

Revival of 'Paduka', an ancient form of Indian footwear to increase foot muscle strength and balance: A randomized controlled trial - A hypothesis

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Abstract

Background: Foot muscle strength is one of the intrinsic factor responsible for maintaining balance in older population. Footwear is another extrinsic factor having an impact on foot muscle strength, balance and gait. Footwear recommendation by clinician is rational due to role of footwear style in leading to fall or even increase in the risk of fall is unclear. Thus training intrinsic factor, that is foot muscle strength and balance, seems to be sensible which may help individual to maintain control in the conventional footwear. Foot muscle strengthening is mainly limited to short foot exercises, toes curls and its variations. In this study we reintroduce an age old Indian 'Paduka' wooden footwear, an extrinsic factor as a 'practical tool' for rehabilitation. A randomized controlled trial will be conducted where participants will be made to wear 'Paduka' footwear, which has a flat wooden sole and a toe knob to hold between great toe and second toe, to perform a multidirectional walking protocol. They will be assessed for foot muscle strength using MicroFET3 handheld dynamometer and enhanced paper grip test and balance using various clinical tests. Results will be compared with barefoot group following same walking protocol and passive control group. This will be followed by statistical analysis within and between groups.

Clinical Importance: 'Paduka' footwear can give an efficient strategy towards training foot muscles strength and balance amongst elderly in shorter duration, increase compliance and promote a new perspective towards fall prevention strategy.

Future research: Biomechanical implications and gait parameters can be assessed and further studied. Cost effectiveness, environmental factors and footwear preference over minimalist footwear for training can be considered.

Keywords: Wooden footwear, Intrinsic foot muscles, community dwelling elderly, fall prevention

CTRI trial registration number: CTRI/2020/09/028137

THESIS SUMMARY

Introduction

The foot is a complex structure with its 26 bones, 33 articulations (each with 6 degrees of freedom of motion) and more than 20 muscles including 4 layers of arch muscles [1]. While considering standing, walking or running, the foot is the only structure in touch with the ground forming our base, thus making it very crucial structurally and functionally, allowing foot to play an important role in providing a base of support, balance, serving as a shock attenuator, being able to adapt to uneven terrain, and serving as a rigid lever for push off [1,2]. The intrinsic muscles of the arch, with their small cross-sectional areas and short moment arms are primarily stabilizers, in contrast to the larger extrinsic foot muscles which are primarily mobilisers explained as foot

core system [1]. Foot muscles are more active in dynamic activities such as walking compared to standing and as postural demands increase, such as a change from double to single limb stance, so does the activity of the intrinsic foot muscles [3]. Weakening of foot muscle strength and its relation to the inability to maintain balance in elderly are known to be at risk of falling owing to aging process itself [4-8].

With the importance of the foot comes along the importance of appropriate footwear which is an interactive layer between foot and ground having an influence on force transmission and weight distribution during locomotion. Therefore, alternative footwear or modified footwear is observed and assessed to see its effects on foot muscle strength or balance [9,10]. Range of footwear commonly used

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for casual or recreational purposes such as flip flop, clog style crocs, five finger shoes, slippers, high heels, boots, minimalist footwear or modified footwear with wider base, having certain effect on either foot strength or balance has been widely studied [9-12]. However role of footwear style in leading to fall or even increase in the risk of fall is confusing, with clinicians being rational in footwear recommendation. It may be possible that it was not the style of footwear, rather how accustomed the individual is to wear that particular style of footwear [12]. Conventionally, foot muscles and balance are trained using foot strengthening exercise which includes toe curls or short foot exercises and balance exercises respectively [9,10]. Using a challenging footwear as a tool to train foot muscles and balance opens up a new perspective in rehabilitation.

Indian 'Paduka/Khadau' is an oldest traditional footwear known to this country. Today it is usually used by Indian 'sadhus and sadhvis', the ascetic holy men and women [13,14]. Footwear has two sets of function: cultural and biomechanical. 'Paduka' is most typical footwear, but it seems to be less understood biomechanically and functionally. 'Paduka' is a basic structure, having a wooden sole without straps and a knob which is gripped between big toe and second toe [13-15]. Foot strengthening and balance training is of utmost importance in community dwelling elderly. Along with conventional foot strengthening exercises bringing a challenged footwear, as recommended, will open up new perspective in foot muscle training, variation in balance training and compliance. In this study, we use 'paduka' footwear to see its effect on strength and balance in community dwelling elderly.

