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Variations in lower limb biomechanical alignments and their association with quadriceps angle between university level male sprinters and sedentary young males

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Abstract
The endeavour of the present study was to see the impact of lower limb biomechanical alignments on the magnitude of Quadriceps angle between university level male sprinters and sedentary young males. 50 male university level sprinters and 50 sedentary young males of age group 18-28 years were included purposively from Odisha for the study. All the selected lower limb biomechanical alignment variables were recorded thrice and median value considered as criterion to eradicate error. Selected variables such as height, weight, Body Mass Index, total leg length, lower leg length, tibiofemoral angle, femoral anteversion, Quadriceps angle, genu recurvatum, tibial torsion, and navicular drop were measured on each subject following standard techniques. The Results showed right and left Quadriceps angles have highly significant positive correlation ($p \leq 0.001$) with right and left femoral anteversion, tibial torsion and navicular drop. On the basis of results of the study, it may be concluded that femoral anteversion, tibial torsion and navicular drop have significant impact on the magnitude of the Quadriceps angle.

Keywords: quadriceps angle, sprinters, femoral anteversion, navicular drop, tibiofemoral angle

1. Introduction

Q-angle is defined as drawing an imaginary line from the anterior superior iliac spine (ASIS) to the centre of the patella and from centre of patella to the tibial tuberosity, delineates the Q-angle (Horton and Hall, 1989 and Livingston, 1997) [2]. The Q-angle normally varies between 6° and 27°, with a mean value of approximately 15° (Aglietti *et al*., 1975) [3].

It has been suggested that biomechanical changes resulting from abnormal alignment may influence joint loads, mechanical efficiency of the muscles, and proprioceptive orientation and feedback from the hip and the knee, resulting in altered neuromuscular function and control of lower extremities (Daneshmandi *et al*., 2009; Shultz *et al*., 2009) [4, 5].

The importance of assessing Q-angle is cited by several studies involving biomechanics, clinics and knee surgery. This angle helps indicating the force vector acting on patella and patellofemoral joint (Hamill *et al*., 1999; Emami *et al*., 2007; Biedert and Warnke, 2001; Livingston and Spaulding, 2002; Woodland and Francis, 1992) [6, 7, 8, 10]. Furthermost it is also used as a criteria to identify candidate for surgery or as predictor of risk of injury (Herrington and Nester, 2004; Livingston and Spaulding, 2002; France and Nester, 2001) [11, 8, 12].

There are more recent indications that the smaller Q-angle in men may be the result of either differences in strength (Byl, Cole and Livingston, 2000) [13] or differences in height (Grelsamer, Dubey and Weinstein, 2005) [14]. Although there may be some differences between the sexes, this Q-angle occurs in both groups as the femoral shaft adducts so the tibia is able to transmit the body's weight perpendicularly to the foot and ground. Therefore, when we stand on one leg, forces are directed toward the medial side of the knee. An excessive Q- angle is referred to as genu valgum, or knock knee. Conversely, if the Q-angle is closer to 0° or the knee joint is convex laterally, the alignment is referred to as genu varum or bowleg. Q-angles have been found to be greater in those individuals reporting patellofemoral pain than in non-painful groups (Näslund *et al*., 2006; Doucette and Goble, 1992) [15].

Regarding the clinical significance of Q-angle, it is observed that changes angle is associated with chondromalacia patella; erosion of patellar cartilage and of the lateral condyle; femoral internal rotation; foot pronation and internal tibial torsion (Biedert and Warnke, 2001) [8].

According to Devan *et al*., 2004, changes in the Q-angle in valgus knee alter the biomechanics and impair muscle levers and consequently, its function. The Q-angle shown an inverse relationship with quadriceps strength, as smallest the angle greater the force reproduced by the quadriceps, which assumes that individuals with above normal Q-angle have lower quadriceps strength and are more subject to diseases of patellofemoral joint (Herrington and Nester, 2004) [11].

