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Research Article

To Evaluate the Effect of on a Flatfooted Person's Energy Expenditure While Walking on a Different Plane and Effect of Concentric and Eccentric Exercise in the Rehabilitation of Flat Foot: Case Study

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Abstract

Introduction: A flat foot is deformity that occurs when the arch of the foot collapses and makes touch with the ground, a flat foot deformity results. It is also known as the pes planus deformity and can happen at birth or over time, usually as a result of ageing or injury. Foot arches are crucial for healthy foot movement and contribute suppleness and flexibility. Intense foot discomfort in the feet, ankles, and lower leg muscles can result from a falling arch.

Objective: Effect of concentric and eccentric exercise along with medial arch support on the energy expenditure while walking on a different plane in a patient with flatfoot.

Design: Case study

Subject: 1

Method: A 21-year-old male with 68 kg body weight was selected for study who is suffering from bilateral rigid flatfoot and the subject is prescribed conventional exercises protocol for 25 days and preferred to wear a medial arch support insole the data has been collected prior to the intervention and post intervention and was compared for the result.

Results: The result were calculated using 3 outcome measure *i.e.* Modified Borg scale, functional severity scale and pulse oximeter which show significant reduction in exertion while walking, fatigue and heart rate respectively when compared with pre intervention data.

Conclusion: By the virtue of the study, we concluded that the heart rate, exertion while walking and fatigue is significantly co-related with the use of short foot exercises, concentric, eccentric exercise and use of medial arch insole. And addition of all of the above mention protocol helped into correction of bilateral rigid flatfoot is proved to be effective in order to reduce the fatigue and discomfort to some extent.

Keywords: Bilateral, Rigid flat foot, Heart rate, Medial arch support, Short foot exercises, Fatigue

INTRODUCTION

The ankle is the part of the lower limb encompassing the distal portion of the leg and proximal portions of the foot. The ankle encompasses the ankle joint, an articulation between the tibia and fibula of the leg and the talus of the foot (Flores DV, et al. 2019).
The human foot has 26 bones, 10 major extrinsic tendons and their respective muscles, numerous intrinsic musculotendinous units, and more than 30 joints. These musculoskeletal structures work together with the neurovascular elements, fat pads, and skin to provide a mobile, sensate, adaptive foundation during standing and to provide a means of balance and locomotion during gait. To allow the foot to maintain standing weight and absorb impact, store and release energy, and adjust to shifting loads during exercise, these structure must work to get the bony alignment creates three arches which provide efficient weight distribution while avoiding compression of plantar neuro-vascular structures.

Arches of foot

The foot contains three arches: One front transverse arch, two longitudinal (medial and lateral) arches. The ligaments and tendons in the foot support these arches, which are created by the tarsal and the arches shape is created similarly to a spring; it supports the weight of the body and absorbs the shock caused by movement. The flexibility of the foot provided by the arches makes it easier to perform regular locomotors activities like walking and sprinting (Jayakumar S, et al. 1977). The energy-saving spring theory of the foot's arch has emerged as a key concept in explanations of the mechanical behavior and evolutionary history of the foot.

Anatomy of arches

The arches are classified into
Longitudinal

- Medial longitudinal
- Lateral longitudinal

Transverse

- Anterior
- Posterior

Function of arches

- The arches of the foot distribute body weight to the weight-bearing areas of the sole, mainly the heel and the toes. Out of the latter, weight is borne mainly on the first and fifth toes. The lateral border of the foot bears some weight, but this is reduced due to the presence of the lateral longitudinal arch.
- The arches act as springs (chiefly the medial longitudinal arch) which are of great help in walking and running.
- They also act as shock absorbers in stepping and particularly in jumping.
- The concavity of the arches protects the soft tissues of the sole against pressure.
- The character of the medial longitudinal arch is resiliency and that of the lateral longitudinal arch is rigidity (Karimi MT, et al. 2013).

Medial arch

The medial arch is the higher of the two longitudinal arches. It consists of the first, second, and third metatarsals and also the calcaneus, talus, navicular, and three cuneiforms. Its peak is located at the superior articular surface of the talus, and its two extremities, or piers, are the heads of the first, second, and third metatarsal bones anteriorly and the tuberosity on the plantar surface of the calcaneus posteriorly, on which it rests when standing (Ravichandran H, et al. 2022).

