International Journal of Medical and Health Research
www.medicalsciencejournal.com
ISSN: 2454-9142
Received: 20-07-2022, Accepted: 07-08-2022, Published: 22-08-2022
Volume 8, Issue 4, 2022, Page No. 62-70

Association of ankle joint proprioception and foot posture with disability and severity of disease among patients with knee osteoarthritis

Hingarajia Dharti
Sr Lecturer, SPB Physiotherapy College, Surat, Gujarat, India

Abstract
Background and Purpose: Mechanical changes at ankle and subtalar joint complex contribute to altered foot posture in individuals with Knee OA. However, there is a dearth of literature on the role of ankle joint position sense and foot posture on severity of osteoarthritis and functional disability. The primary aim of this study was to know the role of ankle joint position sense and foot posture on severity of knee osteoarthritis and functional disability in patients with Osteoarthritis.
Methodology: The study was performed on 120 subjects aged between 40-70 years of age. The study sample consisted of individuals diagnosed with osteoarthritis of knee joint with Knee pain (VAS ≤ 7/10) for at least 1-month duration. Knee radiographs were graded by an orthopedic surgeon following which subjects were evaluated for FPI 6, ankle JPS using bubble inclinometer and WOMAC scale.
Results: Results of pearson's and spearman's test showed a positive correlation of ankle JPS and FPI with functional disability respectively (r=0.5222, r=0.9644 respectively with p value <0.05) but no significant correlation was found with severity of Knee OA. Also observed was an extremely significant positive correlation between Foot Posture Index (FPI) and ankle Joint Position Sense (JPS) (r=0.6354, p value<0.05).
Conclusion: The present study concludes that altered foot posture and ankle JPS is a contributory factor to functional disability but does not show a significant effect on severity of disease in patients with knee osteoarthritis.

Keywords: ankle joint position sense, foot posture index, functional disability, knee, osteoarthritis

Introduction

According to World Health Organization (WHO), Osteoarthritis (OA) is the second most common musculoskeletal problem in the world population (30%) after back pain (50%) [1]. Osteoarthritis is defined as degenerative, non-inflammatory joint disease characterized by destruction of articular cartilage, with evidence of accompanying peri-articular bone resorption resulting in sub-chondral bone sclerosis and attempted new bone formation in the form of osteophytes [2]. Due to its chronic nature, OA is a leading cause of disability in the elderly. OA is a leading cause of pain and functional disability because of involvement of key joints like tibio-femoral and patello-femoral joint of the knee complex [3]. Out of the two main articulations medial tibio-femoral joint is most commonly affected, which in turn affects the quality of life and function [4]. OA is a common condition with a prevalence of 22% to 39% in India [5, 6].

Farrokhi *et al* (2016) [7] stated that patients with knee OA reported more pain and difficulty compared to the asymptomatic population, with functional activities like prolonged sitting, ascending and descending stairs, walking, squatting, rising from a chair and kneeling [7]. Ultimately these limitations lead to loss of functional independence, decrease in muscle strength, proprioception, balance [8]. Disability can increase because of changes in mechanical alignment of lower extremity which is seen as a result of the ongoing disease process. During standing, in the normally aligned knee, joint reaction forces pass almost equally between medial and lateral tibio-femoral joint [9]. While walking, total knee joint reaction forces increase to three times body weight. During heel strike, point of contact is just lateral to the midline and hence resulting ground reaction force passes medial to knee joint, thereby creating a net varus torque with every step. Hence walking results in increased joint reaction forces on the medial compartment [9]. In response to loading during weight bearing, cartilage in healthy knees demonstrate certain adaptations in morphology and mechanical properties, causing certain regions of the cartilage to accommodate well to loading, while other regions are less well suited to accommodate loading. Alterations in normal knee kinematics, shift loading from those cartilage regions adapted for loading to regions less well suited. This leads to the initiation and progression of degenerative processes consistent with knee OA thus contributing to uni-compartmental medial knee joint arthritis [10].

As the severity of knee OA increases, mechanical alterations in the lower extremity also increase which in turn favours progression of the disease. Apart from the mechanical alterations seen at knee joint, changes may also be present in the entire lower extremity kinetic chain especially at the ankle and foot complex. The foot and ankle complex is multi-functional, being one of the dynamic structures of human skeletal system. There have been

numerous reports indicating effect of foot posture on lower limb injuries. It has been suggested that high arched feet are inflexible while flat feet are more mobile and hence susceptible to high degrees of pronation. This pronated foot posture is a risk for MTSS (Medial Tibial Stress Syndrome) and patello-femoral pain [11] People with medial compartment Knee OA exhibit altered foot kinematics during gait that are indicative of a more everted foot type [12] With progressing disease, medial joint compressive forces increase because of increased medial compartmental pressure. This causes genu varum mal-alignment of knee further contributing to progression of knee OA [13]. This in turn may lead to compensatory changes in the lower limb including ankle-subtalar joint complex. Studies conducted previously have shown that patients with medial compartment knee OA have a more everted calcaneum in the frontal plane and higher scores of FPI (indicating pronated foot posture) [14,15] This pronated foot posture is a contributing factor for impaired balance in normal population [16] and the problems may be magnified in patients with knee OA.

Though studies have claimed that foot posture is affected in patients with knee osteoarthritis, there is less published literature to ascertain the extent to which this altered foot posture can be correlated with progression of disease and result in functional disability. With constantly changing alignment of lower extremity, input from proprioceptors (eg. Knee, ankle) also gets altered which in turn affects ankle Joint Position Sense (JPS) in individuals with knee OA. JPS is a major component of proprioception which plays an important role in co-ordinating and refining motor activity. Previous studies have reported that subjects with OA knee displayed increased postural sway, quadriceps weakness, impairment in knee proprioception and also indicated that those who had greater functional disability had worse knee JPS [17, 18]. Histological studies of OA knee ligaments show decrease in the number of mechanoreceptors which leads to alteration in proprioception [19]. Thus, there were many studies to support the concept of alteration of Knee JPS in patients with knee OA [19, 20, 21] and consequently research was conducted to train and improve knee joint proprioception in OA [22].

