Kinetic and Kinematic Variables in Middle-Aged Women with Normal and Genu Varum Knee Angle with Emphasis on Walking and Running Activities

Ali Asghar Norasteh [1], Sara Emami [2*], Ali Shamsi Majelan [3]

1. PhD, Faculty of Physical Education, University of Guilan, Rasht, Iran.
2. Msc, Faculty of physical education, University of Guilan, Rasht, Iran.
3. PhD, Faculty of physical education, University of Guilan, Rasht, Iran.

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A B S T R A C T

Purpose: The purpose of this study is to examine the differences of kinetic and kinematic variables in middle-aged women with genu varum and normal knee angle during walking and running.

Methods: Eight middle-aged women with genu varum (age: 45.12 ±12.74 y, height: 160.62 ± 5.26 cm, weight: 71.75 ± 16.38 kg, right tibiofemoral angle: -4 ± 3.9, left tibiofemoral angle: -5.1 ± 4.6) and 7 with normal knee (age: 40.71 ± 11.32 y, height: 157.85 ± 5.01 cm, weight: 71.71 ± 14.00 kg, right tibiofemoral angle: 7.2 ± 2.1, left tibiofemoral angle: 7.8 ± 1.8) volunteered to participate in this study. We measured knee angle in frontal plane based on anatomical axis of femur and tibia by goniometer. This factor was labeled as tibiofemoral angle.

Results: Participants walked a 7-m pathway 6 times with self-selected speed, then they ran the same route 3 times. Independent t tests were used to determine statistical differences. Significance level was $P < 0.05$. The results showed that there was no significant difference between the groups in walking with self-selected speed regarding knee normalized ground reaction force, in medial-lateral and vertical plane, but this variable was significantly greater in anterior-posterior plane among normal knee group ($P < 0.05$). There was also no significant difference in medial-lateral plane in normalized ground reaction force between the groups while they ran. However, this variable in both vertical and anterior-posterior planes was significantly greater in normal knee group ($P < 0.05$).

Conclusion: The results did not show any difference between the groups in angular velocity of knee joint in sagittal plane during swing phase under two situations. According to the findings, the genu varum in dynamic activities such as walking and running is more related to kinetic variables like ground reaction force. These effects are not limited to the frontal plane, however, this variable in vertical and anterior-posterior planes is significantly lower in genu varum knee angle group.

Keywords:
Middle-Aged Women, Genu Varum Knee, Kinetic, Kinematic, Walking and Running

1. Introduction

Moving is considered a basic necessity for human independency. It appears in two different forms during lifetime. Walking is an appropriate way to pass short distances [24], while running is a better way to travel longer ones. During recent two decades, running has changed to one of the most popular activities and researches interested in the mechanism of running and walking have been in-

* Corresponding Author:
Sara Emami, MSc
Address: Faculty of Physical Education, University of Guilan, Rasht, Iran.
Phone: +98 (933)2673097
Email: semamia86@yahoo.com

creased. Walking and running have continuous cycles in which, different joints of body are changing with distinct kinetics and kinematic patterns and angles. Speed is an important variable that its change during walking and running affects lower organs' kinetic and kinematic. These effects have been investigated in many researches [2, 7] such as Queen and colleagues work (2006) on the importance of standardizing the speed of running and its effects on the lower back's kinetic and kinematic [27].

Stoquart and colleagues (2008) have also studied the effects of speed on kinetic and kinematic during walking on the treadmill [32]. Walking and running are affected by different factors such as runner's shoes [37], clothes, traumas, age [2, 7, 25], and the speed of the activity [2, 7]. Also some studies have investigated the effect of changes in different organs alignment on walking and running pattern [5, 15, 31, 34]. Meanwhile, some studies have discussed that joints alignment as a potential biomechanical endangering factor has an important role in producing and developing osteoarthritis [4]. Many studies on walking claim that having anomaly in femur and knee can cause malfunctions in walking among elderly people [15].

