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# Variation in Calcaneal Eversion Angle between Normal weight and Overweight Individuals

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**Abstract:-**
**Background: Overweight and Obesity is a major health problem, worldwide. Increased body weight is considered to cause overload of the foot which represents the interface between the body weight and ground. Overweight has long-term debilitating effects that may affect the quality of life leading to musculoskeletal disorders, foot problems due to changes in the biomechanics of the foot, in adults obesity is important at most, this can cause various stress and strains while walking.**

**Aims: To find the variation in calcaneal eversion angle of the right leg and left leg between normal weight and overweight individuals.**

**Methods: Sixty subjects (18-26 years) were selected based on inclusion criteria and divided into two specific groups according to the body mass index (BMI). Group A (n=30), subjects with normal weight (18.5-24.9kg/m2), and Group B (n=30), subjects with overweight (25-29.9kg/m2). The Calcaneal eversion angle was recorded in double limb stance.**

**Results: Unpaired t-test was used for data analysis. It showed a statically significant difference ($p \leq 0.05$) between the two groups for calcaneal eversion angle between the right and left legs, with $t = 9.7080$ for the right legs and $t = 7.6782$ for the left legs.**

**Conclusion: In conclusion, the calcaneal eversion angle, when right and left legs were compared between normal weight and overweight individuals, showed a statistically significant difference.**

***Keywords****:- Calcaneal Eversion Angle; Obesity; Body mass index: Normal weight: Overweight*

## I. INTRODUCTION

Overweight and obesity is a major health problem globally when the body weight exceeds 20% than the normal body mass index. There are many debilitating long-term effects of obesity that can significantly reduce quality of life extensively with cardiovascular diseases, diabetes mellitus, and various musculoskeletal and neurological disorders.[1]

The foot has been recognized as one of the dynamic, responsive, and adaptive region of the body, in static or dynamic states of standing, walking, running, swimming, diving, and other related maneuvers. The forefoot is the most anterior aspect of the foot and includes the metatarsals, phalanges, and sesamoid bones. The tarsal bones: calcaneus, talus, navicular, cuboid and cuneiform.[1] Inversion is raising the medial border of the foot. Eversion is raising the lateral border of the foot sole of the looks laterally. The main movement takes place at the clinical subtalar joint. The ligament of the neck of the talus acts as the pivot for the movement. The most important factor in achieving the conversion of the center of mass from serious intersecting arcs of the foot to a smooth curve in the presence of foot attached to the distal end of the limb for bearing the body weight.[2]

The foot serves to absorb the shock and to act as a rigid lever of propulsion, to help in transfering the body weight forward and transversely. Foot functions are mainly achieved through subtalar joint and tarsal joint motions[3]. The foot with minimal muscle work acts as a base of support that provides the necessary stability for maintaining an upright posture. The foot's flexibility tends to adapt to uneven surfaces for the absorption of the shock. It also provides a mechanism for rotation of the tibia and fibula in stance phase of gait and acts as a rigid lever during toe-off.[3]

The subtalar or talocalcaneal joint is a gliding joint with three articulating facets (anterior, middle, and posterior). The weight-bearing function of the subtalar joint is necessary to cushion the rotational forces exerted by the body weight while maintaining the contact of foot with the supporting surface. The subtalar joint is composed of three articulations; this results in a tri-planar motion of the talus around a single oblique joint axis.[3]

The major ligaments related to calcaneum are plantar calcaneonavicular ligament, interosseous ligaments which are tibiocalcaneal ligament, medial talocalcaneal ligament, plantar calcaneonavicuar ligament, calcaneocuboid ligament and calcaneofibular ligament. The calcaneum and the tarsal bones helps plantar fascia in supporting the arch of foot.