Since patients with knee OA have alteration in the alignment of lower limb, mechanical alterations at the ankle joint can be expected. These changes may contribute to alteration in JPS at ankle joint which may be a factor affecting disability and function in knee OA. Additional affection of proprioception at ankle may further impair an individual's ability to perform daily activities which in turn can significantly increase disability. Though alteration of knee proprioception has been described in many studies there is not much published literature to identify changes in JPS at the distal component like ankle in patients with knee OA. In a study conducted in 2012, S.R.S Bagul stated that ankle proprioception was affected in patients with knee OA [23]. However, the extent to which this affection can interfere with day to day activities or how ankle proprioception can be affected with progression of this disease is still unclear.

Hence, the primary objective of this research was to study the relationship of ankle proprioception and foot posture with OA severity [24] and disability [25] in individuals with knee OA.

Methodology

1. **Type of study design:** Analytical, Cross-sectional study.
2. **Duration of study:** 6 months.
3. **Sample size:** 120
4. **Sampling technique:** Convenient sampling
5. **Inclusion Criteria:**

- Males or Females of 40-70 years of age.
- Patients with unilateral symptomatic knee osteoarthritis.
- Subjects having knee pain for more than 1 month.
- Subjects giving their consent to participate.

6. **Exclusion Criteria**

- Rheumatoid arthritis, inflammatory arthropathies, neoplasms.
- Pain score (VAS) of more than 7 on 10.
- Lower limb fracture, knee surgery in past 12 months.
- Intra articular steroid injections into the knee in the past 3 months.
- Congenital deformity of ankle, ankle sprain, ligament insufficiency of ankle or knee.
- Neurologic conditions (hemiplegia, quadriplegia, parkinsons, cerebral palsy, peripheral neuropathy)
- Wheelchair bound.

7. **Study Procedure**

Subjects were screened for Knee OA and participants satisfying the eligibility criteria were included in this study. The purpose of study and study procedure was explained to these individuals. A prior written consent was taken from the participants stating their voluntary participation in this project. Case record sheet which included demographic details of participants was filled. Documentation of their pain on visual analogue scale (VAS), self-reported functional disability (as per WOMAC), assessment of Foot Posture Index, Ankle Joint Position Sense was done. Knee X-rays were checked and then graded by an Orthopaedic surgeon as per Kellgren-Lawrence scale.

8. Outcome Mesures

- **Ankle Joint Position Sense (JPS)**
  JPS was measured using universal goniometer, measured in degrees. Subject was in a high sitting position with thigh fully supported, knee flexed to 90 degree and foot off the ground. Subject was blind folded. Foot was placed off the supporting surface. Foot was positioned in zero degree of inversion, eversion, plantarflexion, dorsiflexion. Therapist brought the patients foot to neutral and then foot was moved to 15° of plantar-flexion. This position was held for 15 seconds and then foot was actively moved into varying degrees of plantar and dorsiflexion and then subject was asked to actively position the foot into 15° of plantar flexion. Before starting the movement, bubble inclinometer was placed on dorsal aspect of foot along third metatarsal. Three readings were taken and difference between initial and final angle was noted and an average absolute error of these three readings was taken for analysis. Reliability of universal goniometer was measured before using it for the study. For assessment of reliability of this instrument a repeated measure was taken after 24 hours to avoid any recall bias.

- **Foot Posture Index (FPI)** [26]
  The FPI is a 6-item foot posture assessment with the subject standing relaxed in a bipedal position. The 6 items of the FPI include talar head palpation, curves above and below the lateral malleoli, calcaneal angle, talonavicular bulge, medial longitudinal arch and forefoot to rear-foot alignment. Each item is scored on a 5-point scale between -2 and +2 and provides a total sum of all items between -12 (highly supinated) and +12 (highly pronated). The total score value then helps to classify the foot type where FPI 0 to 5 indicates normal foot type, +6 to +9 indicates pronated foot, 10+ indicates highly pronated foot whereas -1 to -4 indicates supinated foot, -5 to -12 indicates highly supinated foot. The subject was asked to assume a normal stance position and to march, following which foot posture was observed by the examiner and graded.

- **WOMAC (Western Ontario and McMaster Universities Osteoarthritis index)** [25]
  WOMAC index was developed for individuals with hip and knee OA, however it has been used for other rheumatic conditions (like rheumatoid arthritis, Juvenile arthritis etc.). It is a self-administered questionnaire which includes 24 items divided into 3 subscales (Pain, Stiffness, Physical function) which assesses areas of activity of daily living, functional mobility, Gait, Quality of life. It is quick, easy to administer and takes a time of less than 15 minutes.

- **Kellgren-Lawrence scale measured on radiographs** [27]
  It is the most commonly used radiographic classification system used to classify knee OA in five grades. The classification needs a recent AP /lateral view of knee joint and is most often graded by an orthopedic surgeon.Subject was in a high sitting position with thigh fully supported, knee flexed to 90 degree and foot off the ground. Subject was blind folded. Foot was placed off the supporting surface. Foot was positioned in zero degree of inversion, eversion, plantarflexion, dorsiflexion. Therapist brought the patients foot to neutral and then foot was moved to 15° of plantar-flexion. This position was held for 15 seconds and then foot was actively moved into varying degrees of plantar and dorsiflexion and then subject was asked to actively position the foot into 15° of plantar flexion. Before starting the movement, bubble inclinometer was placed on dorsal aspect of foot along third metatarsal. Three readings were taken and difference between initial and final angle was noted and an average absolute error of these three readings was taken for analysis. For assessment of reliability of this instrument a repeated measure was taken after 24 hours to avoid any recall bias.

