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The Relationship Between the Range of Hip Rotation and the Quadriceps Angle in Subjects With and Without Flat Foot

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Abstract

Background: Alignment of the lower limb is an important factor, influencing balance and gait in kinematics and kinetics, in patients with and without a flat arched foot. Flat arched foot are associated with the range of motion (ROM) of the hip and alignments of the knee joints, is strongly influenced.

Objects: The purpose of this research was to investigate the relationship between hip joint ROM and quadriceps angle (Q-angle), by dividing them into two groups according to the presence or absence of flat feet, using a navicular drop test (NDT) and resting calcaneal stance position (RCSP).

Methods: Forty elderly patients were allocated to the experimental group (flat foot group, n_1=20) or the control group (non-flat group, n_2=20). Universal and digital goniometer, tractograph and tape measure were used to determine the related changes in the hip ROM, Q-angle, NDT and RCSP.

Results: Data were analyzed using the Pearson correlation coefficients. Active internal ROM of the hip joint (right, r=.803, p<.001), (left, r=.951, p<.001) were highly correlated with NDT, and also, was moderately correlated with Q-angle (right, r=.562, p=.019), (left, r=.757, p<.001). Passive internal ROM of the hip joint (right, r=.742, p=.001), (left, r=.922, p<.001) were highly correlated with NDT, and also, was moderately correlated with RCSP (right, r=-.530, p=.029) and with Q-angle (right, r=.710, p=.001), (left, r=.698, p=.002) in the flat foot group. However, no strong correlation among the hip ROM, NDT, RCSP and Q-angle were found in the non-flat foot group.

Conclusion: This research may provide evidence of the correlations between hip internal ROM and flat foot.

Key Words: Alignment; Correlation; Flat foot; Hip rotation; Range of motion.

Introduction

The foot supports body weight and performs various functions for balance and walking (Scott et al, 2007). The plantar arch of the foot is composed of seven ankle bones and is formed by medial and lateral longitudinal archs and transverse arch. The medial longitudinal arch was considered to be the most functionally important structure for shock absorption of the foot (Balen and Helms, 2001), and the collapse of the medial longitudinal arch has a significant impact on the pronation of the subtalar joint (Schulthies and Draper, 1995). In the sitting position, the medial longitudinal arch is not affected by body weight and the talus and navicular bones are in the normal position. However, in the standing posture, the body weight is loaded onto the talonavicular joint, pushing the talus bone downward to make the medial longitudinal arch flat (Jung et al, 2011).

The arches of foot provide functions of force absorption, base of support and acts as a rigid lever during gait propulsion. The medial longitudinal arch,

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lateral longitudinal arch and transverse arch are the 3 arches that compromises arches of foot. Flat foot is a postural deformity relating to the collapse or flattening of the medial longitudinal arch (Harris and Beath, 1948). It is said that a flatfoot can be made by pushing down the talus bone (Neumann, 2011). Arnold et al (2009) suggested that flatfoot may negatively affect muscle activity and alignment of the lower limbs due to an inaccurate proprioceptive sensory input of the soles. Neumann (2011) reported that excessive or overpronation of the midfoot can cause a cascade effect through the ankle, knee and hip via inducing changes of tibial and femoral rotation and altering the normal dynamic control of these joints. These changes, although sometimes subtle, can predispose your knee and hip joints to increased instability or misalignment. In other words, flatfoot can lead to a series of musculoskeletal problems associated with the hip and knee joints can also cause various problems like back pain or abnormal walking by affecting the pelvis and spinal joints (Nakhostin-Roohi et al, 2013).

Hip joints are multiaxial joints that control movement at various angles during walking. Neumann (2011) reported that the motion of the hip joints occurs mainly in the sagittal plane, frontal plane, and horizontal plane combined with pelvic movement. An appropriate femoral anteversion angle is an important factor for the stability of the hip joint for various functional movements like gait (Gulan et al, 2000). The increase of this femoral anteversion angle not only causes genu valgus of the knee joint, but also causes dislocation of the femur bone and external torsion of the tibia (Arnold et al, 1997; Blauth and Tillmann, 1983).