In standing position, supination occurs with calcaneal inversion, talar abduction, and dorsiflexion, whereas pronation occurs with calcaneal eversion, talar adduction, and plantar flexion. The neutral subtalar definition is used to evaluate the position of the hindfoot to assess its potential role in dysfunction of more proximal and distal joints of foot and is similarly used as the reference point for assessing position on the forefoot.[3] Abnormal subtalar joint pronation may cause a prolonged and increased loads on the structure of the foot, and may result in an increase in maximal calcaneal eversion. Calcaneal pronation, the frontal plane component of subtalar joint pronation, has been used as a sign of pronation.[3]

Overweight and obesity is also associated with structural and functional limitations with impairment of normal gait, flat foot arches and ankle pronation.[4] Body composition was found to have influence on arch index values in overweight and obese individuals. Obesity increases hind foot movements during walking and causes the forefoot to abduct significantly with an increased force on weight-bearing joint that is greater than in individuals with normal weight.[5]

Calcaneal Eversion Angle: As per data the calcaneum should be vertical by the age of seven of a child. Later in adults, the calcaneal eversion angle develops due to some factors. Overweight and obesity is the major cause, as due to, the arch of the foot reduces its height and leads to overpronation of the midfoot and increases the calcaneal eversion angle. The variation in the calcaneal eversion angle could lead to changes in biomechanical function of the foot, knee, hip, sacroiliac joint, and lumbar which could lead to low back ache.[6]

Postural instability in extremely in obese individuals had inadequate postural instability as measured of balance maintenance, medial, and lateral sway of the trunk. Obese subjects also walk significantly slower than their obese counter parts. BMI was one of the factors affecting the differences in cadence as well as walking distance.[4]

Overweight and obesity is a risk factor for developing unilateral plantar fasciitis, which is associated with chronic plantar heel pain. Arch biomechanics are thought to play a major role in the cause but other studies have not concluded this. Obesity is also a risk factor for trochanteric bursitis, a common cause of lateral hip pain in middle-aged and elderly people.[4]

The normal movement pattern with its relationship of it with different segments of the body creates a kinematic chain to perform certain activities. Abnormal movement patterns increase the risk of lower extremity injuries which may occur at any segment of the lower limb from the pelvis to the foot.[4,5,6] It is hypothesized that, more than normal, the abnormal gait pattern can result in flattening, inversion, or eversion of the forefoot, with pelvic tilt, hip anti-version, anti-torsion, knee valgus, and varus deformities. The pes planus have that instability, may affect the internal rotation of tibia and femur ultimately affecting the alignment of patella.[7, 8]

Anatomical deviations in the morphology of the human foot may be due to pes planus also known as flat foot. Obesity has been identified as a risk factor for postural instability when performing activities. The mechanism of changing body geometry due to excessive accumulation of body fat in certain areas such as the abdomen, hips, and trunk creates an imbalance in bodies balance performance which leads to initiate stress on the lower extremity leading to instability.[9]

In overweight and obesity, increased pressure exerted due to increased mass in the body, usually reduces the proprioception, fat mass increased in the abdominal area causes forward shifting of the line of gravity due to an imbalance in weight distribution due to increased weight on the anterior part of the trunk.[10] Therefore uneven transfer of body weight results in stress and eventually fatigue leading to injury. The pelvic tilt is a result of muscle imbalance or is secondary to increased lumber lordosis usually causes pain in the lower back and sometimes in the hip as well.[11]

The correlation between obesity and postural instability has been reported in many previous studies. Lumbar spine lordosis due to excessive body mass in the abdominal area eventually leads to anterior pelvic tilt, normal recommended range of pelvic tilt is between 4.9 to 11 degrees posterior to anterior and has measured with radiological images and digital photographs in the past. The direction of pull of the quadriceps muscle can change the tibial rotation by increasing or decreasing the angle of pull.[12, 13]

Ultimately, the change in the direction of pull of quadriceps muscle affects the alignment of foot and may lead to foot deformities. It is believed that altered direction of weight transfer from the upper trunk to the lower limb, due to obesity is thought to cause an increase in Q-angle which in turn creates problems with pelvis, knee, and foot.[13]

The body mass index (BMI) is used to determine the anthropometric classification of individuals. The common explanation is that it is an indicator of an individual's physical fitness based on their height and weight. It has been used in several researches as a risk factor for the development or to determine the prevalence of certain health issues. Additionally, it serves as a marker in determining public health policies. The BMI has been useful in population-based studies due to its widespread acceptance in identifying specific body mass categories as a health problem.[14]

