ABSTRACT:

Purpose – Muscle imbalance is one of the leading factor causing collapse of the foot arch such as dysfunction of tibialis posterior muscle and tendon which causes tightness of gastrosoleus complex. Literature background suggests physiotherapy techniques that concentrate shoe modifications, taping and strengthening of intrinsic musculature of the foot. However, the factors such as tight extrinsic muscles of foot that include gastrosoleus complex are neglected and hence need to be concentrated along with conventional treatment. The objective of the study is to evaluate the combined effect of anti-pronation taping and gastrosoleus complex stretching in subjects with flexible flat foot.

Methods – 24 subjects were screened for flexible flat foot and 20 subjects underwent anti-pronation taping along with Gastroc-Soleus Complex stretch for 1 week and were assessed on Chippaux index, Transmalleolar Axis and Foot Posture Index. The readings were taken pre and post intervention on the specified outcome measures.

Results – Chippaux Index and Foot Posture Index scores showed statistically significant changes towards the correction of flat foot (p= 0.0001) whereas Transmalleolar Axis scores were not statistically significant(p= 0.6544)

Conclusion – Antipronation taping along with gastrosoleus stretching is an effective combination for flexible flat foot and should be included in the management of flat foot to further prevent complications.

Key words – Flexible Flat Foot, Muscle Imbalance, Gastroc-Soleus complex, Tibialis posterior, Anti-pronation Taping
INTRODUCTION
There are two major arches of foot longitudinal arch and transverse arch these arches plays an important role in maintaining the posture of foot. “These arches distribute the weight of the body evenly on the foot and also help during the gait during push off phase”. The collapse of the arches leads to variant changes on the sole wherein the medial sole of the foot comes to complete or near-complete contact with the ground causing flat foot.

According to a study performed in India, 10-20% females are affected more than the males of the total population. Flat foot is present in early age of life cycle but as the child grows changes in foot takes place and the foot forms the arches and gains normal posture. As the age progress the structure loses the strong integrity to hold the arch together and hence collapse of the arches are seen which results into flat foot. Some individuals (an estimated 10-20% of the general population) have an arch that simply never develops in one foot (unilaterally) or both feet (bilaterally) [1].

Flat foot can be presented as symptomatic and asymptomatic. Symptomatic foot will have pain due to collapse in arch whereas asymptomatic foot is pain free but arch is collapsed. Flat foot can also present as flexible and rigid foot. The most common form of flatfoot seen is flexible flat foot and is marked by an arch that reappears when foot is in certain posture or by simply hyperextending the Meta-torso Phalangeal joint in weight bearing.

Gastroc-Soleus complex is said be a complex because both have a common tendon which attaches to calcaneum the major action of both the muscle is plantar flexion of the foot. Together they function to provide efficient force during push off phase over a rigid lever formed by the action of tibialis posterior [2, 3]. Review of biomechanics shows one of the major causes of flat foot is posterior tibialis tendon dysfunction (PTTD) as tibialis posterior maintains the navicular position and hence supports medial arch, elongation of which results in collapse of arch hence resulting in flat foot. This dysfunction of tibialis posterior causes increased work load of gastrocsoleus which is contributing factor to the tightness of the gastrocsoleus muscle [4, 5].

In a normal foot the tibia is placed anteriorly when compared to fibula this formation is called Transmalleolar Axis (TMA)/Tibial torsion. Transmalleolar axis an angle which formed by connecting an imaginary line from the tip of the tibial malleolus to the fibular malleolus which intersects a horizontal line and creates an angle with the normal ranges varies from 0°-25° [6]. The transmalleolar axis is altered in pathological conditions i.e. in high arch foot it increases and in flat foot the angle reduces. This may be due to subtalar eversion and calcaneo-valgus which pulls the anteriorly placed tibia posteriorly and hence decreasing the TMA.

Foot deformities can be assessed by various methods which include traditional observation methods like Chippaux-Smirak Index, Foot Posture Index (FPI) and TMA. They also include assessment using application of sophisticated and expensive technologies like X-rays, Computerized Tomography scan which can be more valid but hazardous to the patient with unnecessary exposure to radiations. Observation methods are known to be safe and simpler methods while being reliable for evaluation of flat foot deformity.

Physiotherapy management for flat foot is strongly recommended especially when it is flexible and at initial stage to prevent further complication. Physiotherapy treatment includes Anti-pronation taping, bracing, shoe modification, strengthening of intrinsic muscle of foot. Anti-pronation taping is technique
which maintains the foot in neutral position and elevates the arch by elevating navicular bone, correction of calcaneo-valgus and hence helping the tibialis posterior muscle to function accurately by providing a rigid lever for gastrocsoleus complex [7].

