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Original Research Article

RELATIONSHIP AMONG LOWER EXTREMITY BIOMECHANICAL ALIGNMENT AND BALANCE ABILITIES IN COMMUNITY DWELLING OLDER ADULTS

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ABSTRACT

Background: Balance deficit is one of the leading factors resulting in falls. Relative contribution of sensorimotor factors to balance abilities is well described in the literature. However, the relationship of lower extremity biomechanical alignment with balance abilities in older adults is still unexplored. The cross-sectional study was aimed to examine how changes in lower extremity biomechanical alignment were related to balance abilities in community dwelling older adults.

Materials and Methods: 300 community dwelling older adults (50 – 80 years) were recruited according to specific selection criteria from areas in and around Patiala. Balance abilities were assessed using Multi-item Fullerton Advanced Balance (FAB) scale categorizing subjects into two groups: (i) those having good (n = 125) and (ii) poor balance (n = 175) abilities (cut – off score ≤ 25/40). Static lower extremity biomechanical alignment (Femoral torsion, Q-angle, Tibio-femoral angle, Tibial torsion, Navicular height and Rearfoot angle) was measured clinically.

Discussion and Conclusion: Femoral torsion, Q-angle, Tibio-femoral angle and Tibial torsion showed significant differences between the subjects having good and poor balance abilities. Univariate logistic regression showed significant association of only three factors with balance abilities i.e., Femoral torsion (OR = 0.40, 95% CI = 0.23 - 0.69), Tibio-femoral angle (OR = 0.37, CI = 0.16 – 0.87) and Tibial torsion (OR = 2.07, CI = 1.15 – 3.70). Hence, lower limb biomechanical alignment alteration i.e. increase in Femoral torsion, Tibio- femoral angle and Tibial torsion were significantly associated with balance abilities in older adults.

KEY WORDS: Balance, Lower Limb Alignment, Geriatrics.

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BACKGROUND

"Population aging is a triumph of humanity but also a challenge to society" [1]. According to report by United Nations [2], the major causes of disability and health problems in old age are non-communicable diseases including the "four giants of geriatrics," namely: memory loss, urinary incontinence, depression and falls or immobility, as well as some communicable diseases and injuries. Subsequently, the need of hour is that health care professionals must pay attention to problems occurring within "greying population". Falls are a common and complex geriatric syndrome that cause considerable mortality, morbidity, reduced functioning and premature nursing admission [3,4]. Approxi-

-mately 28-35% of people aged of 65 and over fall each year [5-7] increasing to 32-42% for those over 70 years of age [8-10]. In recent years considerable attention has been paid to the problems of falls.

Over the last two decades, there has been emergence of data regarding identification of falls risk factors, as well as development and introduction of a falls risk screening and assessment instruments [11]. In surveys of both independent-living and community-dwelling seniors, motor control and balance are the top two underlying factors in the occurrence of falls [12] whereas a review of factors cited in related research literature shows the primary contributing factors to falls include balance deficits, gait impairments and muscle weakness [12]. Thus, compromised balance is the top contributor to falls as estimated by health care providers [10,12]. Therefore assessing balance and identification of factors associated with it is utmost important.

Balance in the elderly population is a major concern given the often catastrophic and disabling consequences of fall-related injuries [13]. Maintaining balance and performing functional tasks depend on the interaction of multiple sensory, motor and integrative systems [11] and functioning of all these factors decline with age [14,15]. In previous studies examination of relative contribution of visual impairment [16], sensorimotor factors [17,18], vestibular function [19], cognition [20], lower extremity strength [21], range of motion [22] to balance has been done. However, there are number of factors whose association with balance abilities has not been investigated such as femoral torsion, tibial torsion, tibiofemoral angle, Q- angle etc. Therefore research to identify the lower extremity biomechanical determinants that can be used by the clinicians and the therapists to recognize whether a patient is at risk of having poor balance abilities is of critical importance. For these reasons, the aim of the present study was to determine whether clinical measures of lower limb biomechanical alignment are associated with balance abilities in community dwelling older adults.