Abnormal alignment of the knee joint can directly lead to serious problems and pain with anatomical changes (McConnell, 1986). The Quadriceps-angle (Q-angle) is the angle between the line connecting the anterior superior iliac spine (ASIS) to the center of the patella and the line connecting the center of the knee to the tibia tuberosity. It has been used as a clinical index to measure the state of the knee joint and lower limb (Woodland and Francis, 1992). Huberti and Hayes (1984) reported that the Q-angle is associated with femoral anteversion, external torsion of tibia, and genu valgus. Shultz et al (2006) reported that the Q-angle and navicular drop were related to each other. Powers (2003) also reported that the pronation of foot may increase internal rotation of femur, internal rotation of tibia and Q-angle.

However, to date, most studies have been reported problems caused by flat foot, but study related the range of motion (ROM) of the hip and the knee joint with flat foot according to the specific physical examination method are still lacking. The aim of this study was to investigate the cross-correlation of ROM of the hip joint and Q-angle, measured with flat foot screening tests, using active and passive ROM test methods in two groups according to the presence or absence of flat foot.

Methods

Subjects

The subjects were 20 flat footed and 20 non-flat footed, elderly subjects (Table 1). Flat foot criteria were defined as those with a navicular drop test (NDT) greater than 1 ㎝ difference value and a resting calcaneal stance position (RCSP) of less than -3° measure value. Flat foot subjects were selected by the two flat foot measurement methods. The

Table 1. General characteristics of subjects (N=40)

Variables	Flat foot group (n_1=20)	Non flat foot group (n_2=20)	t	p
Age (year)	74.76±4.69[a]	72.64±5.25	-1.239	.224
Height (㎝)	163.52±4.57	164.35±7.25	.396	.695
Weight (㎏)	59.58±6.61	62.88±8.68	1.244	.223

[a]mean±standard deviation.

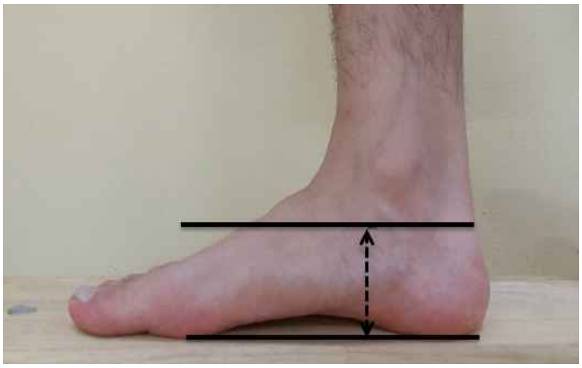

Figure 1. Navicular drop test.

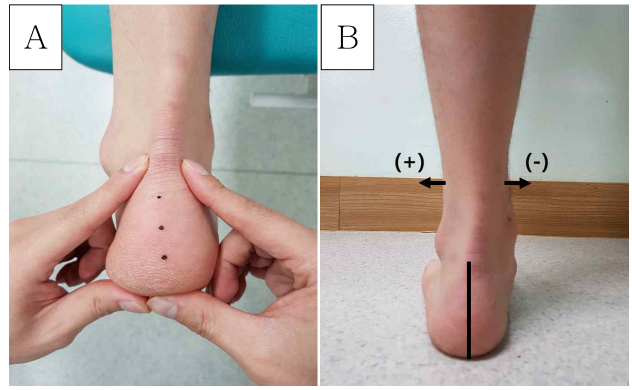

Figure 2. Resting calcaneal stance position (A: Calcaneus palpation, B: Standing position).

general characteristics of the subjects are described in Table 1. The criteria for selection of the subjects were those who had no hip, knee and ankle joint damage within the last 6 months, no congenital anomalies in the lower extremities excluding flat foot, no pain above visual analog scale (VAS) 3 and no sensory deficits. All subjects participated in this study after fully explaining to the subjects the purpose and method of this study, before voluntary consent was obtained, so as to fully understand the experiment contents. This study was approved by the university ethics and institutional review board (approval number: 2017-072).