Due to its height and the numerous tiny connections that connect its individual pieces, this arch's main trait is elasticity. The joint between the talus and navicular is its weakest point, making it the part most likely to give under excessive pressure, but this area is supported by the plantar calcaneonavicular ligament, which is elastic and can quickly return the arch to its ideal state when the disturbing force is removed (Huang YP, et al. 2017).

The Tibialis posterior tendon, which is spread out in a fan-shaped insertion and prevents excessive tension of the ligament or such an amount of stretching as would permanently elongate it, supports the ligament inferiorly and strengthens it medially by blending with the deltoid ligament of the ankle joint. The plantar aponeurosis, the little muscles on the bottom of the foot, the tendons of the Tibialis anterior and posterior and Peroneus longus, as well as the ligaments of all the involved articulations, all contribute to supporting the arch.
Pes planus is a common condition in which the longitudinal arches have been lost. Arches do not develop until about 2-3 years of age, meaning flat feet during infancy is normal (Zhai J, et al. 2021).

A very common foot deformity known as pes planus, or "flat feet," is characterized by the lack of the medial longitudinal arch of the foot where it touches or almost touches the ground.

Flat foot describes the common end point of any abnormality that causes the medial longitudinal arch to collapse. Flatfeet can cause severe symptoms or be asymptomatic. Flat foot is now considered a normal variant assuming it functions in its normal capacity without symptoms (Bac A, et al. 2022).

Rigid flat foot

The arch never appears in a stiff flat foot. Adult-acquired flatfoot is another name for this ailment, as is posterior tibial tendon dysfunction. The posterior tibial tendon, which joins the calf muscle to the inner foot bones, weakens, which leads to the development of this kind of flat foot (Roth S, et al. 2013). This tendon's primary function is to stabilize and support your walking arch. You may acquire a collapsed arch, which ultimately leads to a flat foot, if your posterior tibial tendon becomes ripped, strained, or irritated as a result of an injury or overuse. As a result, you can feel discomfort and swelling on the inside of your foot and ankle. Simple movements become difficult and high-impact activities become impossible because this pain worsens with activity. Women who are pregnant or over 40 are more likely to have rigid flat feet. Also, there is an increased risk for athletes and individuals with medical disorders such uncontrolled diabetes, rheumatoid arthritis, uncontrolled hypertension, and obesity.

The medial longitudinal arch of a healthy foot raises and lowers cyclically throughout the gait cycles. The arch decreases slightly during the majority of the stance period as the body weight is gradually loaded. Structure that prevent the arch from lowering help to absorb body weight stress and hence protect the foot, particularly its osseous structure. The subtalar joint pronates or events throughout the first 30-35 percent of the gait cycle, giving the midfoot some flexibility.

By late stance, the arch rises as the supinated subtalar joint renders the midfoot relatively rigid. The foot is now well prepared to withstand a considerable bending moment exerted across the foot is its capacity to shift from a flexible and shock-absorbing structure to a more rigid lever throughout each gait cycle. The subtalar joint is the primarily joint of pronation and supination kinematics in the foot. Pronation is a kinematics process in which the dorsiflexed talocrural joint and the slightly supinated subtalar joint rapidly planter flex and pronated at the subtalar joint during stance. The ground response force passes just lateral to the anterior posterior axis of rotation through the calcaneus, causing it to tip into eversion. The head of the talus is also pushed medially in the horizontal plane by the simultaneous impact of heel contact. the talus abducts and dorsiflexes the subtalar joint in relation to the calcaneus. These movements are compatible with pronation definition. Second, after initial heel contact, the tibia and fibula, and to a lesser extent the femur, inwardly rotate throughout the stance phase. The internally rotating lower limb leads the subtalar into addition pronation due to the embracing arrangement of the talocrural joint. The dysfunction arises in the foot due to alteration in shape and reduce deficiency of supporting structure. Supporting structure including PTT, accessory navicular bone, spring ligament, sinus tarsi, deltoid ligament, plantar fascia, tarsometatarsal joint due to dysfunction in these structure leads to abnormal weight distribution throughout the foot. Such imbalance forces and loss of supportive structure can lead to collapse of arches.

