

Medical Device Prototype for Planter Intrinsic Muscles: A Scientific Note

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Abstract

Background: Intrinsic foot muscles are the contributors in the medial longitudinal arch and weakness of these muscle contributes to range of foot deformities but the level of weakness is still unknown as there is no valid and reliable method available to measure the strength of these muscles. Previous efforts to quantify these muscle strengths were done like toe dynamometry, planter pressure etc. All such instruments made do not consider two major biomechanical consideration 1. Position of Metatarsophalangeal Joint and 2. Position of Ankle joint which is very important for keeping extrinsic foot muscle in disadvantage and no effort was made to isolate the intrinsic muscle during measurement

Methods: The present prototype is designed to measure the forces of the planter intrinsic foot muscles for research and clinical purposes All the considerations which was not taking care of in previous design considered in the present design of our prototype.

Conclusion: Our device is one stop destination for the assessment and treatment of planter intrinsic muscle where we can measure their strength and also strengthen them on the same platform by various exercises and strengthening and therapeutic devices.

Key words: Ankle Joint, Metatarsophalangeal joint, Planter intrinsic muscle, Toe dynamometry

Introduction

According to Leonardo da Vinci 'The human foot is a masterpiece of engineering and the work of art' the reason he says so is possibly due to the complex nature of the foot with numerous articulations in its credit and its capacity to provide us a static posture as well as do important role in dynamic actions due to its various degree of freedom¹ In the process of evaluation from quadrupedal to bipedal stability component of foot overpower the grasping function with the development of arches ^{2,3} which require some external static (provide by

ligaments and fascia) and dynamic (provide by extrinsic and intrinsic muscles of foot) support to prevent them from collapse

The concept of core stability to the arch of the foot and as there is local stabilizers and global movers in spine this article classifies the intrinsic muscle of foot as local stabilizers and extrinsic muscle of foot as global movers of foot.¹ Weakness of Intrinsic foot muscle can cause foot deformities and disorders ^{4,5}

For the measurement of the intrinsic muscles strength of the foot there is a need for exact measurements of these muscles in isolation. Earlier researchers had used a various direct method for the quantification of intrinsic foot muscles. Most studies have measured toe flexor force using fixed hand-held dynamometry, ^{6,7,8} force Plate, or various special test were used like Paper Grip and Intrinsic Positive Test. ^{9,10,11,12,13,14} The

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different types of toe dynamometry which is used, a toe curling action can occur during toe flexor measurement, which activate the long (extrinsic) toe flexors. Position of ankle is another important consideration overlooked by the previous designs as most of the extrinsic toe flexor become short in plantarflexion of ankle and less likely to influence the movement.¹⁵

Apart from these direct methods some indirect methods were also used to assess the intrinsic muscle strength like Electromyography (EMG), Computerized tomography ultrasound and magnetic resonance Imaging.¹⁶⁻¹⁸ all these indirect methods can differentiate intrinsic and extrinsic muscle but cannot quantify them. These literatures suggest that there is no valid and reliable method available to quantify the intrinsic muscle of the foot. The main challenges are to limit the role of the extrinsic muscle of the foot and also isolate the intrinsic muscle.

There is a need to design a mechanism which will take care of above discussed biomechanical consideration and also before finalize the design isolate the intrinsic muscle

by the help of any of the clinical method so that device can efficiently measure the intrinsic muscle of the foot.

Materials and Methods:

The present Prototype is a Novel Design which is not inspired by any other medical device designed to measure the intrinsic muscle strength. The device is made up of wooden and iron and the base is covered by the carpet. Quantification of the intrinsic foot muscle is done by the The Saehan Hydraulic Hand Dynamometer¹⁹ device with a slight modification, that was securely kept in an angle on a wooden frame.

Design: The design of the instrument is according to the biomechanical consideration which are deficient in previous design before going forward for the design the force analysis of the instrument was done with the help of ANSYS designing software.