Instrumentation

Navicular drop test

The subjects were asked to sit on their chairs without bearing weight on both feet and then we measured the vertical distance from the floor to the navicular tuberosity, after identify the subtalar joint as move on both sides to check the neutral position (Song et al, 1996) (Figure 1). And then, it was measured in the same way on both feet in a standing posture, again. The measurements were taken three times in the sitting and standing postures and the mean values were used (Song et al, 1996). All tests were repeatedly measured by the same tester. The measurement order of the subjects was randomly assigned. Brody (1982), who was the first researcher at NDT, claimed that flat bone height was greater than 15 ㎜. However, in the present study, the reliability of the test was found to be higher than 10 ㎜ (ICC=.94) (Lange et al, 2004).

Resting calcaneal stance position

The subject straightened their knees on the bed in prone position and bisected on the posterior surface of the calcaneus, based on the inner and outer boundary of the calcaneus (Vicenzino et al, 2007). We then measured the angle to the ground using a gravity goniometer in a standing position (Menz, 1995). The angle perpendicular to the ground was defined as 0°. When the bisector of the calcaneal is tilted to the medial side of the body, it is indicated by a negative value, and when it is inclined to the lateral side of the body, it is indicated by a positive value (Vicenzino et al, 2007) (Figure 2). A value of RCSP less than −3° is defined as flat foot (Vicenzino et al, 2007). The bisector of the calcaneal was measured with a tractograph (Tractograph, Nova Medical Inc., Burlington, USA). The angle at the time of standing was measured using a vertical goniometer (Digital absolute axis goniometer, Baseline., White Plains, USA). This test is highly reliable, with an error range of less than 1° from the radiation measurement (Kaye and Sorto, 1979).

Range of motion of hip joint

The subjects were placed in the prone position and both knee joints were positioned at the end of the table. ROM of the internal and external rotation was measured using active and passive methods, after flexion of the knee joint at 90°. The reference point for the measurement was placed on the patella of the knee joint, the stationary arm was parallel to the horizontal line and the moving arm was parallel to the tibial bone, using a universal plastic goniometer (plastic goniometer, Baseline Inc., White Plains, USA) (Ellison et al, 1990). The subjects were placed in a prone position, since the measurement method in the prone position was more reliable than the method in the sitting position (Cibulka et al, 1998).

Quadriceps angle

The measurement method of Q-angle is as follows. First, the subject opens his legs 10 ㎝ in the standing posture. Second, the angle between the line connecting the ASIS to the center of the patella and the line connecting the center of the patella to the tibia tuberosity is measured. The reason for taking the measurement in the standing posture is that the contraction of the quadriceps muscle is good, and it is useful to identify problems related to the arrangement of the legs under the weight loading condition (Paulos et al, 1980; Woodland and Francis, 1992). The subject's posture was fixed for accurate measurement; the average value, measured three times repeatedly, was used. Also, the same test was performed, and feedback was provided only for the correct posture.

Statistical analysis

The general characteristics of the subjects were expressed as means and standard deviations using descriptive statistics to compare the flat foot group and the non-flat foot group. Pearson's correlation analysis was used to evaluate the correlation between NDT, RCSP, ROM of the hip joint and Q-angle. The collected data were analyzed using the statistical program SPSS ver. 20.0 (IBM Corps., Armonk, NY, USA). Statistical significance was set at $p<.05$.

Results

Table 2 shows the characteristics of the study subjects as follows. All subjects underwent AROM and PROM of the hip joint, Q-angle of the knee joint, flat foot tests including NDT and RCSP in both sides.

The correlation coefficient between NDT and active internal rotation of the hip joint in the flat foot group was surveyed (right, r=.803, p<.001), (left, r=.951, p<.001). The correlation coefficient between the NDT and the passive internal rotation was showed (right, r=.742, p=.001), (left, r=.922, p<.001), indicating a high correlation between active and passive internal rotation of the hip joint and NDT in the flat foot group.