As overweight and obesity is a major health problem worldwide, increased body weight is considered major cause to increase stress on the foot and can induce strains during walking.[14] Excess body weight puts stress on the knee due to changes in the biomechanics of the foot. Obese individuals have flatter feet with variations in inversion or eversion range of motion with a peak plantar pressure during walking.[15]

Associated with high foot loading, especially the forefoot and midfoot, the results after taking into account, foot mechanics and walking speed, the body weight significantly increased the pressure exerted to the foot either directly through increased body weight, or indirectly

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through changes in foot mechanics, which may explain the relation between obesity and the development of foot pain. Clinicians addressing foot problems should consider the impact of increased body weight on plantar loading in obese patients.[16]

Rafael ZA Pinto, et al., (2008), conducted a study on the bilateral and unilateral increase in calcaneal eversion affect on pelvic alignment while standing, and concluded that the influence of foot pronation onpelvic alignment during standing has not been clearly determined.[32.]

Dr. Pradnya Mahajan et al., (2021) had done a study on evaluating the effect of obesity on foot biomechanics and foot disability index in adult females and concluded that there was a significant change in calcaneal eversion, the angle of toe out (increased), and gastrocnemius extensibility (decreased) in overweight adult females.[17]

Ni Made Rininta Adi Putri et al., (2021) conducted a study on the correlation between the angle of calcaneal eversion and extensibility of gastrocnemius muscle with low back pain in obese women and concluded that there was a significant correlation between the angle of calcaneal eversion and extensibility of gastrocnemius muscle with low back pain.[19]

Pooja P Popat et al., (2014) had done a study on the biomechanical changes of ankle joint angle in overweight women and concluded that significant changes were observed in calcaneal eversion, angle of toe out increased and extensibility of gastrocnemius muscle decreased in overweight women.[23]

Megha Masaun et al., (2009) did a study on comparing the calcaneal eversion on extensibility of gastrocnemius muscle and angle of toe out between normal and overweight women and concluded that the angle of calcaneal eversion and angle of toe out were greater in overweight women while extensibility of gastrocnemius muscle was greater in normal weight women.[26]

The calcaneal eversion angle in overweight is significantly greater than in normal individuals indicating the potential for increased risk of lower limb injuries and complications. Several studies have found a strong relationship between increased body mass index and significant changes in foot structure and function, including an increase in calcaneal eversion angle.[17]

Overweight individuals may experience altered biomechanics during walking and running, which may increase the risk of foot and ankle injuries such as planter fasciitis, achilles tendinitis, and stress fracture. Monitoring calcaneal eversion angle in overweight individuals can help the healthcare professionals to design an appropriate interventions to prevent foot and ankle problems.[18]

Research has shown a correlation between calcaneal eversion angle and body weight, it cannot definitively say that weight causes changes in structure and function of foot, individual variability exists in the relationship between body weight and calcaneal eversion angle, and some overweight individuals may not experience significant changes in their foot structure.[18]

The objective of this study was to find the variation in the calcaneal eversion angle of the right and left leg between normal weight and overweight individuals. The hypothesis was that there would be significant variation in the calcaneal eversion angle of the right and left leg between normal weight and overweight individuals.

## II. MATERIALS AND METHODS

The institutional ethical committee approval was obtained before the study. All time, during the period of study ethical issues were followed with care and respect to words the “participant’s health”. Demographic data was obtained from all the subjects at the beginning of the study by using a data collection form as per inclusion criteria. The subjects meeting the inclusion criteria were selected and allocated to two specific groups. Normal weight individuals were allocated to Group A (n = 30) with BMI (18.5 to 24.9 $kg/m^2$) and overweight individuals were allocated to Group B (n = 30) with BMI (25 to 29.9 $kg/m^2$).

