ISSN: 2321-5690
IJOPT
INDIAN JOURNAL OF PHYSICAL THERAPY
AN INTERNATIONAL JOURNAL

INDIAN JOURNAL OF PHYSICAL THERAPY
AN INTERNATIONAL JOURNAL
editor.ijopt@gmail.com

INFLUENCE OF ANTHROPOMETRIC FACTORS ON FOOT POSTURE IN HEALTHY VARKARIS RESIDING IN COMMUNITY: A CROSS-SECTIONAL STUDY

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DOI: https://doi.org/10.63299/ijopt.060471

ABSTRACT

Background: In order to detect aberrant alignment patterns that may impact gait, balance, and the likelihood of future musculoskeletal problems, it is crucial to evaluate the foot posture in geriatric. A number of factors can affect foot posture during this period of fast growth and increased activity. Foot posture assessment in Geriatric is essential for identifying abnormal alignment patterns that can affect gait, balance, and risk of future musculoskeletal issues. During this stage of rapid growth and increased activity foot posture can be influenced by several factors. Elder population are more prone to pronation due to ligamentous laxity, with corrections expected as they age, but many retain non-neutral posture. Gender differences are observed, with females often showing a higher prevalence of pronated posture, likely due to anatomical and physiological variables. BMI also plays a significant role- underweight populations tend to have increased pronation, possibly from reduced muscle and tissue support in the feet, highlighting the importance of health in foot posture.

Method: This is a cross- sectional observational study was carried out on Varkari Community Camp. The study involved 300 healthy varkaris both male and female participated in the study.

Results: The result show that pronated foot posture is predominant among elderly, making up the majority cases, Females and Underweight were more likely to have pronation, while neutral posture was rare. Age consistently correlated with a high rate of pronation, especially in elder populations.

Conclusion: The study concludes that pronated foot posture is highly prevalent among elderly especially in females and underweight groups.

Keywords: Foot posture, Pronated, Supinated, Neutral, Varkari, Age, Gender, BMI.

INTRODUCTION

The human foot is a complex structure that serves as the foundation for mobility, posture, and balance. In the geriatric population, maintaining optimal foot function becomes increasingly important due to age-related changes that affect musculoskeletal integrity, proprioception, and neuromuscular control. (1) Foot posture, defined as the static alignment of the foot and its segments relative to the lower limb and ground, can significantly influence gait mechanics, load distribution, and joint alignment. Alterations in foot posture are common with aging and may contribute to increased risk of falls, reduced functional independence, and chronic pain in older adults. (2)

The Varkari movement, a Bhakti tradition in Maharashtra, is deeply connected to walking barefoot as a part of their annual pilgrimage to Pandharpur. (3) This pilgrimage, called the “Vari”, involves thousands of devotees walking hundreds of miles to workship Lord Vitthal, and the barefoot journey is a significant aspect of their spiritual practice. (4) In Varkaris there are not only geriatric populations but also childrens, adults they walk bare footed so the barefooted walking emphasis the strength of foot muscles. So, on the basis of this the alignment of the foot muscles was also defined. (5)

Barefoot walking engages and strengthens various muscles in the feet,ankles and legs. This natural movement improves foot mechamics, balance, and posture while also enhancing sensory feedback from feet to brain. (6)

Muscles strengthened by Barefoot Walking:

1. Foot Intrinsic Muscles: Walking barefoot activates and strengthens the muscles within the foot itself, improving arch support and overall foot stability.

2. Ankle Stabilizers: The muscles around the ankle, such as the tibialis anterior and peroneal muscles, are engaged to maintain balance and control foot movement, leading to better ankle stability and reduced risk of sprains.

3. Leg Muscles: The muscles in the lower leg, including the gastrocnemius and soleus are also activated more during barefoot walking, contributing to overall leg strength and stability.

4. Core Strengthening: While less direct, barefoot walking can improve core strength as it requires more engagement of the core muscles to maintain balance and stability especially on uneven surfaces.