There was a moderate correlation between NDT and Q-angle (right, r=.624, p=.007), (left, r=.740,

Table 2. Characteristics of the subjects with and without flat foot (N=40)

Variable		Flat foot group (n_1=20)		Non-flat foot group (n_2=20)		Right	Left
		Right	Left	Right	Left	p	p
Internal rotation	AROM[a] (°)	38.64±4.88[b]	33.64±4.35	39.05±10.45	39.64±10.20	.884	.036
	PROM[c] (°)	44.47±4.71	37.45±4.14	45.9±10.62	46.21±9.30	.617	.001
External rotation	AROM (°)	48.76±9.07	48.11±11.27	49.05±7.36	47.05±7.70	.918	.751
	PROM (°)	55.15±6.94	57.03±9.62	56.27±9.22	53.47±8.50	.692	.261
NDT[d] (㎝)		1.2±.25	1.24±.32	.74±.22	.84±.22	<.001	<.001
RCSP[e] (°)		-5.05±1.17	-4.74±.63	1.29±.31	1.41±.24	<.001	<.001
Q-angle[f] (°)		16.64±1.27	16.35±1.36	15.7±2.77	16.76±1.78	.217	.456

[a]active range of motion, [b]mean±standard deviation, [c]passive range of motion, [d]navicular drop test, [e]resting calcaneal stance position, [f]quadriceps angle.

p=.001) in the flat foot group. Correlation coefficients between the passive internal rotation of the hip joint and RCSP was showed (right, r=-.530, p=.029). Correlation coefficients between the RCSP and Q-angle was reported a negative correlation (right, r=-.624, p=.007).

The correlation coefficient between the active internal rotation of the hip joint and Q-angle the was showed (right, r=.562, p=.019), (left, r=.757, p<.001). The correlation coefficient between the passive internal rotation of the hip joint and the Q-angle was showed (right, r=.710, p=.001), (left, r=.698, p=.002), indicating a moderate correlation (Table 3).

However, there was no significant correlation between external rotation of the hip joint and NDT, external rotation of the hip joint and RCSP, and external rotation of the hip joint and Q-angle (Table 3).

The correlation coefficient between the passive internal rotation of the hip joint and RCSP in the non-flat foot group was moderate (left, r=.495, p=.043). However, the others correlation coefficients were not statistically significant (Table 4).

Discussion

Flat foot can lead to various structural and functional problems, ranging from the posture to the gait,

Table 3. Pearson correlations coefficient among ROM of the hip joint, Q-angle, NDT and RCSP in the flat foot group.

		Hip internal rotation				Hip external rotation				Q-angle[c]	
		AROM[a]		PROM[b]		AROM		PROM			
		r	p	r	p	r	p	r	p	r	p
NDT[d]	Rt	.803	<.001*	.742	.001*	-.297	.247	.023	.930	.624	.007*
	Lt	.951	<.001*	.922	<.001*	.301	.240	.259	.316	.740	.001*
RCSP[e]	Rt	-.475	.054	-.530	.029*	.320	.210	-.020	.940	-.624	.007*
	Lt	.099	.706	.067	.798	-.003	.991	.027	.917	.078	.766
Q-angle	Rt	.562	.019*	.710	.001*	-.327	.200	-.073	.779		
	Lt	.757	<.001*	.698	.002*	.374	.139	.390	.122		

[a]active range of motion, [b]passive range of motion, [c]quadriceps angle, [d]navicular drop test, [e]resting calcaneal stance position, *p<.05.

Table 4. Pearson correlations coefficient among ROM of the hip joint, Q-angle, NDT and RCSP in the non-flat foot group.

		Hip internal rotation				Hip external rotation				Q-angle[c]	
		AROM[a]		PROM[b]		AROM		PROM			
		r	p	r	p	r	p	r	p	r	p
NDT[d]	Rt	-.320	.210	-.430	.085	-.163	.533	-.007	.979	.030	.908
	Lt	-.117	.655	-.037	.889	.241	.352	.392	.120	-.081	.757
RCSP[e]	Rt	-.072	.785	.093	.722	-.140	.592	.058	.824	-.183	.483
	Lt	.367	.147	.495	.043*	-.111	.670	.120	.648	.227	.381
Q-angle	Rt	.196	.450	.202	.437	.096	.715	-.156	.550		
	Lt	.417	.096	.364	.151	.219	.398	-.057	.829		