The structural analysis was done to validate the instrument and to prove the forces are in the direction which are desirable, to do that first the designing of the instrument was done in CRCO software and the designing of the instrument was done (Fig 1)

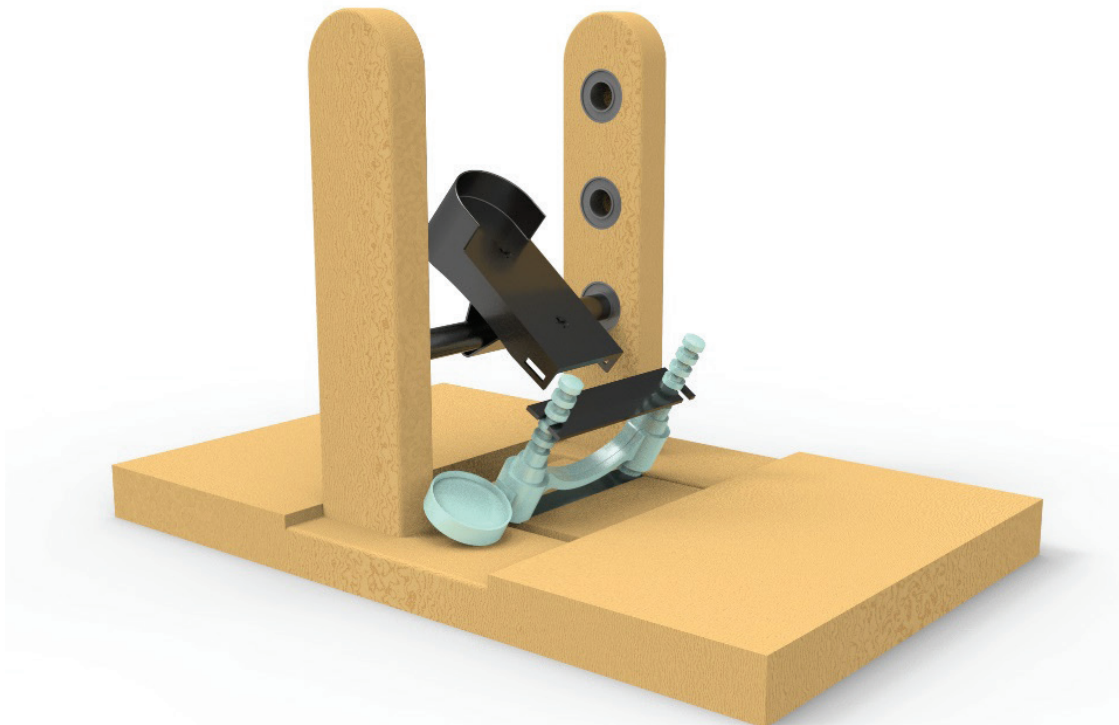


Figure 1: Designing of the instrument in CRCO Software

Once the designing of the instrument was done it is converted in to Finite Filament Analysis (FEA) in which the mashing of the design is done to analysis of the forces

Once the FEA was done the next stage is to do the structural analysis in which the hypothetical diagonal force of 100 N (9.8 Kg) was applied on the design to see the distribution of the forces. (Figure 2)