MATERIALS AND METHODS

Subjects: For the present cross-sectional study, 300 community dwelling older adults either having good or poor balance abilities were recruited from multiple centers and areas in and around Patiala. Free physiotherapy camps were organized from time to time at various centers like Gurudwara Bahadurgarh, Punjab Pensioner's Assosiation (near Sadbhavna Hospital), Senior Citizen Welfare Association, Model Town, Patiala, Punjabi University's Residential Area and areas surrounding it. Subjects to be included in cohort have well defined inclusion (males and females of age group between 50 to 80 years) and exclusion criteria (any lower limb surgery e.g. TKR, THR; Lower extremity injuries; Grade-4 Osteoarthritis; Neurological Disorders such as polyneuropathy, hemiplegia, Parkinson disease, stroke; Orthostatic Hypotension; History of Syncope; Vestibular Disorders; Illness of Drug or alcohol; Hypertension & Diabetes Mellitus - not under control). Informed consent was obtained from each subject before starting the assessment. Written permission to conduct the research study was obtained from Institutional Ethical Committee, Punjabi University, Patiala.

Lower limb biomechanical alignment measurement: To characterize the static lower limb alignment femoral torsion [23], tibiofemoral angle, Q-angle, tibial torsion, navicular height and rearfoot angle [24] was measured using a standard goniometer. Except for femoral (prone-lying) and tibial torsion (supine-lying), rest all measurements were done with subject in bipedal quiet standing without shoes as shown in Table 1. To reduce measurement errors, all subjects were measured with same goniometer and by the same examiner.

Balance Abilities: Fullerton Advance Balance (FAB) Scale was used to assess balance abilities. FAB include 10 test items which were: stand with feet together, eyes closed; reaching forward to object; turn in full circle; step up and over; tandem walk; stand on one leg; stand on foam, eyes closed; two- footed jump; walk with head turns and reactive postural control. Each test items was scored from 0 to 4, with a score range of 0 to 40 [25]. A cut-off score of 25 out of 40 on FAB scale has determined [26] and subjects who scored 25 or lower on FAB scale were at high risk for falls and hence had poor balance

Table 1: Biomechanical Alignment Measurement Methods.

Alignment Variables	Position	Position	Reference Landmark
Femoral Torsion	Prone Lying	Goniometer	Goniometer Angle formed by the shaft of the tibia relative to the [24]
Tibiofemoral Angle	Standing	Standing	Angle formed by the lines from midpoint between ASIS & greater trochanter and from knee center to distal landmark i.e., midpoint between medial and lateral malleoli [25].
Q-Angle	Standing	Goniometer	Angle formed by the lines from ASIS to patella center and line from patella center to tibial tuberosity [25].
Tibial Torsion	Supine Lying	Goniometer	Angle formed by line bisecting the bimalleolar axis and the true vertical [25].
Navicular Height	Standing	Ruler	Difference between the heights of navicular tuberosity in subtalar joint neutral and relaxed stance [25].
Rearfoot Angle	Standing	Goniometer	Difference between the angle formed by line from mid point of distal one third of lower leg and longitudinal midline through medial & lateral malleolus in subtalar joint neutral and relaxed stance [25].

abilities. Test-retest reliability has been reported as *r* = 0.96, and inter rater reliability in the range of *r* = 0.91-0.95, when the test is administered by trained raters.

Statistical Data Analysis: Data analysis of the experimental data was made possible by means of Statistical Package for Social Sciences (SPSS) 19.0 version. Mean and standard deviation for Age, BMI and frequency distribution for demographic characteristics such as Sex, community and Balance abilities was calculated. The study population was further divided into two groups based on their balance scores in Fullertron's Advanced Balance Scale (FAB). To identify the biomechanical factors affecting balance abilities amongst two different groups unpaired t-test was used. Further univariate logistic regression was used to understand the relationship among balance abilities and identified biomechanical variables.

RESULT

The mean age of study population was 64 ± 9.70 years and mean BMI was 23.87 ± 3.21 kg/m^2 and it comprises of 67.7 percent males and 32.3 percent females. 39 percent subjects belong to urban community, 30 percent from sub – urban and 31 percent from rural areas as shown in Table 2. Out of the total, 125 subjects have good balance abilities and 175 have poor balance abilities based on scoring criteria of FAB scale.

Table 2: Demographic characteristics of study population.