Results

The data was entered using Microsoft office 2007 and analyzed using SPSS 15.0 version. Intra-rater reliability of Ankle Joint Position Sense (JPS) with bubble inclinometer was assessed and Intra-class Correlation Coefficient at 95% Confidence interval (ICC at 95%CI) was calculated. Descriptive analysis of numerical data was expressed in mean and standard deviation, frequency of categorical data was expressed in percentage. Normality of data was assessed using the one sample Kolmogorov-Smirnov test. Demographic data Age, BMI were normally distributed. Out of all the outcome measures Ankle JPS, WOMAC were normally distributed whereas FPI and Kellgren-Lawrence scale were not normally distributed. Hence, Pearson correlation co-efficient was calculated for correlation between Ankle JPS and WOMAC and Spearman's correlation was calculated for Correlation between FPI and WOMAC, FPI and Kellgren-Lawrence scale, Ankle JPS and Kellgren-Lawrence scale, FPI and Ankle JPS and Kellgren-Lawrence scale and WOMAC.
P-value less than 0.05 were considered as statistically significant.

Table 1: Descriptive statistics of demographic data and outcome measures

Variables	Mean ± Sd	Median	Min	Max
Age (years)	40.00 ± 9.614	59	40.00	70.00
BMI (kg/m^2)	20.99 ±4.808	27.20	20.99	38.79
Kellgren- Lawrence Scale	2.5 ± 0.78	2.00	1.00	4.00

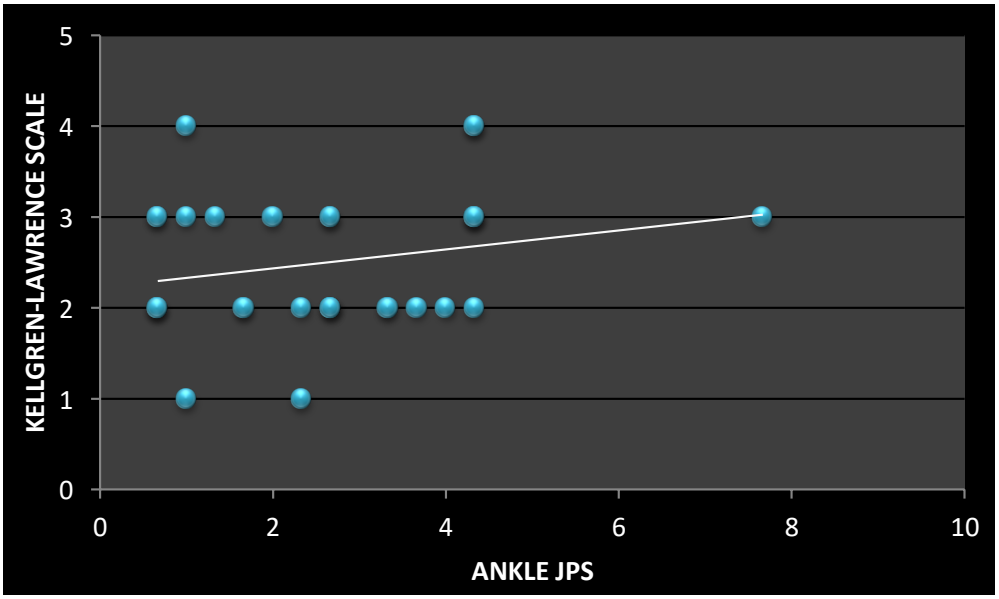
WOMAC	51.63 ± 9.31	54.50	35.00	68.00
JPS	2.63 ± 1.64	2.67	0.67	7.67
FPI	6.87 ± 2.43	7.50	2.00	13

Correlation Analysis

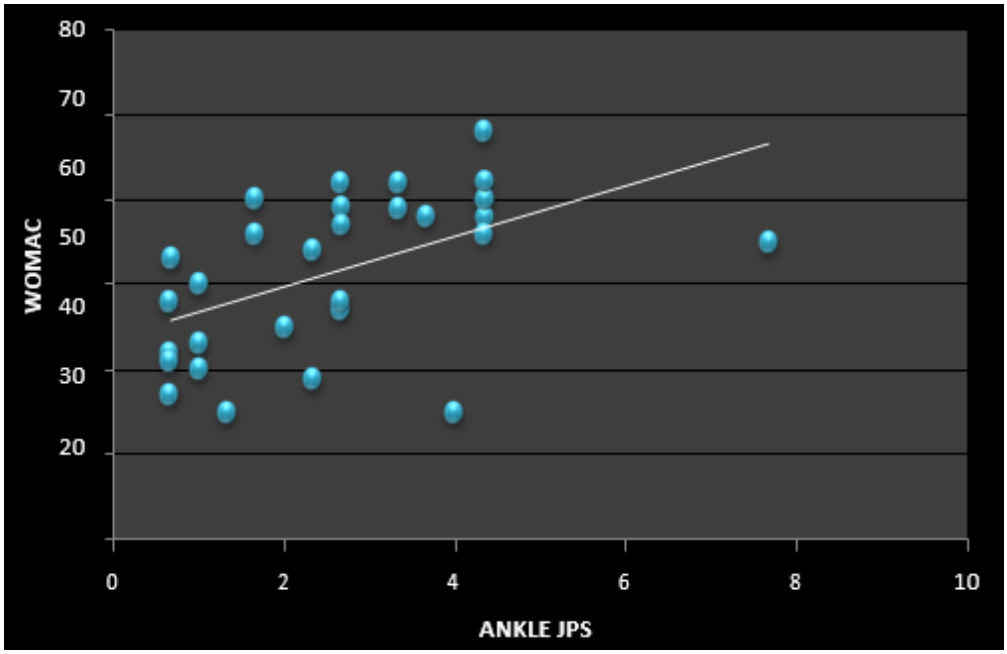
Table 2: Spearman's correlation coefficient for correlation between outcome measures