The Foot Posture Index (FPI) is a validated and clinically useful tool developed to assess static foot alignment across three anatomical planes. Unlike traditional footprint or single-plane measures, the FPI-6 provides a multi-faceted assessment based on six observational criteria: talar head palpation, curvature above and below the lateral malleoli, the prominence of the talonavicular joint, medial longitudinal arch height, abduction/adduction of the forefoot on the rearfoot, and calcaneal position in the frontal plane. Each criterion is scored from -2 (indicative of supination) to +2 (indicative of pronation), resulting in a composite score ranging from -12 to +12. This scale allows clinicians to categorize foot posture into supinated, neutral, or pronated. Although the FPI has been extensively studied in pediatric and athletic populations, its application in geriatric healthcare remains relatively underutilized. Older adults are particularly susceptible to foot posture changes such as pes planus (flattened arches), hallux valgus, and rearfoot valgus, which may arise due to ligamentous laxity, muscle atrophy, or degenerative joint disease. These changes can compromise postural stability and gait efficiency, leading to an increased risk of falls and associated injuries—a major concern in elderly care. Furthermore, inappropriate foot posture can alter proximal joint mechanics, contributing to conditions such as knee osteoarthritis, hip pain, and lower back discomfort. (7,8)

Assessing foot posture in older adults using tools like the FPI is critical for early identification of biomechanical abnormalities and for informing therapeutic decisions such as orthotic prescription, footwear modifications, balance training, and targeted rehabilitation.(9) A better understanding of foot alignment in this population can aid in preventing secondary complications and optimizing functional outcomes.(10)Incorporating the FPI into routine geriatric assessments can thus play a pivotal role in comprehensive musculoskeletal evaluation and fall prevention strategies. As aging populations continue to grow globally, simple and reliable tools such as the FPI are essential in promoting healthy aging and preserving independence in later life. (11)

A foot inclinometer is a clinical tool used to measure the angular alignment of the foot and its segments, particularly the calcaneal inclination angle and arch height. It quantifies the orientation of foot structures relative to the ground or other anatomical landmarks, helping clinicians objectively evaluate static foot posture. Unlike qualitative tools like the Foot Posture Index (FPI), a foot inclinometer offers numerical, angle-based data, which can be useful in precise assessment, documentation, and monitoring of foot deformities and biomechanical alignment over time.The normal values according to FPI Highly Supinated -12 to -5, Supinated -4 to -1, Neutral 0 to +5, Pronated +6 to +9, Highly Pronated +10 to +12. (12,13)

Development of instrument:

The instrument was designed to be used with the subject in double limb standing because: (a) weight-bearing measures better represent foot function than non-weight- bearing measures, (b) this position is well-known to practitioners. (14) To measure Foot posture ratings concurrently with a detailed objective measure of static foot posture, 4 pressure sensors at anatomical landmark (a) first metatarsal (b) fifth metatarsal (c) Midfoot (d) Calcaneum and 1 Adxl320 accelerometer sensor (proximity sensor) at Achilles tendon is used. The 4 pressure sensors are attached on 2 soles of standard size for each foot. (15)

To enhance the accuracy and efficacy of static foot posture measurement, the Foot Inclinometer (FI) is an innovative tool. Through the use of advanced sensor technology, the FI reduces the human error that comes with using traditional techniques. The apparatus is made up of carefully positioned sensors at anatomical position that can measure the angles and positions of the foot with accuracy when it is stationary. Real-time data collection is made possible by this technology, guaranteeing reliable and consistent assessments of foot posture. (16,17)

The objective of the device is to make easy operated, low costing unit for measuring foot posture, the device measures the foot posture through a series of pre- fed program into the software. It is a simple effective device which is made with minimal equipment and easy to operate. It gives visual feedback via digital display. This equipment does not need any special training and skill to operate. It can be installed at any setup with no special requirements. The device needs very less space. (18)

Adxl320 accelerometer sensor - The accelerometer measures static acceleration forces, such as gravity, which allows it to be used as a tilt sensor. We hold it on Achilles tendon because Achilles tendon is a strong cord that connects the calf muscles to the heel bone. Foot posture is associated with the thickness of the Achilles tendon. All Mechanical data is collected from the sensor and converted into digital data using Ardino Nano processor which is connected to programming unit which will show the details or tilt measurement on screen. (19)