Stief and colleagues (2011) have extended this issue to the youth. They have declared that anomalies in the lower organs' frontal plane in youth endanger osteoarthritis development in their knees [31]. In addition, the developed anomalies in genu varum may cause arthritis based on its excessive pressure on medial compartment. Therefore, studies related to knee joint alignment are very significant. The study of genu varum trauma needs more consideration based on its prevalence [29]. Some researches show that there are some obvious changes in kinetic and kinematic of dynamic activities such as walking and running following the genu varum. However, these studies have a particular focus on walking [31, 34]. Regarding the ground reaction force, which is 2.8 to 3 times more than body weigh in running [2], this study tries to investigate kinetic and kinematic variables of walking and running among middle-aged women.

2. Materials & Methods

This study is a semi-testimonial case study research. Statistical population included middle-aged women who lived in Rasht, Iran. We selected 10 women with genu varum based on random sampling method and volunteering. According to the inclusion criteria, the researchers defined 4 conditions, which make samples inappropriate for the test group: 1) history of tendons and meniscus knee injury, 2) history of severe damage in knee since past 6 months, 3) feeling pain in muscular-skeleton system during the research, and 4) having other anomalies in lower back such as retreated knee, femoral anteversion, and tibia spiral.

After selecting 8 persons in genu varum group, 7 persons were selected with normal knee with similar height and weight as per control group. All the procedures were explained verbally to the participants before the study, and all of them signed a written consent form. Personal information was recorded in some other forms. Participants' height was recorded with a stadiometer, body weight also measured with Camry bascule (Germany made with accuracy of 0.1 cm in 1 kilogram). Lower back's length and the width of knee and leg wrist were also measured to enter in the motion analysis software. In lower back's measurement, we recorded the distance between the most swollen part of the greater trochanter and the ground via tape meter.

In addition, we recorded the distance between lateral and medial epicondyle of femur, and the distance between medial and lateral ankle by Collis to record the knee width and wrist, respectively. The knee angle in frontal plane was recorded based on leg anatomical axes and big tibia, which measured by goniometer and labeled as tibiofemoral angel [10, 30]. We also measured and controlled two other structural criteria in the lower back: femur anteversion and tibial torsion [29].

Kinetic data were collected by force plate device (A 9286 Kistler Co, Swiss made), with 60 Hz frequency, and kinematic data were gathered by motion analysis device (460 Vaikom Co, British made) and analysed Vaikom Workstation software with 120 Hz sampling frequency. Camera static and dynamic calibration process and the test space definition were operating few minutes before each participant. Anthropometric tests, including height, weight, lower back's length, wrist width, knee width, femur anteversion, and tibia spiral were measured separately. In the next stage, participants wore their sport suits and warmed up their bodies with 10-15 minutes extension exercises and slow walking. Each participant traveled a 9-m path 10 times in order to register her preferential walking speed at first.

In doing so, we determined each person's required time to travel this distance, the number of steps, and the preferential walking speed. [16]. Using metronome to adjust their speed, researchers asked participants to walk with their preferential speed. They also jogged with a normal speed. Sixteen markers were attached to their lower back. They connected to anterior superior iliac spine

Table 1. Participant's personal traits (Mean ± SD).

	Genu varum knee (8 persons)	Normal knee (7 persons)	T	Sig.
Age (y)	45.12 ± 12.74	40.71 ± 11.32	-0.704	0.494
Weight (kg)	71.75 ± 16.38	71.71 ± 14.00	-0.005	0.996
Height (cm)	160.62 ± 5.26	157.85 ± 5.01	-1.039	0.318
Right tibiofemoral angle (Grade)	-3.9 ± 4	7.2 ± 2.1	-0.066	0.930
Left tibiofemoral angle (Grade)	-4.6 ± 5.1	1.8 ± 7.8	-0.072	0.994
Preferential speed (m/s)	72.79 ± 15.13	79.43 ± 8.36	1.029	0.322
Lower back length	4.23 ± 82.75	81.71 ± 4.88	-0.44	0.667
Knee width	111.90 ± 2.51	11.10 ± 1.78	-0.70	0.496
Leg wrist width	6.62 ± 0.45	6.97 ± 0.98	0.89	0.388

Normal Data distribution investigated Kolmogorov-Simonov test

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landmarks (ASIS), posterior superior iliac spine (PSIS), femur, knee, stalk, external ankle, talon, and second metatarsal.