The value of Q-angle varies according to the patient's gender, the state of contraction of the quadriceps and the position adopted by the patient, standing or lying down (Biedert and Warnke, 2001) [8]. The rotation of the lower limbs has direct influence on the alignment on the alignment of the knees, altering them according to their position (Livingston and Spaulding, 2002; Livingston and Madingo, 1997) [8, 2].

Any alteration in the alignment that can increases Q-angle is thought to increases the lateral forces on the patella. An increase in this lateral force may increases the compression of the lateral patellar facet against the lateral lip of the femoral sulcus. In the presence of a large enough lateral force, the patella may actually subluxate or dislocate over the femoral sulcus when the quadriceps muscle is activated with an extended knee.

The Q-angle is usually measured with knee at or near full extension because lateral forces on the patella may be problematic in this position. With the knee flexed the patella is set within the femoral sulcus and even a very large force on patella is unlikely to result in dislocation. Furthermost, the Q-angle would diminish with knee flexion as the tibia rotates medially in relation to the femur (Hvid *et al*., 1987) [19].

2. Materials and Methods

2.1 Subjects

This study was based on cross-sectional design in which 50 university level male sprinters and 50 sedentary young males of age group 18-28 years were included to provide a general description and variations of lower limb alignment and their association with Quadriceps angle. The subjects were selected purposively from Odisha. The data was collected under natural environment conditions while maintaining the privacy of the subjects. A written consent was obtained from the subjects prior to data collection.

2.2 Anthropometric Measurements

All the five anthropometric variables, *viz*. height, weight, body mass index, total leg length and lower leg length were measured by the techniques described by Lohman *et al*. 1988. The height was recorded during inspiration using anthropometric rod to nearest 0.1cm. Weight was measured by digital standing scales (Model DS-410, Seiko, Tokyo, Japan) to nearest 0.1 kg. Body mass index (BMI) was calculated using the formula weight (kg)/height^2 (m^2). Total leg length and lower leg length were measured by anthropometric rod in cm.

2.3 Lower Limb Variable Measurements

1. **Quadriceps angle/Q-angle (QA):** Standing Q-angle was measured with the subject in a standing, relaxed position with a standard goniometer (Shultz *et al*., 2008) [21]. Q-angle represents the angle formed by a line from the anterior superior iliac spine to the patella centre and a line from the patella centre to the tibial tuberosity (Livingston and Madingo, 1997) [2].
2. **Tibiofemoral angle (TFA):** It is the angle formed in the frontal plane by the anatomical axes of the femur and tibia (Moreland *et al*., 1987) [22]. With goniometer axis (modified with an extension piece on the stationary arm) over the knee centre (midpoint between the medial and lateral joint line in the frontal plane), the stationary arm was aligned along from the knee centre to a proximal landmark (midpoint between the anterior superior iliac spine and the most proximal aspect of the greater trochanter), and the movable arm was aligned along a line from the knee centre to the distal landmark (midpoint between the medial and lateral malleoli).
3. **Femoral anteversion (FA):** It is measured by Craig's test (Magee; 2008) [23] with the subject prone and the knee flexed to 90°. The examiner palpated the greater trochanter while passively rotating the hip until the most prominent part of the greater trochanter reached its most lateral position. The between true vertical (verified by the bubble level) and the shaft of the tibia was measured using standard goniometer.
4. **Genu recurvatum (GR):** It was measured with the subject in supine and a bolster positioned under the distal tibia. The goniometer axis was positioned over the lateral joint line, the stationary arm aligned with the greater trochanter, and the movable arm aligned with the lateral malleolus. The measurement was recorded while the examiner applying a posteriorly directed force to the anterior knee until passive resistance is achieved (Nguyen *et al*., 2007) [24].
5. **Tibial torsion (TT):** It was measured using a modified technique (Stuberg *et al*., 1991) [25]. With the subject in supine and the knee extended, the subject had rotated the leg until the line between the femoral epicondyles was parallel to the table. A line should be drawn on the bottom of the heel horizontal to the tabletop. A second line is drawn on the bottom of the heel in line with both malleoli. The axis of the goniometer center over the intersection of the two lines and stationary arm align parallel to the tabletop in line with the horizontal line on the heel. Moving arm align along the line connecting the two malleoli. The angle formed by the line bisecting the bimalleolar axis and the horizontal was measured using a standard goniometer.
6. **Navicular drop (ND):** It was measured using a modification of a technique described by Brody (1982) [26]. The navicular tubercle was palpated and marked with the subject in a bilateral stance. Navicular height was measured with a straight edge ruler, with the subject in subtalar joint neutral, the position in which the medial and lateral aspect of the talar head would be equally palpable on both sides. Then the subject was instructed to relax the stance, and the difference in centimetres between the height of navicular in subtalar joint neutral and relaxed stances was recorded.