The device goal is to create low-cost, user friendly foot posture measurement tool.It does this by feeding a series of pre-programmed programs into the software. It is a straightforward, efficient gadget that requires little equipment and is simple to use. It uses a digital display to provide visual feedback. Operating this equipment doesn’t require any specialized knowledge or expertise. It doesn’t require any extra configuration to be installed. The gadget requires very little room. (20,21)

NEED OF STUDY

Foot posture is a critical determinant of lower limb biomechanics, postural stability, and gait efficiency. In the geriatric population, age-related physiological changes such as decreased muscle strength, ligamentous laxity, loss of fat padding, and degenerative changes in joints significantly alter foot structure and function. One of the most common age-associated changes is the collapse of the medial longitudinal arch, leading to a more pronated foot posture. This altered alignment can result in increased stress on the ankles, knees, hips, and lumbar spine, thereby affecting mobility and increasing the risk of musculoskeletal pain and falls. (22)

Falls are a major public health issue among the elderly, often resulting in fractures, hospitalization, loss of independence, and reduced quality of life. According to WHO, one in three adults over the age of 65 experiences at least one fall each year. Poor foot alignment has been recognized as a contributing factor to reduced balance and increased fall risk, yet foot posture is rarely assessed in standard geriatric screenings. Early identification of foot abnormalities can play a pivotal role in fall prevention and overall geriatric care. (23)

While clinical tools like the Foot Posture Index (FPI) offer a subjective measure of foot posture, they rely on visual inspection and palpation, which may be prone to inter-examiner variability. In contrast, a Foot Inclinometer provides a more objective, quantifiable, and repeatable measurement of foot posture by assessing angular deviations, especially in the rearfoot (such as calcaneal eversion or inversion). This makes it a valuable tool for both clinicians and researchers seeking precise biomechanical data, especially in older adults whose musculoskeletal systems are more vulnerable to malalignment-related complications. (24,25)

Despite the utility of the foot inclinometer in orthopedic and sports populations, there is a notable lack of research on its application in geriatric assessments. (26) Most existing studies focus on younger or athletic individuals, and the elderly—who could arguably benefit most from early detection and correction of foot posture abnormalities—remain underrepresented in this area of research. Furthermore, standardized foot posture assessment tools tailored for the elderly are scarce, leaving a gap in evidence-based strategies for managing age-related postural deviations of the foot. (27,28)

By focusing on foot posture assessment using a foot inclinometer in the geriatric population, this study aims to:

1.Fill the existing gap in geriatric biomechanics literature

2.Provide clinically relevant data for preventive strategies (e.g., orthotic use, fall prevention programs)

3.Promote integration of objective foot assessment into routine geriatric physical examinations

This study will contribute not only to improved musculoskeletal care for the elderly but also to a broader understanding of how foot biomechanics influence overall health outcomes in aging individuals.

METHODS:

AIM: To evaluate and quantify foot posture in the varkaris aged 60 and above using a foot inclinometer and to determine its correlation with age, gender, and body mass index (BMI).

OBJECTIVE: 1. To measure foot alignment in varkaris geriatric healthy populations using a foot inclinometer in a standardized weight bearing position. 2. To determine the prevalence of normal, pronated, and supinated foot postures in the study populations. 3.Investigate the relationship between right and left foot posture in the term of BMI, sex and age among varkaris aged 60 and above.

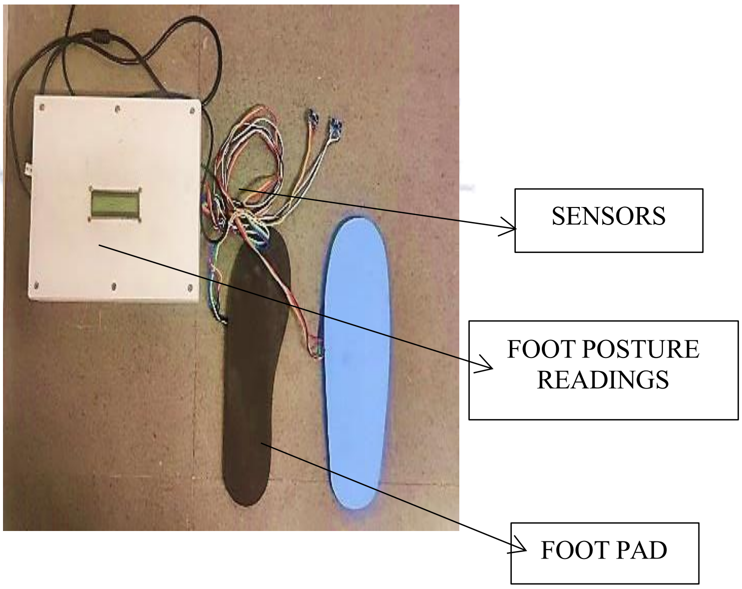
STUDY DESIGN: The current study was a cross-sectional study that was carried out among healthy varkaris aged 60 and above. The study was conducted over a period of six months. The Open EPI approach was used to calculate the sample size, guaranteeing sufficient statistical power and target population representation.