Variables	Correlation coefficient (Rho)	P Value
Ankle JPS and Kellgren-Lawrence scale	0.04	0.579
Ankle JPS and WOMAC	0.01	0.868
FPI and Kellgren-Lawrence scale	0.14	0.053
FPI and WOMAC	0.46	<0.001
FPI and Ankle JPS	-0.60	<0.001

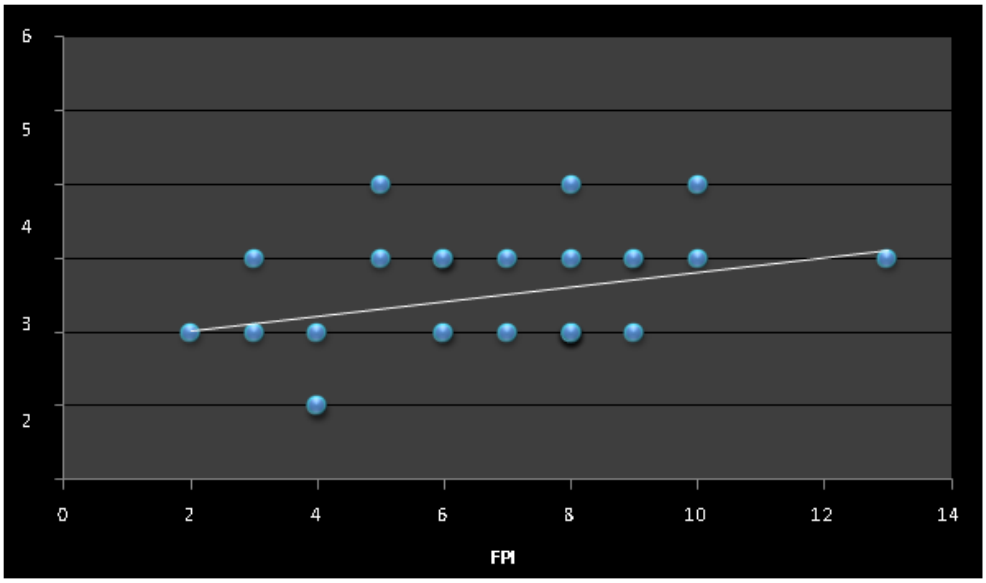
*Correlation is significant at p<0.05



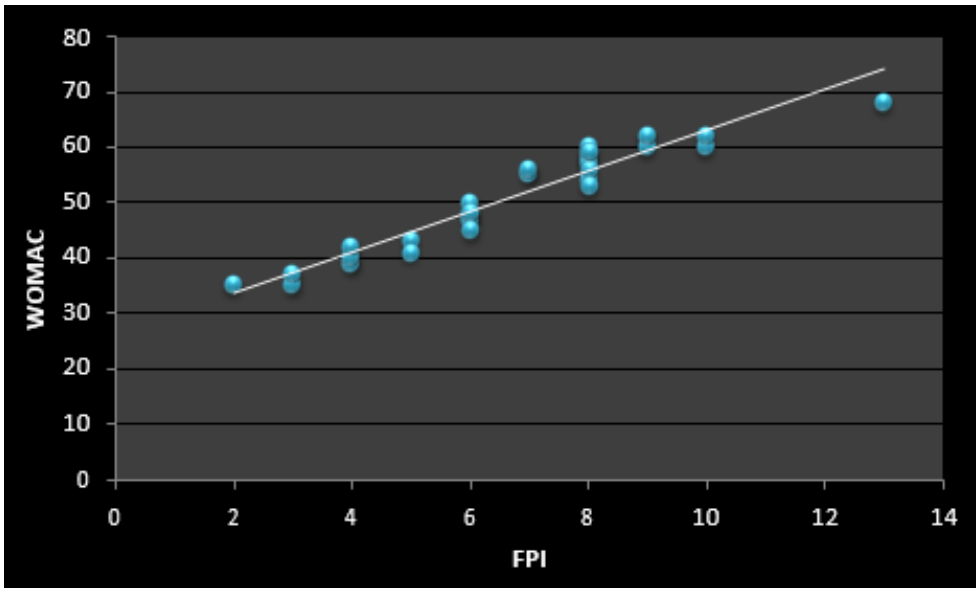
Graph 1: Scatter plot representing correlation between Ankle JPS and Kellgren-Lawrence scale



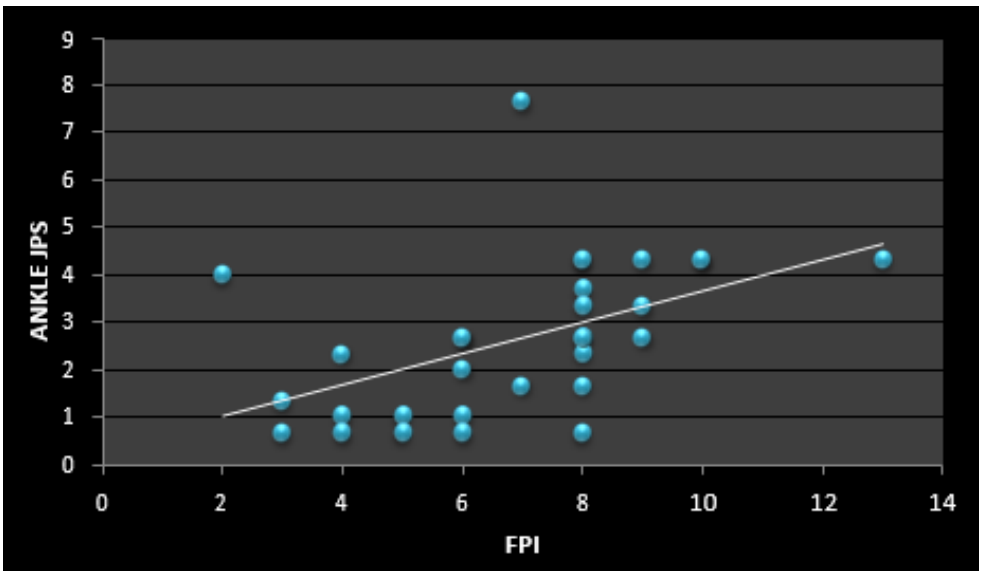
Graph 2: Scatter plot representing correlation between Ankle JPS and WOMAC