DEMOGRAPHIC CHARACTERISTICS	
AGE(years)	64 (9.70) †
BMI(kg/m^2)	23.87 (3.21) †
SEX	
Male (%)	203 (67.7) ‡
Female (%)	97 (32.3) ‡
COMMUNITY	
Urban (%)	117 (39) ‡
Sub-Urban(%)	90 (30) ‡
Rural (%)	93 (31) ‡
BALANCE ABILITIES	
Good (FAB>25)	125 (41.7) †
Poor (FAB≤25)	175 (58.3) †

† Indicates Mean (Standard Deviation)

‡ Indicates Total number (Percentage)

Lower limb biomechanical alignments were compared between subjects having good and poor balance abilities from age ranging from 50-80 years as shown in Table 3. Comparison of femoral torsion between subjects having good (M = 16.30, SD = 2.46) and poor (M = 17.37, SD = 2.81) balance abilities showed highly significant difference (t = -3.49, p<0.0001). Similarly, comparison of Q-angle also showed highly significant difference (t = -2.96, p<0.0001) between good (M = 14.36, SD = 2.06) and poor (M = 15.02, SD= 1.66) balance groups. Comparison of Tibio-Femoral angle between subjects having good (M =12.76, SD= 1.68) and poor (M= 17.62, SD= 3.61) balance abilities showed highly significant difference (t= -15.57, p< 0.0001). Similarly, highly significant difference (t= -3.90, p<0.0001) was seen for Tibial Torsion in groups having good (M= 15.11, SD= 2.59) and poor (M= 16.34, SD= 2.69) balance abilities whereas there was insignificant difference seen in Navicular Height (t= 1.81, p>0.05) and Rearfoot Angle (t= -1.74, p>0.05) between groups having good and poor balance abilities respectively.

Table 3: Comparison of Lower Limb Biomechanical alignment among 50-80 years with different Balance Abilities.

Biomechanical Alignment	GOOD	POOR	t – value	95% CI	
				LL	UL
FEMORAL TORSION (degrees)	16.30 (2.46)	17.37 (2.81)	-3.49***	-1.67	-0.47
Q ANGLE (degrees)	14.36 (2.06)	15.02 (1.66)	-2.96***	-1.09	-0.22
TIBIO-FEMORAL ANGLE (degrees)	12.76 (1.68)	17.62 (3.61)	-15.57***	-5.47	-4.24
TIBIAL TORSION (degrees)	15.11 (2.69)	16.34 (2.69)	-3.90***	-1.85	-0.61
NAVICULAR HEIGHT (mm)	3.85 (1.12)	3.62 (1.04)	1.81	-0.02	-0.48
REARFOOT ANGLE (degrees)	6.46 (1.38)	6.73 (1.18)	-1.74	-0.56	0.04

*p<0.05, **p<0.01, ***p<0.001

Biomechanical Alignment	Constant	Regression Coefficient (B)	SE	ODDS RATIO (OR)	95% CI FOR OR		P
					UL	LL	
FEMORAL TORSION	-0.094	-0.914	0.279	0.401	0.232	0.693	0.001**
Q ANGLE	-0.246	-0.447	0.298	0.693	0.357	1.146	0.133
TIBIO-FEMORALANGLE	0.575	-0.996	0.435	0.369	0.158	0.866	0.022**
TIBIAL TORSION	-0.478	0.725	0.298	2.065	1.152	3.701	0.015**

Table 4: Univariate Logistic Regression of Biomechanical alignment (Effector/Motor Components) with Balance Abilities as the dependent variable.

*p<0.05, **p<0.01, ***p<0.001

Table 4 showed results of univariate logistic regression of lower limb biomechanical alignment with balance abilities. The logistic regression coefficient was -0.914 for femoral torsion, which showed negative relationship of femoral torsion with balance abilities. The odds ratio corresponding to femoral torsion (95% confidence interval) was 0.40 (0.23 - 0.69, $p < 0.05$). Balance abilities decreased 0.40 times with every one unit increase in femoral torsion. There was negative relationship between tibio-femoral angle and balance abilities and regression coefficient was – 0.99, showing that likelihood of having good balance abilities has decreased as tibio-femoral angle increased. The odds ratio corresponding to tibio-femoral angle (95% confidence interval) was 0.37 (0.16- 0.87, $p < 0.05$).