MATERIALS:

A foot inclinometer for measuring stataic foot posture and a weighing machine and stadiometer for measuring height and body weight, respectively, were among the trools utilized in the study to determine BMI. Anthromentric measures were taken using a measuring tape. Consent and participant data forms were used for ethical compliance and documentation. When necessary, photographic documentation and data capture were done using a smartphone. A laptop was utilized for data entry, processing, and statistical analysis, while basic stationary items including pen, pencils, erasers, and folder were used for record organization.

INSTRUMENT:

The Foot Inclinometer (FI) is a novel, affordable, and user-friendly tool intended to improve the precision of static foot posture assessment. Because it more accurately depicts foot function, it is employed in a double-limb weight-bearing position. To measure foot tilt and posture, the gadget uses an Adxl320 accelerometer sensor at the Achilles tendon and four pressure sensors at anatomical landmarks: the first metatarsal, fifth metatarsal, midfoot, and calcaneum. The sensors gather mechanical data, which an Arduino Nano CPU transforms into digital form to provide real-time visual feedback on a digital display. Foot posture is displayed in five categories: neutral (0 to 4), pronated (4 to 8), severely pronated (8 to 12), supinated (-1 to -4), and highly supinated (-4 to -8). The FI is easy to use in any clinical or research setting, reduces human error, and doesn't require any specialized training.



PARTICIPANTS:

A total number of 300 participants was recruited for this cross-sectional study. The study included healthy varkaris aged 60 and above comprising both male and female who were ambulatory and able to stand independently. Participation was permitted on basis of consent. Varkaris were excluded if they had any history of recent lower limb surgery or injury (<6 months), Neurological disorders affecting posture or balance (e.g., stroke, Parkinson's disease), Severe foot deformities (e.g., Charcot foot, advanced hallux valgus). Those using orthotic devices or special footwear, or presenting with acute pain or inflammation in the lower limbs at the time of assessment, were also excluded from the study.

DATA COLLECTION:

When the gadget is powered on, the operator will instruct the participant to stand on their soles barefooted (black for the left foot and blue for the right). After that, he will calibrate the gadget by placing the proximity sensor against the Achilles tendon of one foot and then the other. It is recommended that the participant stand. Remain motionless for a minute. Along with the degree of tilt, the device will display the reading as pronated, supinated, or neutral. The average of the three readings is shown as the outcome.

RESULT:

Statistical Analysis of Geriatric Foot Posture Study

Main Finding: The majority of participants fall in the Young-old (60–74) category (267/293), with progressively in Old-old (75–84) (25/293) and Oldest-old (85+) (1/293). Pronated foot posture is most prevalent, especially among the Young-old.

1. Age Category Distribution

Participants were classified per WHO elderly age groups:

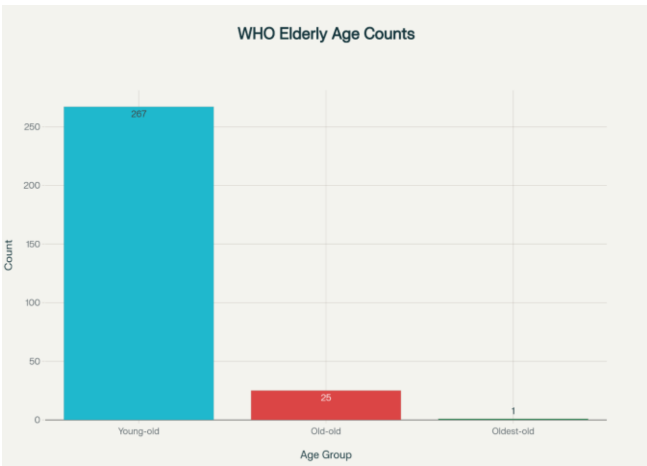
- Young-old (60–74)
- Old-old (75–84)
- Oldest-old (85+)