During typical speed walking, the amplitude of pronation at the subtalar joint is only about 2 to 3 degrees on average and lasts only about ¼ of a second. The kinematics of the more proximal joints of the lower extremities are influenced by degree and speed of pronation. During weight bear standing position, the lower leg internally rotates with pronation at subtalar joint simultaneous dropping of MLA. This mechanism if applied with enough force it ends to rotates the hip internally with slight flexion and adduction at the hip joint and put valgus strain on the knee. So due to uncontrolled pronation the entire lower limb biomechanics get affected causing various condition such as shin splint, scoliosis, patella-femoral joint syndrome etc. During supination which occurs at 35% of the gait cycle if a person remains relatively pronated during late stance can affect the stability at midfoot which eventually result in increased demand on intrinsic and extrinsic muscle of the foot to reinforce MLA to clear the push off phase and thus due to over activity of the muscle can lead to generalized muscle fatigue (Shams A, et al. 2023).

MATERIALS AND METHODS

A young male of age 21 years with 68 kg weight and was presented by bilateral rigid flatfoot was recruited for this study. Navicular drop test was carried out to check the flatfoot on the both the lower limb. Then a pre–test was performed on a different level of plane on the basis of Borg protocol for rate of perceived exertion and heart rate were calculated using pulse oximeter and a questionnaire of Fatigue severity scale was asked to fill. A 25 days of conventional exercise protocol was given to patient which includes short foot exercise, towel scrunch, plantar fascia and calf stretching, toe extension, heel raises, stair raises.

Every exercise performed 7 days a week and at least 2-3 times a day for 25 days by the patient with medial arch support was given to the patient.
The post-test was conducted after 25 days of protocol and measurement were taken and compared with pre-test values for the result and conclude the study.
Outcome measure

- Pulse oximeter.
- BORG scale for RPE.
- Fatigue severity scale for level of fatigue.

RESULTS

The result was evaluated on the basis of 3 outcome measure which are

- Pulse oximeter for heart rate.
- Modified borg scale.
- Fatigue Severity Scale (FSS).

There is also a reduction of low back pain in patient because of use of medial arch support.

Figure 1 show the data of heart rate evaluated using pulse oximeter on two different level of inclination on the basis of modified bruce protocol. Data was evaluated prior to the inclination that is day 0 to after the intervention that is day 25 (Table 1).

Table 1. It shows significant effect on heart rate with conventional exercise.

Level	Duration (min)	Day 0 heart rate (bpm)	Day 25 heart rate (bpm)
1 (walk on a plane surface)	5	107	100
2 (stair climbing)	5	112	108

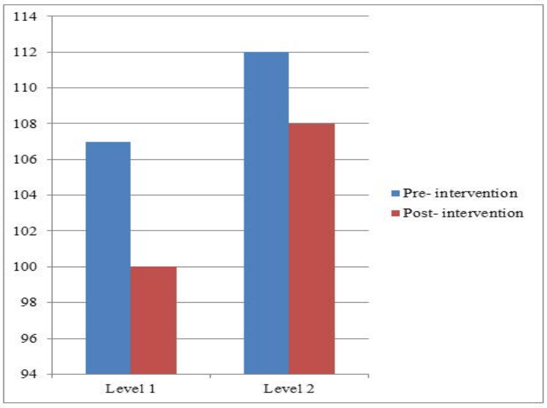

Figure 1. For heart rate.

Figure 2 shows the data of rate of perceived exertion evaluated using modified Borg scale on three different level of exertion. Data is according to before and after the intervention (Table 2).

Table 2. Data is according to before and after the intervention.