- **Inclusion criteria:** Female subjects between 18-26 years with normal and overweight with BMI of 18.5 to 24.9 $kg/m^2$ and 25 to 29.9 $kg/m^2$ respectively. Subjects were selected who could understand instructions and not regularly participated in physical and sports activities.
- **Exclusion criteria:** Subjects with a history of hip, knee, and ankle joint injuries. Congenital deformity of ankle joint, soft tissue injury in hip, knee, and ankle joint. Any neurological condition that affects tissue extensibility and balance. Limb length discrepancy, pregnant ladies, psychological problems.
- **Tool:** Calcaneal eversion angle.
- **Equipment used:** Universal goniometer, Ruler, Stadiometer, Marker, Steel Platform.

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Fig. 1: Universal goniometer, Ruler, Stadiometer, Marker, Steel Platform

- **Data collection:** The subjects signed the consent forms prior to the study. The participants were explained about the purpose of the study. The calcaneal eversion angle of the right and left leg was measured in every included subject of normal weight and overweight groups in the same session.
- **Calcaneal Eversion Angle:** The subject was positioned in prone with, foot out of the couch and a line was drawn from the midpoint of the calf to the midpoint of the calcaneus with reference to calcaneal tendon.

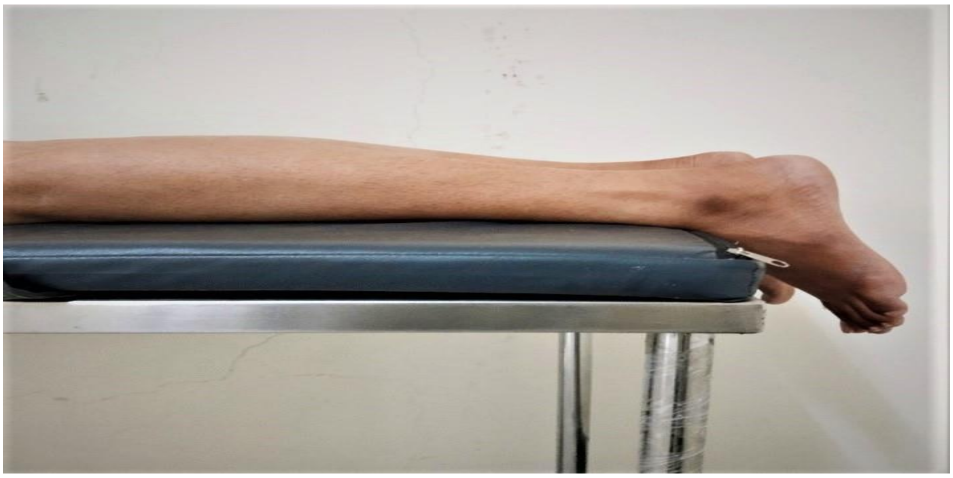


Fig. 2: Subject position

Fig. 3: Line drawn from midpoint of calf to midpoint of calcaneum

Then the subject was positioned in a bilateral weight bearing standing position on an elevated steel platform with both heels placed along the edge of the platform. The subject stood with full extension of the knee and relaxed on a raised platform.

A perpendicular line was drawn from the horizontal axis to measure the calcaneal eversion angle. The fixed arm of the goniometer was aligned in the horizontal axis and the movable arm was aligned with the line drawn from the middle of the calf to the midpoint of the calcaneus. The angle was recorded with reference to the perpendicular line. The Calcaneal eversion angle was recorded in both groups of right and left legs.