Subjects having 9-11 degrees of tibio-femoral angle were 0.37 as likely to have good balance abilities than subjects having angle greater than 11 degrees. Regression coefficient for tibial torsion was 0.73 and odds ratio corresponding to tibial torsion (95% confidence interval) was 2.07 (1.15- 3.70, $p < 0.05$) indicating that likelihood of having good balance abilities has decreased 2.07 times with every one unit increase in tibial torsion. Subjects having tibial torsion 10-11 degrees were unlikely to have poor balance abilities. The probability of having good balance abilities has changed little between 11-13 degrees. The change was incremental in the middle portion of graph as tibial torsion of 13 degrees versus 19 degrees will have marked influence on the probability of having poor balance abilities. Subjects having tibial torsion greater than 19 degrees are very likely to have poor balance abilities. A one unit change from 19-22 degrees has little effect on the probability of having poor balance abilities, because every subject having tibial torsion between 19-22 degrees would have poor balance abilities.

DISCUSSION

One of the novel aspects of the present study wasexamination of relationships of biomechanical alignment with balance abilities. Given the potential interdependence of various alignment faults along the lower kinetic chain [27,28] examining only one or limited number of alignment factors will not identify clinical meaningful relationships [27]. This is the first study, to our knowledge that has examined how clinical measures of biomechanical alignment of lower extremity were related to balance abilities in relation with age. Present study has identified femoral torsion, tibiofemoral angle and tibial torsion as significant predictors of balance abilities. These findings were well supported [29] stating that when there is increase or decrease in frontal plane tibiofemoral angulations, the ability to provide dynamic postural stability in both sagittal and frontal planes may be compromised. The probable explanations could be that when measured in a weight-bearing position (as is the case with the current study), increased pelvic tilt has been associated with internal rotation at the hip [27,30]. This associated hip internal rotation could be further related to change in transverse-plane and frontal-plane knee angles orientation of the anatomical landmarks used for these measurements. For example, this resultant hip internal rotation would effectively displace the anatomical axes of the femur into adduction (in relation to pelvis) and the tibia into abduction (in relation to femur), thereby increasing tibiofemoral angle [27]. Abnormal gait patterns resulting from increased hip internal rotation can also indirectly lead to compensations in other parts of the lower extremity, such as a compensatory external rotation of the tibia on the femur [27], which in turn would position the tibial tuberosity more laterally, resulting in an increase in quadriceps angle [27,31-33].

Similarly, evidence suggested that greater femo-

-ral anteversion may alter hip muscle function leading to reduced hip control and increased dynamic lower extremity malalignment during functional activities [27,29]. Using a simulated hip model, an increase in gluteus medius muscle force was necessary to maintain a level pelvis when femur is internally rotated (where the distal attachment site of muscle [greater trochanter] is more anterior, as in case of femoral anteversion) compared to neutral alignment [27]. Decreased, activation of gluteus medius, as measured by surface electromyography amplitude, has been demonstrated in those with increased relative femoral anteversion [27,29]. Collectively, these findings suggest that individuals with increased force production to control the hip and pelvis, yet they demonstrate decreased activation, which together may severely reduce frontal-plane and transverse-plane hip control during functional activities [27] and therefore justifying that increase in femoral torsion would decrease likelihood of having good balance abilities.

Clinical Relevance: The results of the present study have some meaningful implications for the clinicians who work with older adults. Future studies are needed to determine whether interventions such as correcting biomechanical alignments of femoral torsion, tibiofemoral angle and tibial torsion will directly affect balance abilities in relation with aging. Although various studies have shown that older adults showed improvement in balance abilities through improvement in lower extremity strength and power [34] but present study has made clinicians/therapist think beyond them and consider other physiological factors when conducting examination and establishing plan of care for older adults.

Limitations: Limitations of the present study was that the subjects of age greater than 80 years were not included in the study and was limited only to the location of Patiala.

CONCLUSION

Alteration in lower limb biomechanical alignment i.e. increase in Femoral torsion, Tibio- femoral angle and Tibial torsion were significantly associated with balance abilities in community dwelling older adults with age ranging from 50 – 80 years. Clinicians working with older adults should design specific interventions to correct the alterations in lower limb biomechanical alignment. Future studies focusing on role of these interventions on biomechanical alignment and balance abilities should be done.

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Conflicts of interest: None

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