The counts of participants in each category:

Age Category	Count
Young-old (60–74)	267
Old-old (75–84)	25
Oldest-old (85+)	1

Distribution of study participants across WHO elderly age categories

Table: Number of study participants by WHO elderly age category.



Distribution of study participants across WHO elderly age categories

Table: Number of study participants by WHO elderly age category.

The Young-old group constitutes 91.1% of the sample, reflecting recruitment bias toward younger seniors.

2. BMI by Age Category

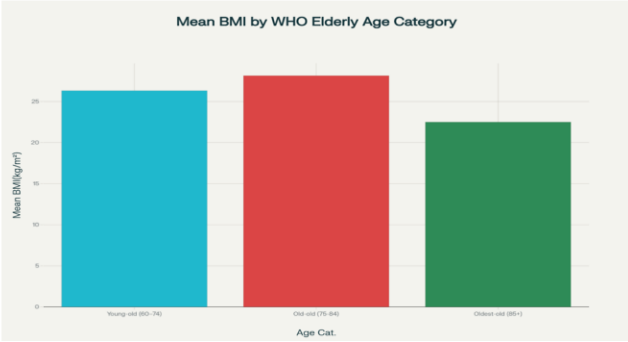
Mean BMI by category:

Age Category	Mean BMI
Young-old (60–74)	26.32
Old-old (75–84)	28.15
Oldest-old (85+)	22.50

Under-60 participants (excluded from WHO categories) had a mean BMI of 26.06 but are not shown above.

Summary Table of Participant Characteristics

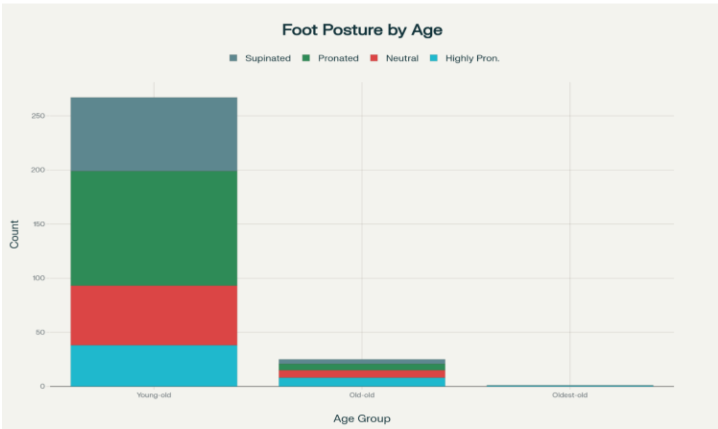
Age Category	Count	% of Total	Mean BMI (kg/m²)	Female (n, %)	Male (n, %)
Young-old (60–74)	267	91.1 %	26.32	154 (57.7%)1	113 (42.3%)1
Old-old (75–84)	25	8.5 %	28.15	14 (56.0%)1	11 (44.0%)1
Oldest-old (85+)	1	0.3 %	22.50	0 (0%)1	1 (100%)1



3. Foot Posture Classification

Foot posture was assigned per the highest-magnitude inclinometer reading among five categories. Cross-tabulation by age:

Age Category	Highly Pronated	Neutral	Pronated	Supinated
Young-old (60–74)	38	55	106	68
Old-old (75–84)	8	7	6	4
Oldest-old (85+)	1	0	0	0



Foot posture distribution by WHO elderly age category. Stacked bar chart of foot posture distribution across WHO age groups.

Among Young-old, Pronated posture is most common (106/267, 39.7%), followed by Supinated (25.5%), Neutral (20.6%), and Highly Pronated (14.2%). Pronated and Supinated combined represent 65.2% of Young-old, indicating prevalent alignment deviations early in aging.