2.4 Statistical Analysis

Descriptive statistics (mean ± standard deviation) were determined for the directly measured and derived variables. To understand the dimension of relationship of Q-angle as dependent variable with set of anthropometric and lower extremity variables, Karl Pearson's moment correlation coefficients were calculated. All the data were determined using SPSS (Statistical Package for Social Science) version 22.0. A 5% level of probability was used to indicate statistical significance.

3. Results

Table 1 and figure 1 showed the descriptive statistics of demographic variables of university level male sprinters and sedentary young males. However, statistically significant differences ($p \leq 0.001$) were found in age and ($p \leq 0.05$) height between them.

Table 1: Descriptive statistics showing demographic variables of university level male sprinters and sedentary young males

Variables	University Level Male Sprinters (N=50)		Sedentary Young Males (N=50)		t value	p-value
	MEAN	SD	MEAN	SD		
Age (years)	19.26	2.54	22.22	2.54	-5.827	**.000**
Height (cm)	168.88	6.12	171.78	6.43	-2.310	**.023**
Weight (kg)	61.90	9.42	64.30	8.46	-1.341	.183
Bmi (kg/m^2)	21.64	2.58	21.84	3.11	-.338	.736

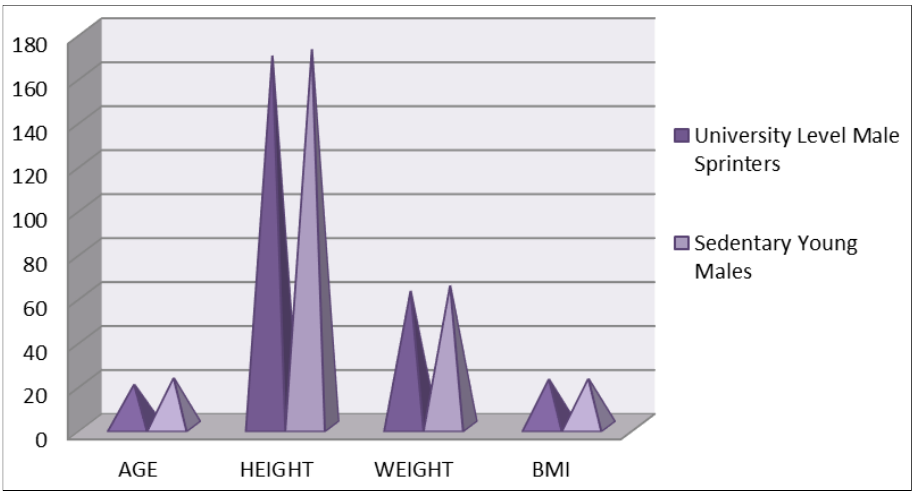

Fig 1: Graphical representation of demographic variables of university level male sprinters and sedentary young males

Table 2 and figure 2 showed the descriptive statistics of Right lower limb anthropometric and biomechanical alignments of university level male sprinters and sedentary young males. However, highly statistically significant differences ($p \leq 0.001$) were found in right tibiofemoral angle, right quadriceps angle, right genu recurvatum and statistically significant difference ($p \leq 0.05$) was seen in right total leg length between them.