Graph 3: Scatter plot representing correlation between FPI and Kellgren-Lawrence scale



Graph 4: Scatter plot representing correlation between FPI and WOMAC



Graph 5: Scatter plot representing correlation between FPI and Ankle JPS

Discussion

The study sample consisted of individuals diagnosed with osteoarthritis of knee joint with knee pain (VAS ≤ 7/10) for at least 1-month duration. Subjects included in this study were 40-70 years of age; 57.1 ± 9.61 (mean ± SD). The mean Body Mass Index was 27.98 ± 4.81 (mean ± SD). Descriptive statistics of demographic data are presented in Table no. 1. Age, Gender, BMI, Pain are secondary influences on knee joint arthritis and disability. Hence, the sample population for this study was selected after being screened for eligibility criteria to avoid any bias.

There is ample published literature which reveals affection of foot posture in individuals with knee OA. Foot pronation is the most common posture seen in these individuals. [15] Also, in knee osteoarthritis, lower extremity mechanical alterations affect proprioceptive input from ankle and hence contribute to alteration of ankle JPS [23,28]. As these facts are already established, current study was conducted with the primary objective to study correlation of ankle JPS and FPI with radiological severity and functional disability in individuals with knee Osteoarthritis. The secondary objectives of this study were to study the correlation between FPI and ankle JPS in individuals with knee Osteoarthritis and to establish reliability of Bubble Inclinometer for assessing ankle JPS in individuals with knee OA.

Proprioception and disability

There are numerous changes that take place at ankle subtalar joint complex which may be attributed to the deviations in ankle joint alignment secondary to the structural changes at the knee in subjects with knee Osteoarthritis [28]. A study conducted by Hubard *et al* (2010) [28] reported that patients with knee OA had significantly less anterior and posterior ankle displacement compared with the control group, as well as compared with their unaffected extremity. Additionally, patients with knee OA had significantly less inversion/eversion rotation than their respective controls. This study further established that patients with knee OA appear to present with mechanical stability changes at the ankle-subtalar joint complex. They stated that as knee OA continues to progress, the alignment of the lower extremity also continues to change because of the abnormal contact pressures that develop within the medial and lateral compartments of the tibio-femoral articulation [29]. These varus or valgus deviations are believed to contribute to abnormal loading patterns observed at the talocrural and subtalar articulations that perpetuate the decreased motion observed at these joints. Gait studies have generally demonstrated that patients with knee OA walk more slowly, have a decreased stride length, and have a longer stance phase of the gait cycle with varying compensation at pelvis, hip and ankle (i.e proximal and distal component) [83].

Recent evidence has also reported that patients with knee OA demonstrate less time in single support, greater time in double support, shorter step length, greater step width, less stride length, less total velocity, greater total time in support, and less total time in swing than the healthy matched controls when ascending and descending stairs. Additionally, patients with mild to moderate knee OA display sagittal and frontal plane kinematic alterations at the hip (increased hip flexion and abduction) and ankle (increased ankle dorsiflexion) during stair climbing [30]. These changes in motion at the hips and ankles may also contribute to the gait changes reported in those with knee OA. However, if ankle-subtalar joint motion is altered secondary to changes with knee OA, the ankle may not be able to compensate as required and function may be further altered. The mechanical stability changes (i.e. decreased antero-posterior displacement and inversion-eversion at ankle, alteration in the axis of rotation at ankle joint) are likely to manifest into larger kinematic changes occurring at the ankle-subtalar joint complex that will certainly impair overall walking gait (either during level walking or on stairs) and other daily functional activities [31]. These mechanical alterations will also impair proprioceptive input from ankle joint. [23] Integrity of sensorimotor function is essential for smooth gait pattern and ambulation. Adequate proprioception is needed for forward placement of limb during heel strike [32]. Sharma *et al*. [33] observed that impaired proprioceptive sense had negative effects on functional parameters such as walking rhythm, shortened distance of step, and decreased speed of walking. Henry *et al* [34] observed increased postural sway in patients with knee OA which may be due to impaired proprioceptive input from ankle mechanoreceptors, muscle spindles, and the cutaneous receptors of the foot, which make important contributions to the maintenance of static postural control. Subsequently, Draz *et al* suggested that improved proprioception would improve overall functional performance [35].

Hence, the results of the current study are in accordance with the published literature in which subjects with knee OA demonstrated altered JPS at ankle joint that contributed to their functional disability. Also, higher the affection of JPS, more was the disability.