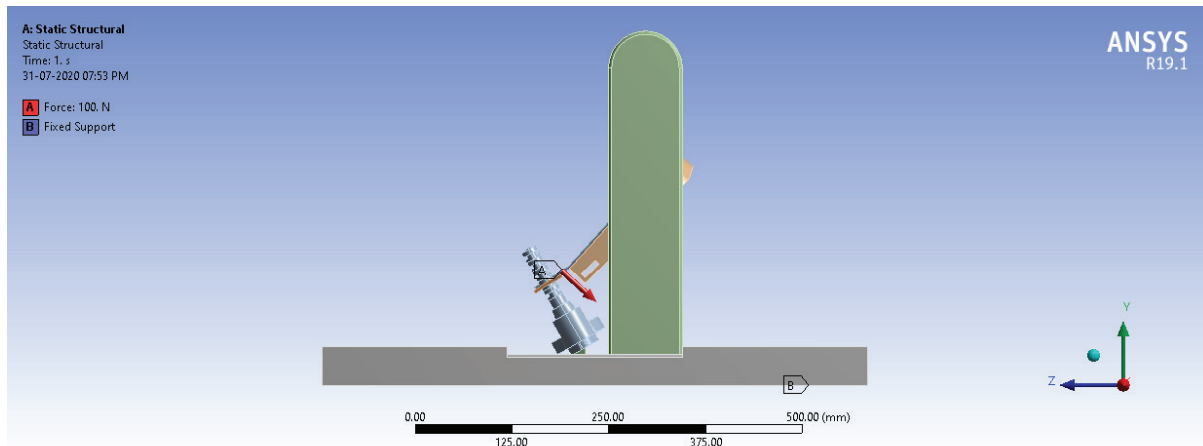


Figure 2: Structural analysis with Diagonal Force of 100 N (9.8 Kg)

The force analysis is explained with the help of different colour scheme where red shows the maximum Force and the Blue colour shows the minimum or no force, (Figure 3) This distribution is clearly shows the during the application of the force from the MTP joint the force is distributed on the direction of the intrinsic muscle that is inwards toward the planter aspect

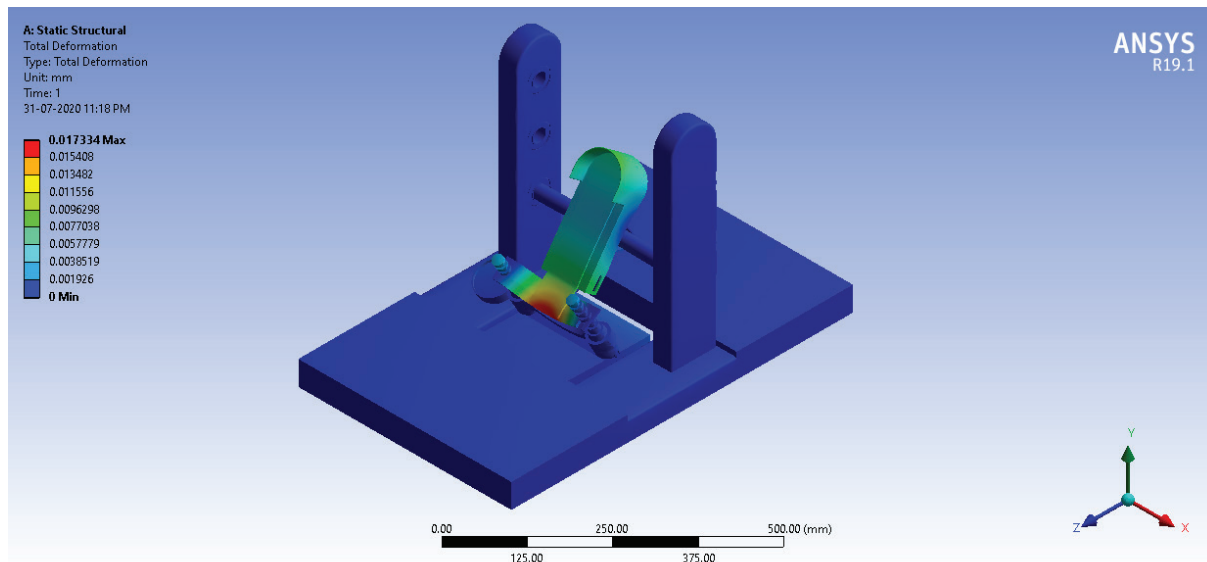


Figure 3: Force Distribution of the device

The design of the instrument is according to the biomechanical consideration which are deficient in previous design. The design has got 4 separate parts which are detachable and can be joined together to use the instrument these 4 different parts are:

- A: Wooden frame
- B. 2 Vertical wooden stirrups with 3 stainless steel bearing on each stirrup
- C. A Metal footrest mounted in an iron road
- D. Saehan Hydraulic Hand Dynamometer device