Table 2: Descriptive statistics of Right lower limb anthropometric and biomechanical alignments of university level male sprinters and sedentary young males

Variables	University Level Male Sprinters (N=50)		Sedentary Young Males (N=50)		t value	p-value
	MEAN	SD	MEAN	SD		
RT TLL (cm)	89.42	3.67	91.74	5.72	-2.414	**.018**
RT LLL (cm)	40.38	2.42	41.18	3.14	-1.428	.157
RT TFA (degrees)	8.78	1.52	10.94	1.59	-6.968	**.000**
RT FA (degrees)	18.74	2.64	17.96	1.92	1.691	.094
RT QA (degrees)	16.28	2.36	14.52	1.98	4.042	**.000**
RT GR (degrees)	8.40	1.34	7.48	1.25	3.551	**.001**
RT TT (degrees)	17.44	2.25	17.00	2.00	1.033	.304
RT ND (cm)	0.79	0.15	0.81	0.18	-.653	.515

RT TLL- right total leg length, RT LLL- right lower leg length, RT TFA- right tibiofemoral angle, RT FA- right femoral anteversion, RT GR- right genu recurvatum, RT TT- right tibial torsion, RT ND- right navicular drop, RT QA- right Quadriceps angle.

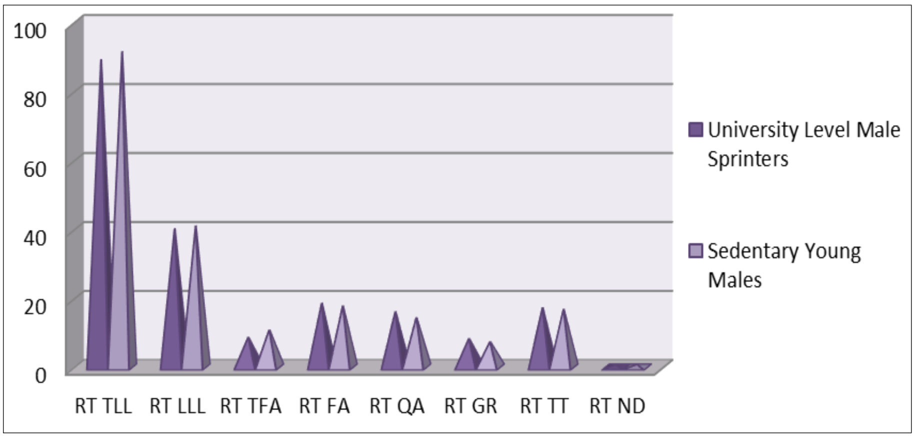

Fig 2: Graphical representation of Right lower limb anthropometric and biomechanical alignments of university level male sprinters and sedentary young males

Table 3 and figure 3 showed the descriptive statistics of Left lower limb anthropometric and biomechanical alignments of university level male sprinters and sedentary young males. However, highly statistically significant differences ($p \leq 0.001$) were found in left tibiofemoral angle, left quadriceps angle and statistically significant differences ($p \leq 0.05$) were seen in left total leg length and left navicular drop between them.

Table 3: Descriptive statistics of Left lower limb anthropometric and biomechanical alignments of university level male sprinters and sedentary young males

Variables	University Level Male Sprinters (N=50)		Sedentary Young Males (N=50)		t value	p-value
	MEAN	SD	MEAN	SD		
LT TLL (cm)	89.44	3.68	91.38	5.75	-2.009	**.047**
LT LLL (cm)	40.34	2.51	40.88	3.05	-.967	.336
LT TFA (cm)	8.08	1.92	10.54	1.42	-7.302	**.000**
LT FA (degrees)	17.78	2.61	17.52	1.92	.568	.571
LT QA (degrees)	15.62	2.04	14.28	2.03	3.292	**.001**
LT GR (degrees)	7.74	1.55	7.38	1.41	1.214	.228
LT TT(degrees)	16.62	1.69	16.86	2.29	-.596	.553
LT ND (cm)	0.71	0.15	0.81	0.18	-3.065	**.003**

LT TLL- left total leg length, LT LLL- left lower leg length, LT TFA- left tibiofemoral angle, LT FA- left femoral anteversion, LT GR- left genu recurvatum, LT TT- left tibial torsion, LT ND- left navicular drop, LT QA- left Quadriceps angle.