All of these treatment methods have been concentrating on the correction of deformity (medial weight bearing, collapsed arch, and excessive pronation) and strengthening of intrinsic musculature of the foot but they do not concentrate on the tight structure like gastrocsoleus complex if ignored it can lead to permanent changes in foot. Hence, the current study concentrates on stretching of tight structures in combination as an adjunct to anti-pronation taping. The objective of the present study was to evaluate the combined effect of anti-pronation taping and gastrocsoleus complex stretching in subjects with flexible flat foot on Chippaux Index, Transmalleolar Axis and Foot Posture Index.

MATERIALS AND METHOD

Study Design and Setting:
The present study was single group pre post study design. A single trained investigator evaluated all subjects and collected all data to eliminate inter-investigator error. This was an experimental study conducted in Health Science University on professional volunteer student population of Belagavi Karnataka, India.

Study Participants:
A total of 20 Twenty volunteer participants (17 Females and 3 Males) with flexible flat foot were consecutively selected from the Health Science University, Belagavi, Karnataka, India. The participants were included based on the following criteria: 1) They should have flexible flat foot which was assessed by Jack’s test[8] in which participants were asked to bear weight and perform heel raise if the medial arch reappeared the test was positive. 2) Decreased transmalleolar angle (less than 20degrees in angle). 3) A positive foot posture index scores (greater than +5). 4) Age group of 18-50 years. The subjects were excluded from the study on the basis of the following criteria 1) Subjects with congenital deformities. 2) Subjects with the history of pain, surgery, trauma, fracture, dislocation in lower limb. 3) History of arthritic hip, knee and ankle complex. 4) Contraindication or allergy to rigid or kinesio tape. 5) Open wound or any skin disease around leg or ankle joint. 6) Subjects with any sensory loss or neuropathy.

Table 1: Distribution of participants based on demographic characteristics

<table>
<thead>
<tr>
<th>Factors</th>
<th>Number</th>
<th>Percentage/SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (M/F)</td>
<td>20(3/17)</td>
<td>(15/85)%</td>
</tr>
<tr>
<td>Sides (Left/Right)</td>
<td>20(9/11)</td>
<td>(45/55)%</td>
</tr>
<tr>
<td>Age (years)</td>
<td>22.65±2.35 (20-25)</td>
<td>1.46</td>
</tr>
<tr>
<td>Height (centimeters)</td>
<td>156.5±12.5 (143-170)</td>
<td>9.49</td>
</tr>
<tr>
<td>Weight (Kgs)</td>
<td>66±19 (47-85)</td>
<td>14.76</td>
</tr>
<tr>
<td>BMI(Kg/m²)</td>
<td>26.9±8.1(18.80-35.00)</td>
<td>4.51</td>
</tr>
</tbody>
</table>
Ethical considerations:
The study was approved by Institutional Research and Ethics Committee of KAHER Institute of Physiotherapy, JNMC, Nehru Nagar Belagavi, Karnataka, India. (Research and ethical committee, KIPT/95/16-10-17). Permission was obtained from the institutional head for the involving volunteer student participants with flexible flat foot in the study. This followed institutional guidelines according to the principles of the Declaration of Helsinki. All subjects completed the entire intervention programme. The individuals in this manuscript have given written informed consent to publish these case details. Their anonymity and confidentiality were assured and all the procedures were performed in compliance with relevant laws and institutional guidelines.

Outcome measures:
All the selected subjects underwent a pretreatment and post treatment baseline assessment using Chippaux Index, Transmalleolar Axis and Foot Posture Index. Readings were recorded pre- and post-intervention (readings were recorded on the 7th day after the removal of tape) and were allotted in a single group where they received both the treatment i.e. anti-pronation taping and stretching of the gastrocnemius and soleus separately.

Foot Posture Index
It is diagnostic clinical tool aimed at quantifying the degree to which a foot can be considered to be in a pronated, supinated or neutral position. It consists of 5 observational tasks and a palpation method for the examination on which final conclusion is made. The readings were taken as instructed in the module-6 where talus placement was palpated and rest of the components was observed and were graded as instructed. (Inter-tester reliability 0.62-0.91, intra-tester reliability 0.81-0.91) [9, 10].