Fig. 4: Measurement of Calcaneal eversion angle

## III. RESULTS

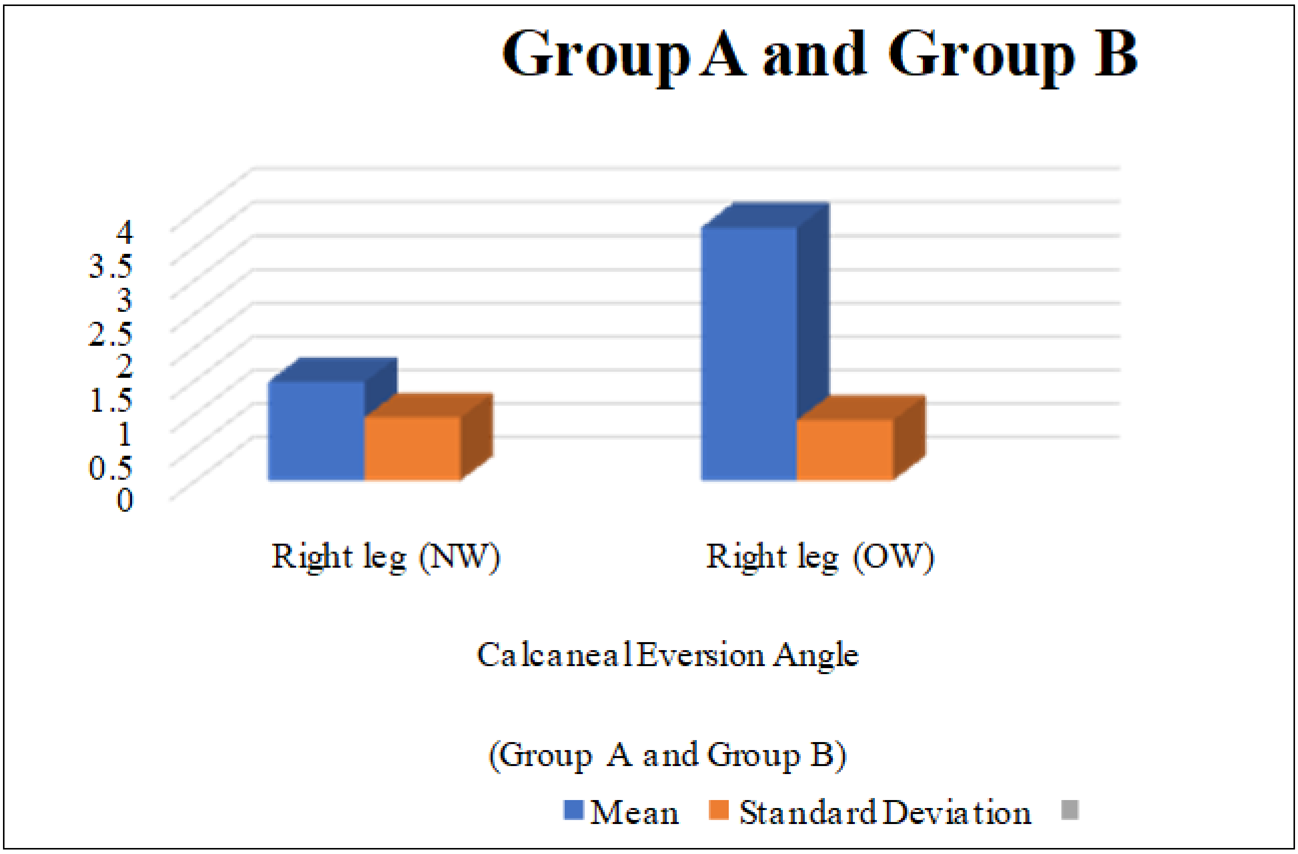
Unpaired t-test was used for analysis by using GraphPad software for both intra-group and inter-group. The result showed that the intra-group analysis of calcaneal Eversion Angle of Group A had statistically significant difference with $p \leq 0.05$ (p=0.0001), with mean 1.47 ± 0.94 for the right leg and 3.90 ± 1.21 for the left leg with t = 8.6931. The intra-group analysis of calcaneal eversion angle of Group B showed a statistically significant difference with $p \leq 0.05$ (p=0.0001), with a mean 3.77 ± 0.9 for the right leg and 6.30 ± 1.21 for the left leg with t = 9.2210.

The intergroup analysis of the Calcaneal Eversion Angle of Group A and Group B between the right legs showed a statistically significant difference with $p \leq 0.05$ (p=0.0001), with 1.47 ± 0.94 for the right leg Group A and 3.77 ± 0.90 for the right leg Group B with t = 9.7080. The intergroup analysis of the Calcaneal Eversion Angle between the left legs showed a statistically significant difference with $p \leq 0.05$ (p=0.0001), with a mean 3.90 ± 1.21 for left leg Group A and 6.30 ± 1.21 for left leg Group B with t = 7.6782.