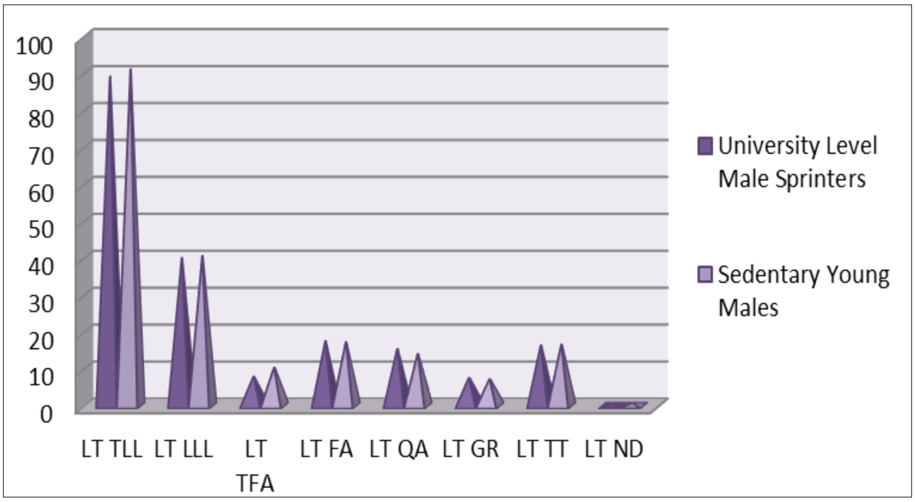

Fig 3: Graphical representation of Left lower limb anthropometric and biomechanical alignments of university level male sprinters and sedentary young males

Table 4 and figure 4 showed the Correlation coefficient of Right Quadriceps angle with Right lower limb alignment variables in university level male sprinters and sedentary young males. Highly statistically significant differences ($p \leq 0.001$) were found in right femoral anteversion, right tibial torsion and right navicular drop.

Table 4: Correlation coefficient of Right Quadriceps angle with Right lower limb alignment variables in university level male sprinters and sedentary young males

Variables	Subjects (n=100)	
	r value	p value
Right total leg length (cm)	.016	.877
Right lower leg length (cm)	.059	.557
Right tibiofemoral angle (degrees)	-.040	.694
Right femoral anteversion (degrees)	.458**	.000
Right genu recurvatum (degrees)	.071	.485
Right tibial torsion (degrees)	.422**	.000
Right navicular drop (cm)	.392**	.000

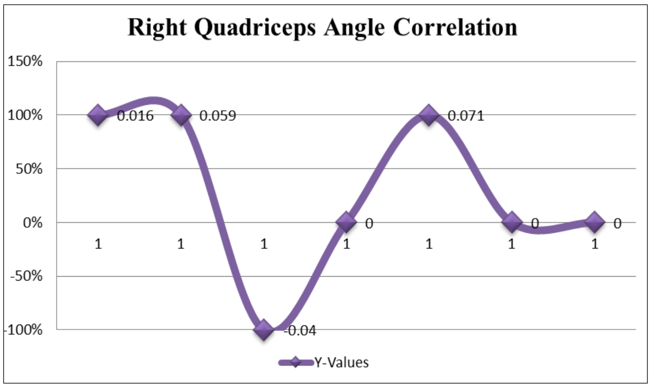

Fig 4: Graphical representation of Correlation coefficient of Right Quadriceps angle with Right lower limb alignment variables in university level male sprinters and sedentary young males

Table 5 and figure 5 showed the Correlation coefficient of Left Quadriceps angle with Left lower limb alignment variables in university level male sprinters and sedentary young males. Highly statistically significant differences (p≤0.001) were found in left femoral anteversion, left tibial torsion and left navicular drop.