Level	Duration (min)	Day 0	Day 25
1	3	0.5	0
2	3	3	0.5
3	3	4	0.5

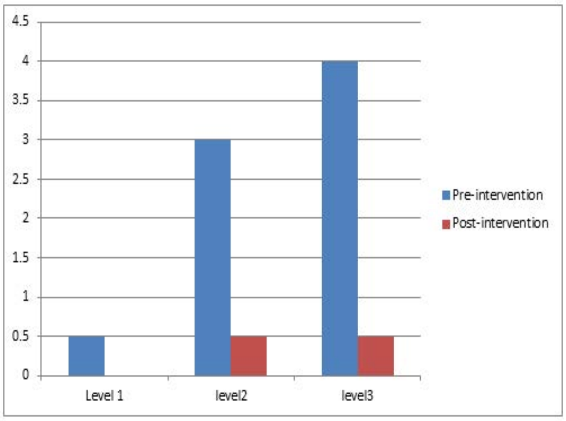

Figure 2. Rate of perceived exertion.

Figure 3 shows the data collected for level of fatigue severity scale which is self-report scale having 9 components and each component is having 7-point grading (Table 3).

Table 3. It shows significant reduction in level of fatigue in subject from bilateral rigid flatfoot.

Fatigue	**Pre-intervention**	**Post-intervention**
score	46	35

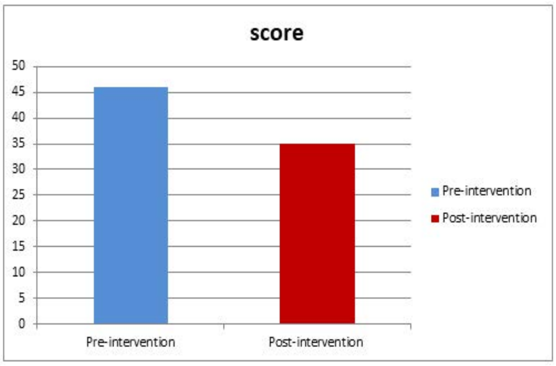

Figure 3. Shows the data collected for level of fatigue severity scale.

DISCUSSION

The following discussion intend to explain observation made and result obtained through this study in light of evidence. The study was done to see the effect of conventional exercises on heart rate, rate of perceived exertion and fatigue in patient suffering from bilateral rigid flatfoot. In this case study a male of age 21 with 68 kg weight suffering from bilateral rigid flatfoot was recruited.

The result showed that there is significant effect in lowering the heart rate, rate of perceived exertion and fatigue (Alowais FA, et al. 2021).

The possible reason is regaining strength and improved biomechanics of the foot.

Evidence of R. I. Harris and Thomas Beath shows that congenital rigid flatfoot occurs due to genetic factors and due to loss of medial longitudinal arch and The most common causes are two anomalies of the bones of the tarsus-the calcaneonavicular bar, and the talocalcaneal bridge. The first was described in 1921 by Sloman and in 1927 by Badgley; the other is described for the first time in this paper as an etiological factor in rigid flat foot though it has been recognized by anatomists for fifty years as a skeletal variation.

Mohammad taghi Karimi 2013 shows that in comparison to average people, flat-footed people consumed much less energy. The flat-footed people walked more effectively after wearing a foot insole. Hariharasudhan Ravichandran 2022 shows that the medial longitudinal arch might be improved by both

eccentric and concentric activities in participants with flexible flat feet. It is advised that future studies include long-term follow-up to validate the findings of this investigation. Abha kishty presents that a Short Foot Exercise is more effective in improving Medial longitudinal arch intrinsic muscle activation as compare to other conventional exercises. The 4-week Short foot exercise program improved foot intrinsic muscle activity in people with flat foot.
So by the use of these articles, we used exercise and medial support arch in protocol which gives a good result in patient with no side effect and there is significant effect is also seen in patient.

We have used Navicular drop test, foot posture index -6 to confirm the flat foot and outcome measures are Fatigue severity scale, Modified Borg scale, Pulse oximeter. These outcomes measures are used before after intervention and differentiate its result and the effectiveness of the conventional exercise with medial arch support. And the significance of the exercises and medial arch support is found to be effective while walking in a different plane like walking and climbing stairs.

CONCLUSION

By the virtue of the study, we concluded that the heart rate, rate of perceived exertion and fatigue significantly co-related with the use of medial support arch. And with use of conventional exercises protocol into correction of bilateral rigid flatfoot is proved to be effective in order to reduce low back pain, heart rate, RPE, and fatigue to some extent.

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