Each marker was labeled separately when motion analysis device got ready to use and the participant declared her readiness for static test. Then we performed dynamic tests as participant walked with her preferential speed until her right foot touched force plate 3 times. The same procedures applied for the running part. We considered a 2-min break after each run in order to prevent fatigue. In the next level, the kinetic and kinematic data were edited. Then, final variables were determined through motion analysis device software.

Dominant leg joint angle was calculated during toe off and in, through motion analysis device and Workstation software based on degree unit [67]. The joint angle

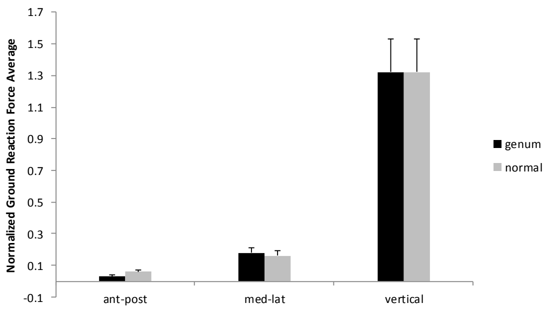

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Figure 1. The normalized ground reaction force average to the body weight in preferential speed.

* Significant difference.

motion calculated through Microsoft Excel software by time/angle (Radian) changes. Also the average of ground reaction force was recorded in these three directions when foot touched the ground: anterior-posterior, medial-lateral, and vertical planes in Newton [31]. Data were analyzed by SPSS software at $P < 0.05$ significance level.

3. Results

Independent t test indicated that there was no significant difference between two groups regarding medial-lateral and vertical planes when they walk with their preferential speed. The anterior-posterior plane of ground reaction force was significantly higher in people with normal knee.

Independent t test demonstrated that there was no significant difference between two groups regarding ground reaction force of medial-lateral plane when they ran. However, in the anterior- posterior and vertical planes, the ground reaction force was significantly higher in people with normal knee in both groups.

The difference between knee angle joint in walking with preferential speed was examined in women with genu varum and normal knee during toe off and while talon contacts with the ground at frontal and sagittal planes. There was no significant difference in frontal and sagittal planes between two groups while talon contacts with the ground and toe off. T test demonstrated that knee angle at frontal plane was significantly different in toe off when the group members ran. However, the dif-

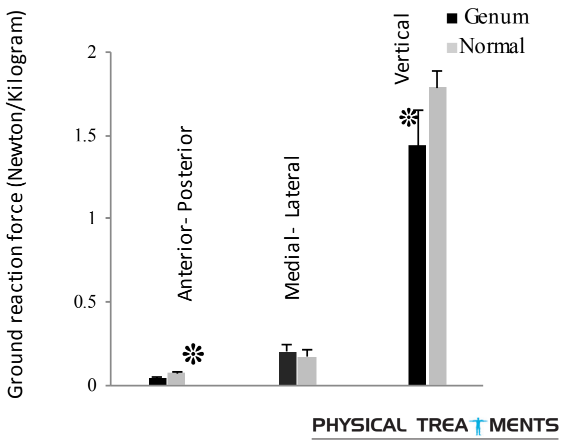

Figure 2. The normalized ground reaction force average to body weight in running.

* Significant difference.

ference of knee angle at sagittal plane was not significant between two groups. T test also indicated that there was a significant difference in frontal plane of knee angle between two groups in running. However, the knee angle difference in sagittal plane was not significant. In both frontal and sagittal plane, the knee angle in genu varum group was to some extend higher than the other group, but it was not statistically significant when the talon contacts the ground.

4. Discussion

In this study, we investigated the difference of kinetic and kinematic variables (ground reaction force, knee joint angle and angular velocity) between women with genu varum and normal knee when they walk and run with their preferential speed. The ratio of normalized ground reaction force average to the body weight was significant in preferential speed and running in anterior-posterior plane (Y). It was also significant in vertical plane (Z) so that, it has a higher degree in participants with normal knee. Researches on people with genu varum declare that knee adduction torque enters some force into the knee joint. The major part of this knee adduction torque is produced by the ground reaction force exerted on knee joint axle while walking. This torque tends to place knee into parenthetical shape [1].