Chippaux Index
Frequently used test to assess the flat foot by calculating the narrow base divided by broad base area multiplied by 100. The participants were assessed pre and post by taking the foot print of the affected foot with the application of ink and then immediately were asked to stand on A4 paper which was collected. The readings were taken by measuring the broad area and narrow area by a standard ruler in centimeters. The calculation was done by dividing the narrow area by broad area and multiplying the score into 100. (AUC 0.83 and Sensitivity 94.2%) [11–13].

Transmalleolar Axis
Tool to check the axis of talocrural joint with respect to the two malleoli which increases and decreases in foot pathologies and remains around 20-25 degrees in normal. The axis were taken on A4 size paper on which the patient were asked to stand and an outline of the foot were marked using a pencil and the malleolar marking were done by placing the pencil parallel to malleolus the markings were made on the paper once the tip of malleolus is parallel to pencil. The two markings were connected by a line which intersects a horizontal line and makes an angle which was quantified in degrees and recorded pre and post intervention [Fig.1] [14, 15].

Intervention procedure
All the participants received both the treatment i.e. stretching and taping. The subjects were taught self-stretching of Gastroc-Soleus complex and received taping and passive stretching for three times on alternate days over 1 week.
**Gastrocsoleus complex stretching:** Stretching was given for gastrocnemius and soleus separately for 30 sec hold and in 3 sets prior to taping and then they were taught self-stretch for the same. The individuals received passive stretching on the day tape was applied and were instructed to do active stretch at home.

Passive stretching: The position of therapist was at the foot end of couch on the affected side. The therapist clasped the patient’s heel (calcaneus) with the hand which is towards the foot, and place forearm along the plantar surface of the foot, the therapist applies pressure cephalically from its forearm to the plantar aspect and simultaneously pulls the calcaneus caudally and stabilizes the knee joint with the other hand so that it does not flex while performing the stretch. Three sets of 30 second stretches each separated by 10 second rest is given for 6 days in a week [fig.2a.] To eliminate the effect of the two-joint gastrocnemius muscle, the knee must be flexed. Hand placement, stabilization, and stretch force remain same as when stretching gastrocnemius for Solues [fig.2b] [16].

Active stretching: Subjects were asked to stand facing a wall with foot pointed forward. Place your palms against the wall and step your right foot back. Were instructed to flex there left knee, keeping contralateral (the side to be stretched) knee straight and heels flat on the muscles the right foot was flexed (the side to be stretched) and the same procedure was asked to floor. They were instructed to stop when they felt stretching in the calf muscles and were asked to hold for 20 to 30 seconds. Repeat three times, and then switch legs. To eliminate the two joint perform by the participants [17].

**Anti-Pronation Taping:** Taping was given with rigid tape for 3 times a week with an interval of 2 days i.e. on every 2nd day the old tape was removed and a fresh tape was applied. Position of patient: The patient will be in supine lying or long sitting position on treatment couch where patient’s foot is out of the plinth. The therapist is at the bottom end of couch on the affected side. Pre wrap was applied prior to the application of tape [fig.3]. Intervention - (1) The foot is positioned in approximately two-thirds supination and the first ray plantar flexed. 1st strap of tape is applied from the medial aspect of the neck of the first metatarsal till the lateral aspect of the neck of the fifth metatarsal covering the medial, lateral and posterior border the tape is ‘U’ shaped. The strap is applied with the forefoot slightly adducted. 2-3 mini-strap were applied on the plantar aspect from the lateral aspect to the medial aspect of the foot (from the tape which was applied from medial to lateral). (2) An anchor is then applied one-third up the length of the leg, with application of a circumferential strip. Each reverse six is applied from the medial malleolus, directed laterally across the dorsum of the foot, under the midfoot in a lateral-to-medial direction, then crossed over its origin and continued up to the anchor strip. (3) Each calcaneal sling is applied from the anterior aspect of the anchor, coursed distally and posteriorly over the medial Achilles tendon, around the posterior lateral calcaneum, under the calcaneum and midfoot, and, finally, coursed proximally up the anteromedial aspect of the distal leg to insert on its origin. (4) The finished taping technique consisting of three reverse six and two calcaneal slings [fig.4] [7].