Foot posture and ankle proprioception with severity of knee OA

As medial compartmental knee OA continues to progress, the alignment of lower extremity changes in response to changes in medial compartmental pressure. There is an increased varus alignment of lower limb which causes changes in ankle-foot alignment, predisposing the foot towards pronation [9]. The altered rearfoot posture of pronation in patients with knee OA appears to be a compensatory response to the varus alignment, to allow the foot to be plantigrade [36]. The foot is thought to play an important role in knee OA owing to rotational coupling between the rearfoot and tibia. However, Ohi *et al* (2017) [37, 39] reported that increased varus knee alignment (decreased corrected Anatomical axis angle) was associated with an increase in the supination angle of the calcaneus relative to the floor. They stated that this discrepancy could possibly be attributed to a reduced compensatory capacity of the ankle/subtalar joint complex or a reduced range of motion in subtalar pronation. [37]

Norton *et al*. showed that the relationship of the mechanical axis and the hindfoot valgus angle was stronger in severe varus mal-alignment, weaker in patients with a milder varus mal-alignment [38]. The authors further emphasized that significant relationship of the corrected AAA (Anatomical Axis Angle) with the calcaneus angle relative to the floor indicated that the calcaneus angle might be more sensitive to the altered frontal plane alignment rather than midfoot/forefoot alignment.

Navicular height and navicular height/ foot length, two of the midfoot alignment measures, were not significantly associated with the corrected AAA. Navicular height in patients with knee OA is similar to that in healthy adults, even in patients diagnosed to have a pronated foot according to foot posture index and arch index. [12] These results indicate a connection between altered frontal knee alignment and foot posture, which may be helpful in understanding the pathogenesis of altered foot posture observed in patients with knee OA. However, Lijima *et al* [39] observed that knee OA severity and frontal plane alignment were similar in patients with or without flat feet. This is contrary to the theory that structural changes and varus alignment lead to knee pain and subsequent flat feet as a compensatory posture. Thus, much of the published literature supports the concept that patients with Knee OA have pronated foot, however this rearfoot compensation might not be sufficient alone to result in a progressive pronation with progressing severity of Knee OA. Pronation also includes components of midfoot and rearfoot which are not strongly associated with varus deformity [38]. This might be the reason why a linear association between pronated foot posture and severity of knee OA could not be established in this study.

The factors mentioned above, affect mechanical alignment causing resultant changes at ankle-subtalar and foot complex and thus affect ankle proprioception [23, 35]. This is seen because the input from ankle and foot receptors to the higher centres will be compromised because of mechanical changes at the ankle foot complex. [35] However, compensatory changes at the hindfoot, midfoot and forefoot are not consistent with progression of the disease hence resultant proprioceptive input (ankle JPS) from proprioceptors may not correlate linearly with severity of the disease as seen in this study. On extensive review of literature, this seems to be the first study correlating ankle JPS with severity of knee OA and the results do not support a linear relationship between affection of ankle JPS and severity of disease.

Foot posture and disability

Aala *et al* proved that there is a significant effect of pronated foot posture on Arabic WOMAC (Ar-WOMAC) physical function subscale while no significant effect was found in the other two subscales (pain and stiffness) of the Ar-WOMAC index [40]. This is in accordance with the results of the current research which is suggestive of a significant correlation between FPI and functional disability. A study conducted by Al-Abdulwahab and Kachanathu 2016 [16] concluded that higher score of FPI might have an effect on standing dynamic balance in healthy subjects. The current study population included subjects affected with knee osteoarthritis and hence pronation of foot may further impair their balance and result in increased functional disability. As foot pronation increases, foot mobility increases and its adaptability in weight bearing position increases. However, this is associated with a decrease in stability thereby contributing to functional impairment, increase tendency for falls and resultant functional disability [93].

Guler *et al*. observed that coexisting foot deformities, including flat feet, increase the disability in women with knee OA [42]. It is conceivable that structural changes such as medial joint space narrowing and frontal plane knee mal-alignment result in worse knee pain and a compensatory response to allow the foot to be plantigrade during weight-bearing, which in turn causes flat feet. In clinical practice, these foot deformities are preventable/ correctable and hence need to be worked on at a stage of primordial and primary prevention.

Foot Posture Index and Ankle JPS

The most common foot posture observed in patients with mild to moderate knee OA is normal to pronated foot [12, 14, 15]. This everted and pronated foot posture occurs because of weakness and inadequate muscular stabilization which results in splaying of foot. Cornwall in 2011 found that individuals with increased vertical or medial- lateral mobility tend to have lower dorsal arch heights and greater mid-foot widths compared to those with less foot mobility [43]. Excessive pronation results in flattening of medial longitudinal arch and hypermobility of mid foot. This places greater demands on the neuromuscular system to stabilize the foot and maintain upright stance [44]. Thus, structural changes within knee as a result of arthritis contribute to changes at ankle joint. As a result of these changes, the cumulative neural input from mechanoreceptors located in the joint-capsule, ligaments, muscles, tendons, and skin is affected which contributes to affection of proprioception at ankle joint.

Gabell and colleagues reported that undefined ‘‘foot problems’’ were associated with a 4-fold increased risk of falling [44]. The proprioceptive mechanism is essential for proper function of the joint in sports, for activities of daily living, and for some occupational tasks. Aydin *et al* stressed-on assessment of proprioceptive sensibility as it is valuable for identification of proprioceptive deficits and for subsequent planning of a rehabilitative program. [45]

Proprioception is the ability to detect without the visual input, the spatial position and /or movement in relation to the rest of the body. Chivate and colleagues found a significant change in foot posture and higher levels of foot pain in classical dancers as compared to western dancers. However, there was no adequate loss of proprioception in ankle joint in classical as well as western dancers. [46] The inadequate loss of proprioception may be explained by the fact that the participants were younger, physically active and involved in dance i.e. this group was constantly using the proprioceptors of the lower limb despite affection of foot posture and presence of foot pain.

The sample population of the current study was already affected with an underlying pathology of knee arthritis and included more number of subjects above 50 years of age who were less physically active. This could be the reason for the significant correlation between foot posture and ankle JPS.