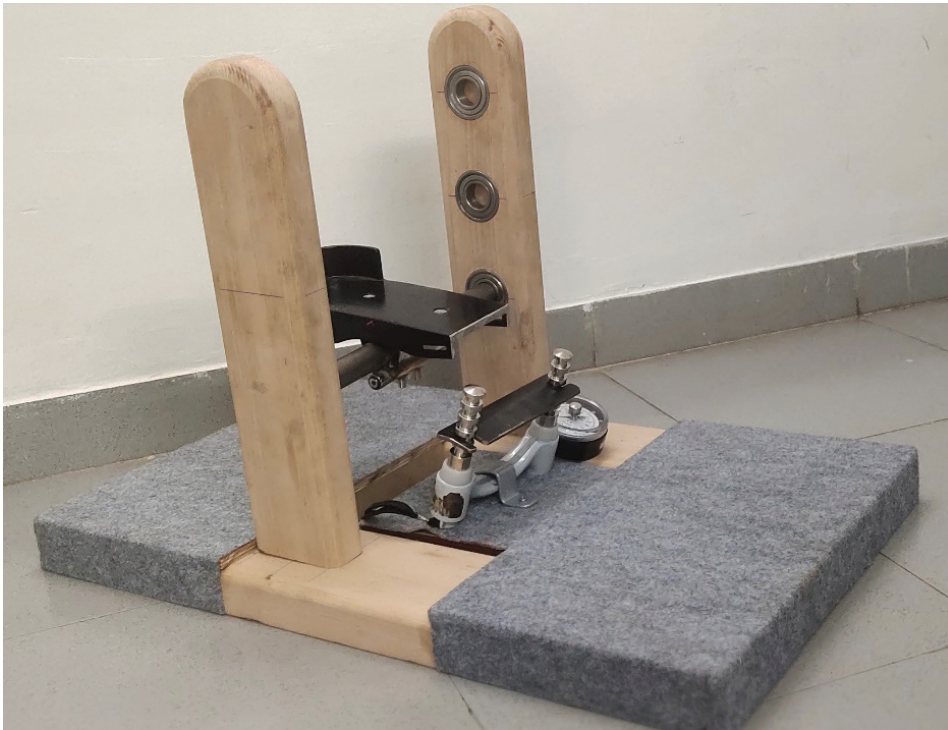


FIGURE 4: Medical Device Prototype for Foot Intrinsic Muscles

Procedure

The measurement of the muscular strength was done in the high sitting with both the legs are parallel to each other and the testing foot is placed in the foot rest and maximum plantarflexion is achieved the ankle is secured with the Velcro straps during the measurement, one the plantarflexion is achieved the subject should press the iron bar attached to the dynamometer and the reading can be measured. Subject should record 3 reading for each foot and the mean of these 3 reading can be taken as the value of intrinsic muscle strength in pounds (lb).

Biomechanical consideration

Design of the instrument is based on 2 major principles

1. We should provide the plantarflexion at ankle joint to cause disadvantage to extrinsic muscle¹⁵
2. Prevention of toe curling by using the iron strip as a force point in the dynamometer

Isolation of intrinsic muscle

To further strengthen our claim to position the foot in the plantarflexion the needle EMG was used to verify

the activation in the intrinsic muscle while measuring the reading the abductor hallucis muscle is used for the insertion of needle. The Ethical Clearance of this procedure was taken from Ethics Committee, School of Physiotherapy, RK. University (ESR/259/Indt/GJ/2016) and the procedure is done by the Neuro physician. The movement of toe flexion with limit curling shows an activity in the testing muscle (Figure 7)