- *Inter Group Analysis:*

Table 1: Mean and SD of Calcaneal eversion angle for Group A and Group B (Right Leg)

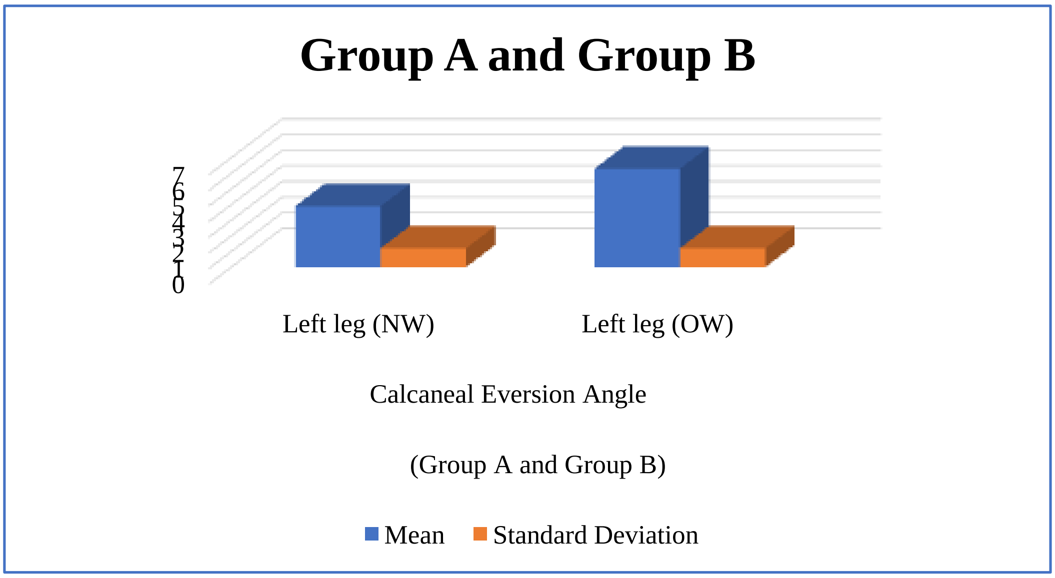
| | **(Group A and Group B)** | |
|---|---|---|
| | **Calcaneal Eversion Angle** | |
| | Right leg (NW) | Right leg (OW) |
| Mean | 1.47 | 3.77 |
| Standard Deviation | 0.94 | 0.9 |




Graph 1: Mean and SD of Calcaneal eversion angle for Group A and Group B (Right Leg)

Table 2: Mean and SD of Calcaneal eversion angle for Group A and Group B (Left Leg)

| | (Group A and Group B) Calcaneal Eversion Angle | |
|---|---|---|
| | Left leg (NW) | Left leg (OW) |
| Mean | 3.9 | 6.3 |
| Standard Deviation | 1.21 | 1.21 |




Graph 2: Mean and SD of Calcaneal eversion angle for Group A and Group B (Left Leg)

## IV. DISCUSSION

The present study was done to evaluate the variation in calcaneal eversion angle between normal and overweight individuals. Anand Heggannavar et al., (2016) did a study on the correlation between leg heel alignment, tibial torsion, and q angle amongst normal, overweight, and obese individuals and concluded that as weight increased, there were changes in Q angle, tibial torsion, and leg heel alignment. There was a significant difference between overweight and normal obese. Due to changes in joint angles in overweight women, there was a significant increase in calcaneal eversion. Pradnya Mahajan et al., (2021) did a study, evaluating the impact of obesity on foot biomechanics and foot disability index in female adults (18-26 years) and concluded with a significant variation in calcaneal eversion, angle of toe out (increased) and extensibility of gastrocnemius muscle (decreased) in overweight females. No variation was found in the foot disability index. Calcaneal eversion was more in overweight individuals due to excessive load which leads to more over pronation and it subsequently leads to alteration of the path mechanics of the foot.