[a]active range of motion, [b]passive range of motion, [c]quadriceps angle, [d]navicular drop test, [e]resting calcaneal stance position, *p<.05.

as well as the lower limbs such as the hip, knee and ankle joints. People with flat foot have been often internal rotation of the hip joint and genu valgus of the knee joint in clinical field, but related work have been limited due to lack of research. The purpose of this study was to compare the relationship between hip joint ROM and Q-angle in subjects with and without flat foot. Unlike similar studies, this study additionally measured both AROM and PROM, and measured on both the right and left sides. And also, NDT and RCSP measurements were used to determine whether the patient had flat foot. As results, internal rotation of the hip joint was found to be highly correlated with the flat foot group. The Q-angle was also moderately correlated. Through this correlation study, the internal rotation of the hip joint is highly related to the genu valgum in the case of a flat foot.

This study emphasizes measurements and procedures as an important study. The flat foot test like NDT, was firstly reported by Brody (1982) as assessing the degree of pronation of the ankle joint and has recently been used to test the extent of flat foot. Until now, radiographs, footprints, and video images have been used for flat foot measurements, but now NDT is to be used a clinically useful (Williams and McClay, 2000). In this study, NDT was used for this reason, and also, it was concluded that the use of RCPS improves the validity of flat foot measurement. Particularly, the reason for the high correlation in NDT seem to be due to measure at two different position considered, in standing with weight bearing and in sitting with non-weight bearing, as well as the high reliability.

The hip joint ROM test was also performed in a prone position to increase the reliability. Cibulka et al (1998) reported that the manual ROM test of the hip joint was more reliable in the prone position than in the sitting position. According to Ellison et al (1990), in the prone position, inter-rater reliability was higher, with ICC=.95 for external rotation and ICC=.96 for internal rotation, which intra-rater reliability was high ICC=.95 for external rotation and ICC=.96 for internal rotation.

The Q-angle measurement can also be used to measure the angle by taking a photograph of the subject's knee joint, but this can lead to many errors (Olerud and Berg, 1984). France and Nester (2001) reported that the Q-angle measurement site may be a error due to the inaccuracies of anatomical palpation. Therefore, the importance of palpation has been described. In this study, direct palpation was performed in the standing position and marked with a pen. According to Piva et al (2006), the goniometer, which is commonly used as a Q-angle measurement tool, has a standard error of 2.4 degrees, so we have tried to reduce the measurement error to below 3 degrees. Horton and Hall (1989) reported that Q-angle measurement was useful in determining the arrangement of the lower limb by measuring under body weight loading rather than lying.

In this study, in the flat foot group, the positive correlation between the active and passive internal rotation of the hip joint and NDT was high value (from r=.74 to r=.92). Similar previous study, although not highly correlated, Souza et al (2010) reported a moderate positive correlation between the internal rotation of the hip joint and the everted ankle joint (r=.56) in the flat foot. And also, correlation coefficients between the internal rotation of the hip joint and the Q-angle was moderate. Han et al (2017) reported that the correlation coefficient between the Q-angle and the valgus of the ankle joint was a high (r=.818). And it is consistent with our study, which the flat foot is also correlated with the valgus knee angle.

The limitations of this study are as follows. First, in a limited area, the size of the sample was limited to the elderly. Second, we separated the flat foot using only clinical evaluation tools. Third, the flat foot could not be distinguished by specific anatomical subdivision. Therefore, in future studies, we would like to propose an investigation of the correlation among various age groups, in specific causes of flat foot, using more objective measure tools.

Conclusion

This study distinguished flat foot through NDT and RCSP in order to investigate the correlation with articulations of the lower limb in flat foot subjects. We also measured the ROM of the hip joint and Q-angle of the flat and non-flat foot groups to determine the correlation. There was a high correlation with hip internal rotation in the flat foot group and a moderate correlation with the flat foot. However, no correlation was observed in the non-flat foot group. Therefore, this study suggests that specific conditions of articulations of the lower limbs, such as hip internal rotation and genu valgum, can be deduced from flat foot subjects. It may be a reference for the measurement and intervention of the range and condition of the articulations of the lower limbs of the flat foot subjects, which is frequently encountered in clinical practice.

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