Table 5: Correlation coefficient of Left Quadriceps angle with Left lower limb alignment variables in university level male sprinters and sedentary young males

	Subjects (n=100)	
Variables	**r value**	**p value**
Left total leg length (cm)	-.028	.782
Left lower leg length (cm)	.034	.737
Left tibiofemoral angle (degrees)	-.040	.695
Left femoral anteversion (degrees)	.343**	.000
Left genu recurvatum (degrees)	-.023	.821
Left tibial torsion (degrees)	.329**	.001
Left navicular drop (cm)	.353**	.000

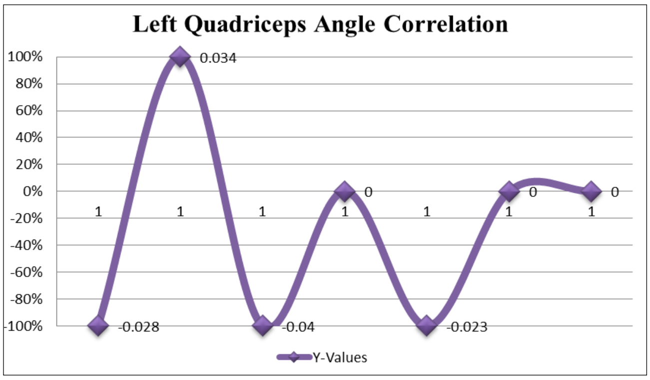

Fig 5: Graphical representation of Correlation coefficient of Left Quadriceps angle with Left lower limb alignment variables in university level male sprinters and sedentary young males

4. Discussion

The anthropometric, anatomical and biomechanical association of lower limb alignments are most frequently studied for diagnosing the malalignments and preventing future injuries which may occur during day to day activities or various athletic events. The outcomes of the study indicate that Quadriceps angle has highly significant positive correlation (*p*≤0.001) with femoral anteversion, tibial torsion and navicular drop bilaterally in university level male sprinters and sedentary young males.

Woodland and Francis, (1992) [10] stated that the Q-angle value can suffer changes due to muscle imbalance, tibial torsion, femoral anteversion and a high or low patella.

A study of Mohanty and Koley, (2018) [27] recorded statistically significant difference (*p*≤0.05) in right tibiofemoral angle and right genu recurvatum. Highly significant positive correlation (*p*≤0.001) of right Q-angle was noted with right femoral anteversion, right tibial torsion and right navicular drop. It may be concluded that femoral anteversion, tibial torsion and navicular drop have significant impact on the magnitude of Quadriceps angle.

Mohanty *et al*., (2019) [28] reported that in state level female basket-ball players, highly significant positive correlation (*p*≤0.001) of right Q-angle found with right femoral anteversion, and right genu recurvatum. Whereas, highly significant positive correlation (*p*≤0.001) of left Q-angle was noted only with left tibiofemoral angle. Significant positive correlation (*p*≤0.05) of left Q-angle was noted with left femoral anteverion, left tibial torsion and left navicular drop; whereas, significant positive correlation (*p*≤0.05) of right Q-angle was noted with right tibiofemoral angle, and right navicular drop.

Daneshmandi *et al*., (2011) [29] reported greater tibiofemoral angle, femoral anteversion and hip internal rotation were significant predictors of greater Q angle (p< 0.05). Greater femoral anteversion, hip internal rotation and tibiofemoral angle results in greater Q angle, with changes in tibiofemoral angle having a substantially greater impact on the magnitude of the Q angle compared with femoral anteversion and hip internal rotation.

5. Conclusion

In human locomotion, lower limb is one that plays most important role. Thus determining the biomechanical factors those influence Quadriceps angle is of considerable importance to minimize potential of injuries. The result of this study would be implicated for clinical diagnosis and treatment of lower limb related complications of athletes and patients. Various corrective exercises programs would be started as preventive measure in case of any malalignment persisting before and can be modified, which would prevent future injuries in sports persons. Moreover, in rehabilitating stage of an injured individual, regular checking of lower limb would provide proper information towards treatment strategies.

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