Figure 5: Needle EMG for the Abductor Hallucis

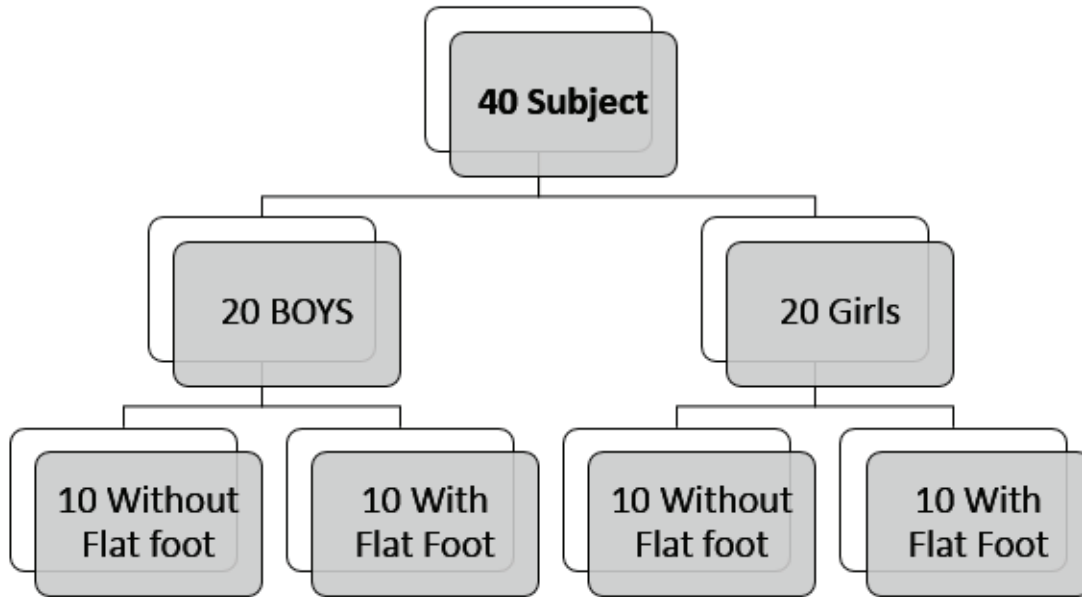
One stop solution

The purpose of designing this prototype is to provide one stop solution to foot intrinsic muscle impairments, this device not only quantify the intrinsic muscle strength but also provide a platform to demonstrate different exercise which are designed to strengthen or stretch the foot intrinsic muscle with the help of certain therapeutic devices

Pilot Study

To check the efficacy of the instrument a pilot study with this instrument to compare the planter intrinsic muscle strength of young boys and girls with and without Flat Feet. Total 40 subject were included in the study. All subjects BMI ranges between 18.5 and 24.9 Age is between 18-24 Years.

Methodology



| 10 Boys without flat foot | 10 Boys with flat foot | 10 Girls without flat foot | 10 Girls with flat foot |
|---------------------------|------------------------|----------------------------|-------------------------|
| BMI: 20.6 ±1.34 | BMI: 21.5 ± 1.0 | BMI: 20.3 ± 1.33 | BMI: 20.9±1.19 |
| Age: 20 years | Age: 20.4 years | Age: 20.8 years | Age: 20.8 years |
| Strength: 27.5 lb. | Strength: 21. lb. | Strength: 23 lb. | Strength: 15.3 lb. |

Results and Discussion

The overall design of this prototype is convincing and fulfil all the biomechanical and clinical consideration apart from the testing and quantification of the intrinsic muscle the design also gives a therapist an opportunity to use this machine as exerciser for strengthening protocol

and very beneficial in-home settings. The pilot study done to check the efficacy of the instrument in different gender and foot morphology also gave promising results described in the Table 1

Table 1: Description of the subjects in terms of BMI, Age and Strength

The result of this small pilot study clearly shows that the subjects with flat feet have less intrinsic muscle strength compared to the subject without flat feet or free from any foot deformity.

The initial results of the pilot study were encouraging and show the relationship between the intrinsic muscle strength and flattening of arch which will prove our claim that the the intrinsic muscle of the foot contributing in the maintaining of longitudinal arch and if the arch is flattened it is clearly reflected in the value of the strength compared to the subject having neutral healthy feet. The structural analysis of the machine also provide the support that the direction of the force is in the same direction as the direction of intrinsic muscle if they perform MTP Flexion. The quantification of these intrinsic muscle certainly opens the doors in the understanding the strength deficit associated with this muscle and we can design the strength program in accordance to the weakness of the muscle.

Further we should prove the reliability of this instrument in both the genders and various age group which is still not been done and we will be doing this research in the future as the validity of the instrument is already proved by the structural analysis also in the future there is a need to design a device to take care of other action of intrinsic muscle like abduction and also role of intrinsic extensor as per today understanding these extensor are rudimentary to the foot muscle function.

Conclusion and Acknowledgement

We conclude that this prototype is an easy to use instrument providing not only the measurements of the intrinsic muscles of the feet but also provide the space for the exercise programme related to the intrinsic muscle and for the impairment associated with them.

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