4. Proportional Breakdown: Proportion of each posture within age groups:

Age Category	Highly Pronated	Neutral	Pronated	Supinated
Young-old (60–74)	14.2%	20.6%	39.7%	25.5%
Old-old (75–84)	32.0%	28.0%	24.0%	16.0%
Oldest-old (85+)	100%	0%	0%	0%

The Old-old show a shift toward highly pronated (32%) and neutral (28%) compared to Young-old, suggesting progressive collapse of medial arch structures.

5. Interpretation and Implications

1. High prevalence of pronation across all elderly groups indicates potential risk for balance impairment and falls.

2. Young-old group exhibits early biomechanical changes; interventions (orthotics, balance training) may be most effective if introduced in this group.

3. Old-old maintain heterogeneous posture profiles; ongoing monitoring is recommended.

4. The single Oldest-old participant showed highly pronated posture, warranting further recruitment to confirm trends.

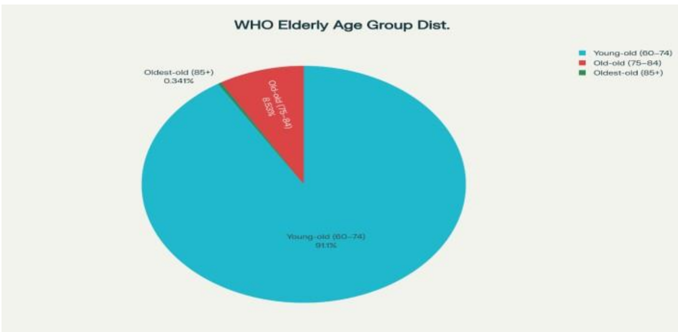
Recommendation: Incorporate inclinometer-based foot posture assessment in routine geriatric screening to identify individuals at risk, with stratified intervention protocols by age category.

Key Findings:

- Participants were predominantly in the Young-old (60–74) category (91.1%).
- Female participants comprised 55.3% (n = 162) and males 44.7% (n = 131).
- Pronated foot posture was most prevalent overall (38.2%), followed by Supinated (24.6%), Neutral (21.2%), and Highly Pronated (16.0%).

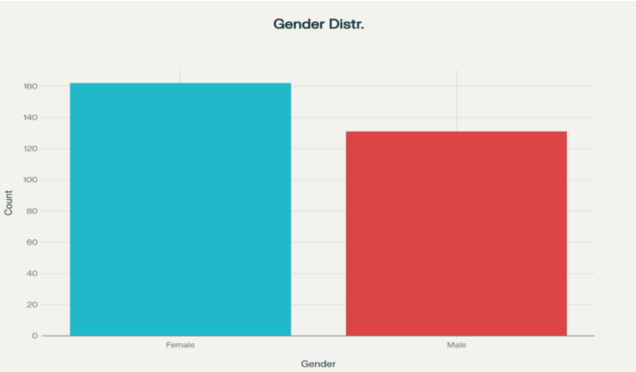
 Participant Distribution by Age

The majority of participants fell into the Young-old category, with very few in the Old-old and Oldest-old groups.



Pie chart of participant distribution by age category

- Participant Distribution by Gender Female participants slightly outnumbered males in the cohort. Bar chart of participant distribution by gender



DISCUSSION:

This study demonstrates a high prevalence of static foot posture abnormalities—particularly pronation—in older adults. The association between higher BMI and pronated posture aligns with existing literature suggesting excess weight increases medial foot loading and arch collapse. Although age category did not significantly influence posture classification, the predominance of the Young-old group may have limited power to detect differences in the Old-old and Oldest-old strata. Likewise, the female predominance in pronation mirrors patterns observed in athletic and pediatric cohorts.

Foot inclinometry provided objective, reproducible measurements that can enhance traditional visual and palpation methods. Early identification of pronation and supination allows targeted interventions such as orthotic prescription, strength training, and balance exercises, which have been shown to reduce fall risk and improve postural control.

CONCLUSION:

Static foot posture abnormalities are common in community-dwelling older adults and are associated with higher BMI. Incorporating foot inclinometry into routine geriatric assessments can facilitate early detection and intervention to mitigate fall risk and related morbidity.

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