Limitations

1. Randomization was not performed for selection of the sample.
2. Foot pain was not considered in the study.

Suggestions

1. A multicentric study and a random sampling technique can be carried out to eliminate bias.
2. Effect of bilateral flat feet and its association with severity and functional disability can be assessed in individuals with knee joint arthritis.
3. In future, experimental studies can be conducted to correct the faulty mechanical alignment and check its effect on functional disability and severity to establish cause-effect relationship.

Conclusion

The present study concludes that altered foot posture and ankle JPS is a contributory factor to functional disability but does not show a significant effect on severity of disease in patients with knee osteoarthritis.

References

1. Shah. Osteoarthritis. In: Shah S, Anand MP, editors. API textbook of medicine. 8th edition reprint. Mumbai: The Association of Physicians of India, 2009, 279.
2. John Ebnezar. Textbook of Orthopedics. Fourth edition. New Delhi; Jaypee Brothers Medical Publishers (P) Ltd., 2010, 674.
3. Sharma MK, Swami HM, Bhatia V, Verma A, Bhatia SPS, Kaur G. An epidemiological study of correlates of osteo-arthritis in geriatric population of UT Chandigarh. Indian journal of community medicine.,2009:32: 77.
4. Kim I, Kim AH, Seo Y-II, Song YW, Hunter DI, Jeong IY, *et al*. Tibio-femoral osteoarthritis affects quality of life and function in elderly and Koreans, with women more adversely affected than men. BMC musculoskeletal disorders.,2010:11:129.
5. Chopra A, Patil J, Billampelly V, Relwani J, Tandale HS. The Bhigwan (India) COPCORD: methodology and first information report. APLAR J Rheumatol,1997:1:145-54.
6. Mahajan A, Jasrotia D, Manhas AS, Jamwal SS. Prevalence of major rheumatic disorders in Jammu. JK Science.,2003:5:63-66.
7. Farrokhi S, Chen YF, Piva SR, Fitzgerald GK, Jeong JH, Kwoh CK. The influence of knee pain location on symptoms, functional status and knee-related quality of life in older adults with chronic knee pain: data from the Osteoarthritis Initiative. Clin J Pain.,2016:32(6):463-470. doi:10.1097/AJP.0000000000000291.
8. Kim L Bennel, Rana S hinman, Ben R Metcalf, Kay M, Crossley Rachelle Buchbinder, Michael Smith, Geoffrey McColl. Relationship of knee joint proprioception to pain and disability in individuals with knee osteoarthritis. Journal of Orthopedic Research.,2003:21(6):792-797.
9. Neumann D. Kinesiology of the musculoskeletal system: Foundations for Physical Rehabilitation. First edition.United states of America. Mosby, 2002.
10. Vincent KR, Conrad BP, Fregly BJ, Vincent HK, The pathophysiology of osteoarthritis: A mechanical perspective on the knee joint. PM R.,2012:4(5):S3–S9. doi: 10.1016/j.pmrj.2012.01.020.
11. Neal BS, Griffiths IB, Dowling GJ, Murley GS, Munteanu SE, Franettovich Smith MM, *et al*. Foot posture as a risk factor for lower limb overuse injury: a systematic review and meta-analysis. Journal of Foot and Ankle Research.,2014:7(1):55. doi: 10.1186/s13047-014-0055-4
12. Levinger P, Menz H, Morrow A, Bartlett J, Feller J, Bergman N. Relationship between foot function and medial knee joint loading in people with medial compartment knee osteoarthritis. Journal of Foot and Ankle Research.,2013:6:33. doi: 10.1186/1757-1146-6-33
13. Sharma L, Song J, Dunlop D, Felson D, Lewis CE, Segal N, *et al*. Varus and valgus alignment and incident and progressive knee osteoarthritis. Ann Rheum Dis.,2010:69(11):1940-1945.doi:10.1136/ard.2010.129742.
14. Reilly K, Barker K, Shamley D, Newman M, Oskrochi GR, Sandall S. The role of foot and ankle assessment of patients with lower limb osteoarthritis. Physiotherapy.,2009:95(3):164-169. doi: 10.1016/j.physio.2009.04.003
15. Levinger P, Menz HB, Fotoohabadi MR, Feller JA, Bartlett JR, Bergman NR. Foot posture in people with medial compartment knee osteoarthritis. Journal of foot and ankle research.,2010:3:29. doi:10.1186/1757-1146.3-29.
16. Abdulwahab S, Kachanathu SJ. The effect of various degrees of foot posture on standing balance in a healthy adult population. Somatosensory and Motor Research.,2015:32(3):172-176. DOI: 10.3109/08990220.2015.1029608
17. Hassan BS, Mockett S, Doherty M. Static postural sway, proprioception, and maximal voluntary quadriceps contraction in patients with knee osteoarthritis and normal control subjects. Ann Rheum Dis.,2001:60(6):612-618. doi: 10.1136/ard.60.6.612