**Statistical analyses**

Statistical analyses were performed using SPSS 21.0 statistical package (SPSS Inc.). The Kolmogorov–Smirnov test was used to analyze normally distributed continuous variables. The descriptive statistics was expressed as mean ± standard deviation for the continuous variables and in terms of the number of patients and percentage for the categorical variables. Dependent t-test was applied for the analysis of pre- and post-treatment for all variables since they followed normal distribution. $P < 0.05$ was considered statistically significant. The three outcome measures which were taken to calculate the pre and post data were Chippaux Index.
Transmalleolar Axis and Foot Posture Index. Sample size was calculated on the basis of prevalence of flat foot in India by the method which seeks changes before and after the treatment $2+\{SD/d\}^2\times[Z_{1-\alpha/2}+Z_{1-B}]^2$. So standard deviation value (as from the prevalence study conducted by Aenumulapatti A et al) [1] is 13.06%. Assumed value of ‘d’ is 10 %. $Z_{1-\alpha/2}$ is 5% error i.e. 1.96. $Z_{1-\beta}$ is power of the study was taken as 90% i.e. 1.282 so by substituting value we get the score of 19.80 rounding off it will be 20. 20% extra sample is to be calculated to eliminate dropouts that will be 4. Total sample size is 20+4= 24

RESULTS

Total of 24 subjects was screened and included in the study on the basis of inclusion and exclusion criteria out of which only 20 were taken into the study (There were no dropout). Table 1 depicts the demographic characteristics of study participants. There were 3 males (15%) and 17 females (85%) by this data we can say the females are more effected than the males. There were 9 (45%) participants with left side affected and 11 (55%) with right side affected. The mean age was calculated to be 22.65±2.35years, the mean height of the participants was 156.5±12.5cms, the mean weight was 66±19kgs and the Body Mass Index (BMI) was 24.63kg/m². There were 50% of subjects with normal BMI and 50% subjects with higher BMI. It was found and observed that the subjects with normal or lower BMI improved better than subjects with high BMI.

Table 2 depicts the comparison of pre and post-test values for 3 dependents variables used in the study. Significant difference were noted for Chippaux Index scores ($p=0.0001$) and FPI ($0.0001$) when pre and post intervention value were compared, however the TMA did not show statistically significant change [Fig.5].

<table>
<thead>
<tr>
<th>Outcome measure</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>Mean difference</th>
<th>SD difference</th>
<th>Change (%)</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chippaux index scores</td>
<td>64.84</td>
<td>64.54</td>
<td>10.70</td>
<td>3.86</td>
<td>16.50</td>
<td>12.401</td>
<td>0.0001*</td>
</tr>
<tr>
<td>Foot posture index</td>
<td>8.70</td>
<td>5.55</td>
<td>3.15</td>
<td>0.81</td>
<td>36.21</td>
<td>17.333</td>
<td>0.0001*</td>
</tr>
<tr>
<td>Transmalleolar axis</td>
<td>6.70</td>
<td>7.40</td>
<td>-0.70</td>
<td>6.88</td>
<td>-10.45</td>
<td>-0.454</td>
<td>0.6544</td>
</tr>
</tbody>
</table>

SD: Standard deviation. *Statistically significant

DISCUSSION

The purpose of the study was to evaluate the combined effect of anti-pronation taping and Gastrocsoleus Complex stretching in subject with flexible flat foot on Chippaux Index scores. The current study has concentrated on lengthening of gastrocsoeleus complex muscle along with the correction of the foot with anti-pronation taping which shows a significant on
improvements in terms of Chippaux Index and FPI. According to Chippaux index improvement was noted thru increased arch height ratio and the improvement in the form of reduced pronation of the foot was noted according to FPI.

The current study had more number of female(85%) participants when compared to the male(15%) counterpart (17 female and 3 males) which is in Accordance to the finding of study done by Aenumulapalli A et al, 2017 who studied the prevalence of flat foot in India. The author concluded female are comparatively more affected than the male.[1] A probable reason for higher prevalence of flat foot in females could be due to the wide pelvis in them this increase in pelvis width can cause coxa vara. Coxa vara aligns the femur medially in relation to the tibia which, thereby leads to an increase in the Q – angle. The resultant genu valgum produces a direct increase in load placed at the medial aspect of the foot, which is exaggerated on dynamic weight bearing activities [18, 19]. Prolonged medial weight bearing at the foot leads to structural changes over a period of time. The foot attains a pronated position which causes flattening of the medial arch.