According to lower back's parenthetical shape, which occurs in frontal plane (medial-lateral) in this research, the main pattern of motion and force in walking and running occurs in both anterior-posterior and vertical planes. Therefore, higher reaction force in participants with normal knee seems to be natural. The findings indicated that the knee angle in frontal plane among genu varum group is significantly higher than normal knee group in toe off during running.

In static measurement, genu varum knee is a phenomenon, which observed in frontal plane so that, the tibiofemoral angle increases in negative direction [9]. In the present study, the average tibiofemoral angle in genu varum group were measured as - 5.1± 4.6 for left leg and – 4 ± 3.9 for the right one. Therefore, the genu varum knee can obviously change leg position while running and increase swings in frontal plane. On the other hand, they tend to cross the progress line in stay phase based on their head alignment [33]. The same situation seems to occurr for genu varum knee group while walking and running with the preferential speed in this research.

Table 2. The comparison between angle and angular velocity of knee in two groups.

		Preferential Speed			Running		
		Mean ± SD	T	P	Mean ± SD	T	P
Knee angle during toe off in sagittal plane (degree)	Genu varum	34.31± 12.76	1.237	0.238	30.85 ± 6.02	0.652	0.526
	Normal	42.32 ± 12.			33.80 ± 11.11		
Knee angle during toe off in frontal plane (degree)	Genu varum	-3.66 ± 7.64	-0.345	0.736	-12.14 ± 4.11	2.773	0.016
	Normal	-4.84 ± 5.23			-4.52 ± 6.42		
Knee angle when talon touches the ground in sagittal plane (degree)	Genu varum	5.90 ± 2.20	0.124	0.903	8.49 ± 8.12	0.155-	0.88
	Normal	5.13 ± 2.56			7.88 ± 6.05		
Knee angle when talon touches the ground in frontal plane (degree))	Genu varum	4.49 ± 0.35	0.494-	0.629	-4.10 ± 3.29	0.746	0.470
	Normal	-3.29 ± 0.66			-2.50 ± 4.80		
Knee angular velocity (degree/second)	Genu varum	72.78± 23.3	1.955-	0.072	46.62 ±11.73	0.206-	0.483
	Normal	94.96±20.41			49.37 ±31.00		

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Similarly, Gok and colleagues (2002) who studied kinetic and kinematic traits of walking among people with osteoarthritis, found that maximum angle of varum knee during stay phase and maximum angle of varum knee during swing phase are increasing in frontal plane [14]. Some researchers also mentioned the relationship between speed of steps and knee flexion angle [12]. Lelas and colleagues also found that increase in the speed of steps leads to increase in knee flexion peak in loading response level [20]. In addition, they demonstrated that the maximum angle of knee flexion in swing increases with augmentation in walking speed (2003). These results correspond with Oberg and colleagues [22] and Kirtely and colleagues [19] findings.

The results also indicated that the angle speed of normal knee group was higher than that of the another one while they walk and run with their preferential speed in sagittal plane, however, the difference does not seem to be significant. Knee moves in flexion direction since toe off in swing phase. Then it moves in extension direction until the talon hits. The maximum speed of the knee angle can be determined in the beginning and at the end of the stance phase [11]. In doing so, Foroghi and colleagues reported a significantly higher angular velocity of knee joint in people with osteoarthritis [13].

Angular velocity of knee joint reaches up to 300 degree/second in flexion direction at the beginning, and about 400 degree/second in extension direction in the end [36]. In this study, we considered angular velocity of knee average, which was 72.78 and 94.96 degree/second for genu varum and normal knee group, respectively. This average increases when the speed of walking rises. We could not find any relevant studies about angular velocity of knee between genu varum and normal knee groups, therefore the comparison between current results and the others would not be possible.

In conclusion, this research investigated some differences in kinetic and kinematic parameters of walking and running between middle-aged women with genu varum and normal knee. Results showed that genu varum group could change the quantity of ground reaction force in walking and running so that, the variable in anterior-posterior and vertical planes were significantly lower than that of in normal knee group, which seems to be based on pressing more force in medial-lateral direction among genu varum knees. It is also observed that people with genu varum adopt more adduction angle in knee's frontal while running. In fact, they cross running progress line inside the direction. According to the observed kinetic and kinematic differences in our study, as well as the fact that genu varum causes knee osteoarthritis in long run, this subject obviously needs more consideration.

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