study. Jang *et.al* (26), after examining the upward and downward plantar pressure distribution according to the ankle angle in healthy individuals, discovered that the 5° ankle angle increased the high-pressure distribution in the tarsal 2-5, midfoot, and rear foot, 5° and 0° ankle angles caused high-pressure distribution in the tarsus and rearfoot, and 10° ankle angle caused high-pressure distribution in the metatarsal 2-5 and midfoot, which are consistent with some of our research results.

The review of gait-related variables showed that genu varum group in the medial forefoot and the healthy group in the first tarsal had the highest asymmetry in the plantar pressure distribution. Also, the genu valgum group had better symmetry between left and right feet than the other groups, but we observed no significant difference among them. These findings are consistent with the studies of Wafaee(21), Jang (26), Britty (19), Gazovik (27), Uzoyak (28), Boken (29), Sejubert (30), Farjad (15), Jafarnejadgaro (31) and the Memar (32). They believe the highest asymmetry in the plantar pressure distribution was distributed on the tarsus and forefoot in children and adolescents, which increases with age from 14 onwards, especially in girls, and contradicted the studies of Zigziang (20), Britty (19), Mayolas (33). They believed the most asymmetric pressure distribution during gait was distributed on the medial heel foot in children and adolescents. Since we calculated pressure from the division force on the cross-sectional area on which the force is to be applied, the first pressure peak occurs during gait at the rear foot stance phase with the ground when resisting pressure. After the rear foot, the body's weight would transfer from the mid-foot to the forefoot. This weight transfer rapidly occurs and may be one factor reducing the stance surface in the mid-foot, thereby causing a further reduction of pressure in this area than in other areas. Because of the high pressure in the 3rd metatarsus, it may be possible to point out the important role and specialist properties of the metatarsus in transferring body weight. The strong connection of this bone with the mid-foot and its density has created a strong base in the forefoot and can bear more weight and higher pressure than other metatarsals (16). The primary function of the subtalar joint is to absorb the rotation of the lower limb during the stance phase and increase the absorption of shock in this area by performing the pronation movement. Rotating the tibia on the subtalar joint causes the center of pressure to move the lateral foot and leads to increasing and decreasing mechanisms in the moment of the upper joints of the lower limb and changing its muscle activity (5). Changes in foot structures can alter foot function to control posture. The poorer balance of individuals can be attributed to their greater reliance on the subtalar and midtarsal joints .People with knee deformity are more dependent on the plantar flexor muscles as regulators of inversion and eversion of the subtalar and midtarsal joints, while healthy people use the plantar flexor muscles more often in the talocrural joint to maintain balance (34). Probably, one reason for the higher asymmetry during the stance phase of gait is the maximum knee internal rotation moment during the stance phase(35). Knee varus also causes valgus of the forefoot, thereby reducing the cross-sectional area of the tarsal 2-5. The forces and moment in this area increase while the cross-section decreases; therefore, this issue can result in increase in the pressure in this area. Therefore, there are controversial results according to what was mentioned in the symmetry of plantar pressure distribution and diagnostic parameters to evaluate the ankle and knee because the reason for the difference and asymmetry in the two limbs is the e lateral deviation posture of the individual when standing with the tendency to bend forward and backward in terms of daily habits, mechanical changes, neuromuscular problems, body mass index, heart rhythm, respiration or obstruction of vascular circulation in the foot based on the rate of weight distribution in the front and back areas of the foot(36-38). Finally, according to previous studies and results got from the present study, it can state that genu varum group with less pronation and the genu valgum group with more pronation in the subtalar joint at the beginning of the stance phase of gait have an increase in the maximum pressure in the lateral forefoot in genu varum and medial forefoot in genu valgum while no significant difference was observed between people with knee deformity and healthy individuals.

The limitation of the present study was the lack of measurement of the electrical activity of lower limb muscles and kinematic and kinetic measurements of the knee. Proper postures of the limbs allow a person to perform daily activities and sports by spending less energy and applying less pressure and fatigue to the joints and muscles. . In the meantime, adolescents and youngers experience unfavorable alignment of the lower limbs, especially the knees. This problem increases the risk of diseases and problems with the knee, reduce the levels of public health, and increase the cost of treatment. Therefore, a study of low-cost, non-invasive, and simple treatments is the most important in correcting the complications of musculoskeletal deformities. Meanwhile, as the finding of the present showed, gait on the slope can be the safest way can to improve the pressure distribution pattern and gait patterns. Considering the importance of slopes in daily activities and changing gait patterns in case of anomalies and physiological differences between girls and boys, it is recommended evaluating gait biomechanics, how to distribute plantar pressure along with electromyography activity, and effect of the training and correction programs with a slope in the rehabilitation of people with knee disorders.

Conclusion

The current study's findings showed Genu varum and genu valgum anomalies affect the symmetry indices of the plantar pressure distribution in adolescent girls. But no significant differences were seen between the groups on different slopes. However, more studies and scientific documentation are needed to generalize and apply the results. Therefore, the slope can be suggested to improve the plantar pressure distribution pattern in adolescent girls with genu varum and genu valgum knees.

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Conflict of interest

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Authors' contributions

All authors made substantial contributions to the conception, design, analysis, and interpretation of data.

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