In the current study, the statistical analysis of correlation between BMI and flat foot was not done. However, on observation of the results the subjects who had lesser BMI showed a greater improvement in pre and post values of outcome measure when compared to subjects with higher BMI. BMI has been co-related with flat foot in a study by Vijayakumar K et al, 2016. The authors stated increased fat mass over the body that causes the raise in the BMI leads an exertion of greater force over the sole of the foot. Obesity not only affects the foot by causing pain it also leads to other musculo-skeletal problems which in turn results in disturbances and muscle imbalances in weight bearing joints.[20]

The posterior tibialis tendon functions to invert the subtalar joint adduct the forefoot and stabilize the longitudinal arch. It acts as a rigid lever at midfoot over which the hind foot elevates by contraction of the triceps surae. Dynamically, dysfunction of the posterior tibialis tendon ultimately leads to an inability to stabilize the transverse tarsal joints sufficiently.

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Fig 5: Comparison of pre and post-test Chippaux Index, Foot Posture Index and Transmalleolar Axis scores
enough to allow the heel to rise relative to the forefoot which causes over-activity of Gastrosoleus complex. At hind foot causes pronation of foot due to unopposed peroneus brevis, which causes eversion of calcaneus at the subtalar joint as it continues to drift laterally, bounds initially against the anterolateral shoulder at the talus, blocking the sinus tarsi, and then against the lateral malleolus with increasing heel eversion. With longstanding valgus, the Achilles tendon shortens and becomes contracted, providing an additional valgus deforming force at the subtalar joint [5].

The results of the present study demonstrated, significant improvement in flat foot measures with gastrosoleus complex stretching. When a muscle is stretched or pulled, both longitudinal and lateral force is transmitted to the muscle via endomysium and perimysium. When initial lengthening occurs in the series elastic component, tension rises sharply. There is another explanation indicating neural and biochemical changes in muscle. There is disruption of the cross bridges as the filaments slides apart, leading to initial lengthening in series in elastic component is followed by abrupt lengthening of sarcomere. When this stretch force is released, the individual sarcomeres return to their resting length. If more permanent length increases are to occur, the stretch force must be maintained over an extended period of time. [16]

Another reason could be explained through a study conducted by Farnettovich M et al. 2008 where the authors assessed the effects of anti-pronation taping technique on medial arch and EMG activity of extrinsic foot muscles. The authors convened that anti-pronation taping not only improves the medial arch support but also reduces the activity of the extrinsic muscle of foot which correlate in the reduction of over activity of gastrosoleus muscle at foot during the heel off phase. This finding can be correlated to the present study that addition of gastrosoleus complex stretching along with anti-pronation taping helps in improving the scores of the foot. [21]

Based on critical review by Farnettovich M et al. 2008, anti-pronation tape changes foot and leg posture statistically and possibly dynamically by increasing navicular height and arch height ratio. In addition it causes reduction in the tibial internal rotation and calcaneal eversion and alteration in plantar pressure patterns. This can be explained biomechanically as the application of tape elevates and supports the navicular bone which apparently increases the arch height ratio. The correction of the calcaneus eversion can be seen because of this taping technique maintains the neutral position of foot and causes changes in weight bearing of the foot. Following can be possible factor in the current study which showed the positive changes in all the outcome measure. [7]

The therapeutic dose for stretching of Gastrosoleus complex was given in the present study [22] which was 30 seconds hold with 3 sets this therapeutic dose was chosen according to the study done by Bandy W et al. here the authors have compared 5 different doses of stretching on hamstring muscle in order to find the best dose for stretching. The author concluded that 3 sets of 30 seconds stretch or 2 sets of 60 seconds were the most effective of all the 5 doses.

**LIMITATION**

The present study had a few limitations. The present study tried to find combined effect of taping and stretching and hence there was no control group to compare the results. Inclusion of the control group would have reflected stronger evidence in research. However, specific inclusion of stretching for gastrosoleus complex which is an extrinsic foot muscle has not been studied before. Hence a preliminary study was conducted with single group pre and post study design. A long term follow up was not done to study the carryover effect owing to greater loss to follow up. The transmalleolar axis did not show any improvement. Longer duration
of treatment for up to 6 weeks might show significant changes.

CONCLUSION

The current study conclude that due to the muscle imbalance in the musculature of foot causes weakness of Tibialis Posterior (dysfunction) leads to the tightness Gastroc-Soleus muscle addition of stretching for Gastrocsoleus is significantly effective for the treatment of flexible flat foot when given in combination with Anti-pronation taping should be included in the management of flat foot to prevent further complications.

Future studies may include comparison with a control group and inclusion of more sophisticated assessment tools like EMG activities of gastrocsoleus complex and tibialis posterior and Center of pressure analysis.

ACKNOWLEDGEMENT

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CONFLICT OF INTEREST

There is no conflict of interest to be declared.

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