Harris RL, Beath et al., (1992) T. hypermobile flat foot with short Achilles tendon suggested that extensibility of gastrocnemius muscle is less in overweight women and the excessive pronation was the lead cause. This caused the Achilles tendon to shorten and lead to instability of the subtalar and mid tarsal joints. Kristina Toman Kova et al., (2015) did a study on the effect of obesity on foot morphology in females and concluded that obesity affects all parts of the foot (heel, longitudinal foot arch, forefoot) and there was a significant difference in the central sensitization inventory between normal weight and overweight, which had confirmed being overweight and obese documents a high BMI having undesirable negative impact on the foot, possibly due to greater mechanical loads in the lower limb. It's thought that body fat, rather than changes in morphology and sturcture of foot, which in turn can cause an increased midfoot contact area and ultimately leads to collapse of arches. Aparna Sarkar et al., (2017) conducted a study on the impact of BMI on the biomechanics of adult female foot and concluded that a high BMI could influence the characteristics of the foot which may in turn predispose individuals to cause musculoskeletal pain. The calcaneal eversion was greater in overweight women but was not statistically significant, the angle of toe out was greater in overweight women and the extensibility gastrocnemius muscle was less in overweight women.

Pooja P. Popat, Ankur R. Parekh et al., (2014) did a study on the Biomechanical variation of joint angle in overweight women and concluded that the significant variation was found in calcaneal eversion, the angle of toe of toe out (increased) and extensibility of gastrocnemius muscle (decreased) in overweight women.

In the present study, the subjects were divided into Group A normal weight individuals and Group B overweight individuals. In Group A normal weight individuals, intragroup analysis, showed a statistically significant difference between the right and left leg with a mean value of $1.47 \pm 0.94$ and $3.90 \pm 1.21$ and $p \leq 0.05$ ($p = 0.0001$). In Group B, overweight individuals, the intragroup analysis, showed a statistically significant difference between the right and left leg with a mean value of $3.77 \pm 0.90$ and $6.30 \pm 1.21$ and $p \leq 0.05$ ($p = 0.0001$). The inter-group analysis of right leg values between the normal weight and overweight groups, showed a statistically significant difference with $p \leq 0.05$ ($p = 0.0001$). The inter group analysis of left leg values between the normal weight and overweight group, showed a statistically significant difference with $p \leq 0.05$ ($p = 0.0001$).

The results of the present study state that the calcaneal eversion angle in overweight individuals was more in both right and left legs when compared to normal weight individuals. On comparing the right and left legs of normal weight individuals, the left leg calcaneal eversion angle was more, when compared to the right leg and in overweight individuals the left calcaneal eversion angle was more compared to the rightt. This variation could be due to the dominancy of the side or due to excessive load on the leg. The suggested reasons are, foot overpronation where the medial arch is reduced or absent and is associated with reduced ankle dorsiflexion. The occurrence of the eversion of the calcaneus in which excess body weight impacts on the medial side of the foot and forces the longitudinal arch to collapse. Change in calcaneal eversion angle could be due to the extensibility of the Achilles tendon or the gastrocnemius, soleus and plantaris muscle. Another reason could be due to calcaneocuboid ligament laxity, the arch support is reduced and leads to the collapse of the arch, which alters the position of calcaneum and leads to increase in calcaneal eversion angle. There was variation in calcaneal eversion angle among the normal weight individuals those were professional roller skaters and skiers. The variation of calcaneal eversion angle among roller skaters and skiers, could be due to calcaneocuboid ligament laxity as the body weight totally falls on the medial aspect of foot and results in excessive pronation of the foot. Therefore the overweight and obesity are not only the predisposing factors but the day to day weight bearing activities also could result in variation of calcaneal eversion angle. Excessive pronation of calcaneum can cause cumulative stress on the skeletal system and can cause foot and ankle pain, which can affect proximal joints such as knee, hip, and spine, potentially leading to low back ache.

Hence when the calcaneal eversion angle of right legs between normal weight and overweight individuals and left legs between the normal weight and overweight individuals were compared, alternate hypothesis was accepted and the null hypothesis was rejected.

## V. LIMITATIONS OF STUDY

Only the female adult group was considered, and sample size was smaller. Dominant limb was not taken into consideration. Restrictions were not imposed from participating in physical and sports activities. Lifestyle activities were not analyzed.

## VI. CONCLUSION

In conclusion, the calcaneal eversion angle, when right and left legs were compared between normal weight and overweight individuals, showed a statistically significant difference.

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