18. Hassan BS, Dohetry SA, Mockett S, Dohetry M. Effect of pain reduction on postural sway, proprioception and quadriceps strength in subjects with knee osteoarthritis. Ann rheum Dis.,2002:61(5):422-428.
19. Koralewicz LM, Engh GA. Comparison of proprioception in arthritic and age matched normal knees. Journal of Bone and Joint Surgery.,2000:82(11):1582-8.
20. Kumar A. Joint Proprioception in Normal and Osteoarthritic Knees. J Yoga Phys Ther,2012:2:119. doi:10.4172/2157-7595.1000119
21. Macwan N, Parmar L. Proprioceptive Impairments in OA Knee Patients. International Journal of Multidisciplinary Research and Development.,2015:2(5):351-357.
22. Cho y, Kim M, Lee W. Effect of proprioceptive training on foot posture, lower limb alignment and knee adduction moment in patients with degenerative knee
23. Sreeraj SR, Bagul N. Ankle proprioception in individuals with knee osteoarthritis and normal. International journal of medical and clinical research.,2012:3(5):164-167.
24. Thumboo J, Chew LH, Soh CH. Validation of western Ontario and McMaster university osteoarthritis index in Asians with osteoarthritis in Singapore. Osteoarthritis cartilage.,2001:9(5):440-446. DOI:10.1053/joca.2000.0410.
25. Mark D, Kohn BA, Adam A, Sassoon MD, Navin D, Fernando MD. Kellgren- Lawrence Classification of Osteoarthritis, Clin Orthop Relat Res.,2016:474:1886-1893, DOI 10.1007/s11999-016-4732-4
26. Cornwall M, McPoil TG, Lebec M, Vicenzino B, Wilson J. Reliability of modified Foot Posture Index, Journal of the American Podiatric Medical Association.,2008:98(1):7-13.
27. Riddle DL, Jiranek WA, Hull JR. Validity and Reliability of Radiographic Knee Osteoarthritis Measures by Arthroplasty Surgeons. Orthopedics.,2013:36(1):e25-32. doi: 10.3928/01477447-20121217-14.
28. Hubbard TJ, Little CH, Cordova M. Changes in Ankle Mechanical Stability in Those with Knee Osteoarthritis. Arch Phys Med Rehabil.,2010:91(1):73-77. DOI: 10.1016/j.apmr.2009.09.015.
29. Tallroth K, Harilainen A, Kerttula L, Sayed R. Ankle osteoarthritis is associated with knee osteoarthritis: conclusions based on mechanical axis radiographs. Arch Orthop Trauma Surg.,2008:128:550-60.
30. Bejek Z *et al*. Gait parameters of patients with osteoarthritis of the knee joint. Physical Education and Sport.,2006:4(1):9-16.
31. Hicks-Little CA, Peindl RD, Hubbard TJ, Scannell BP, Springer BD, Odum SM. Lower extremity joint kinematics during stair climbing in knee osteoarthritis. Med Sci Sports Exerc.,2011:43(3):516-24. DOI: 10.1249/MSS.0b013e3181f257be.
32. Ferrell WR, Baxendale RH, Carnachan C, Hart IK. The influence of joint afferent discharge on locomotion, proprioception and activity in conscious cats. Brain Res.,1985:347(1):41-8.
33. Sharma L, Pai YC, Holtkamp K, Rymer WZ. Is knee joint proprioception worse in the arthritic knee versus the unaffected knee in unilateral knee osteoarthritis? Arthritis Rheum.,1997:40(8):1518-25.
34. Henry SM, Fung J, Horak FB. EMG responses to maintain stance during multidirectional surface translations. J Neurophysiol,1998:80(4):1939-50.
35. Draz AH, Abdel-azeim AA, Elnahas NG. The effect of knee osteoarthritis on ankle proprioception and concentric torque of dorsiflexor and plantar-flexor muscles. Physiotherapy Practice and Research.,2015:36:121-126, DOI 10.3233/PPR-150054.
36. Riegger-Krugh C, Keysor JJ, Skeletal mal-alignments of the lower quarter: correlated and compensatory motions and postures, J Orthop Sports Phys Ther,1996:23(2):164-70.
37. Ohi H, Lijima H, Aoyama T, Kaneda E, Ohi K, Abe K. Association of frontal plane knee alignment with foot posture in patients with medial knee osteoarthritis. BMC Musculoskeletal Disorders.,2017:18:246. DOI: 10.1186/s12891-017- 1588-z.
38. Norton AA, Callaghan JJ, Amendola A, Phisitkul P, Wongsak S, Liu SS, *et al*. Correlation of knee and hindfoot deformities in advanced knee OA: compensatory hindfoot alignment and where it occurs. Clin Orthop Relat Res.,2015:473(1):166-74.
39. Iijima H, Ohi H, Isho T, Aoyama T, Fukutani N, Kaneda E. Association of bilateral flat feet with knee pain and disability in patients with knee osteoarthritis: a cross-sectional study. Journal of Orthopaedic Research., 2017. DOI 10.1002/jor.23565.
40. Aala *et al*. Effect of Pronated Foot Posture on the Arabic Version of WOMAC Index in Women with Medial Compartment Knee Osteoarthritis. Med J. Cairo Univ.,2018:86(3):1111-1117.
41. Awale A, Hagedorn TJ, Dufour AB, Menz HB, Casey VA, Hannan MT. Foot function, Foot pain, and falls in older adults: The Framingham Foot study. Gerontology.,2017:63:318-324. DOI: 10.1159/000475710
42. Guler H, Karazincir S, Turhanoglu AD, Sahin G, Balci A, Ozer C. Effect of coexisting foot deformity on disability in women with knee osteoarthritis. J Am Podiatr Med Assoc.,2009:99(1):23-7.
43. Cornwall MW, McPoil TG. Relationship between static foot posture and foot mobility. Journal of Foot and Ankle Research.,2011:4:4.
44. Gabell A, Simons MA, Nayak USL. Falls in the healthy elderly: predisposing causes. Ergonomics.,1985:28:965-975.
45. Aydin T, Yildiz Y, Yildiz C, Atesalp S, Kalyon TA.Proprioception of the Ankle: A Comparison between Female Teenaged Gymnasts and Controls. Foot & Ankle International.,2002:23(2):123-9.
46. Chivate SD, Kulkarni MP. Evaluation of foot posture, Pain and ankle proprioception in classical and western dancers: A cross-sectional study. JMSCR,2017:5(10): 29039-29044.