Hypothesis

Footwear is recognised as one of the extrinsic factor involved in foot structure, foot muscle strength, balance, gait and its modification is frequently considered in fall prevention strategies. 'Paduka' footwear described using footwear assessment tool [16] as a reference falls under other or unique footwear style, which is more than a sole with a toe knob from which possibly backless slippers and slippers have evolved. It is completely a wooden footwear with no other fixation such as straps or back support which makes it a challenging tool in motion control. There is no cushioning with hard and flat sole. With no other evidence present describing its functional use, biomechanical understanding on foot structure, balance and locomotion, merely based on the challenges offered by the footwear it might have been considered as a footwear prone to injury and not of any biomechanical advantage even though it is still existing and used by many as a spiritual symbol. Here we explore 'Paduka' not as a footwear of recommendation but as a 'practical tool' to be used in clinical or community rehabilitation using its features to our advantage. This study is based on the hypothesis that foot muscles activation will be constantly triggered to stay adherent to the footwear while walking, thus increasing the strength of foot muscles strength especially the intrinsics which are main stabilizers of the foot. Furthermore, the fact that footwear does not provide any support will challenge the balance improving postural control in static and dynamic

activity. Adding to it, we also get a subjective feedback from participants on the use of 'Paduka' for exercise. For this purpose, a randomized, single blinded, passive control, parallel group, multiple arm trial that studies the effects of 'Paduka' footwear walking on foot muscle strength and balance in community dwelling elderly, the approval for which has been obtained from institutional review board, will be conducted. The sample calculation using G Power will be done followed by sample collection from the community settings with age group between 60 to 75 years with no active pathology or pain in lower limb. Participants will be divided equally in three groups, interventional group ('Paduka' group), barefoot group and passive control group with random sequencing done using computer generated randomization. The intervention group shall receive 'Paduka' footwear walking intervention in multiple directions for 25 min per session, four times per week for four weeks. The barefoot group will receive same walking intervention in multiple directions without any footwear for 25 min per session, four times per week for four weeks. The passive control group would not receive any intervention or exercise and shall be asked to continue with their activities of daily living. Intervention exercises will include forward walking, side walking, backward walk, zigzag foot walk, figure of eight and mini hurdle [17]. The selection of the mode of exercise is done keeping in mind the combination of challenged footwear, walking and balance training in elderly. The primary outcome measure, foot muscle strength shall be assessed at week zero, after week two and after week four using MicroFET3 handheld dynamometer and enhanced paper grip test. The secondary outcome measure balance using clinical tests for static and dynamic shall be assessed at week zero and after week four. Both the outcome measures will be assessed by a blinded assessor. This will be followed by statistical analysis within and between groups. Statistical analysis using ANOVA repeated measures within group and one way ANOVA between group for strength, Paired t test within group and one way ANOVA between group for balance will be done.

Discussion

In the process of evolution over centuries, bipedal locomotion is the hallmark of homo sapiens. With the emergence of being upright, evolution of foot to have a stiff long arch, an adducted hallux, and short toes that significantly aid our bipedal gaits by forming a stiff lever along with the role of foot muscles to assist in walking became the characteristic feature [2]. From there, barefoot upright walking to evolution of footwear lead to increasing amount of research to understand muscles in the foot, its role in balance, gait, interaction with extrinsic factor such as footwear with final aim to understand risk of fall, injury and its prevention in various age groups especially in athletic and geriatric population [18].

Barefoot walking helps to understand wearing footwear having an impact on the foot structure, natural gait, proprioceptive and sensory feedback arising from the feet, foot muscle activity, postural control and balance [19]. Evidence suggests barefoot walking is better for foot health for long term over using footwear, but walking outside barefoot may not be feasible to most population. Minimalist footwear is

intermediate to barefoot and conventional footwear in terms of kinetics and kinematics [20]. Using minimalist footwear while walking has shown to increase foot muscle strength similar to that of foot strengthening exercises in young adult in 4-8 weeks [9]. The use of minimalist footwear in an older age population in their daily life have not shown improvement in postural control and balance, some improvement of foot muscle strength, in 4 months when compared with participants wearing conventional footwear for the same period of time. However, qualitatively some perceptible improvements in balance and balance confidence when walking in minimalist shoes is reported. This may be possibly due to thin sole and the reduction in input interference, sensory sensitivity and increase awareness of surface lead to increase in balance confidence [18]. Recent study has shown use of minimal shoes improves postural stability and might be beneficial over conventional shoes [21]. Another evidence is suggestive of Indian 'Kolhapuri' footwear simulates barefoot walking with biomechanical implications yet there is no evidence its role in muscle strength, balance and fall [22]. This study concentrates on using a 'Paduka' footwear as a practical tool for rehabilitation improving strength and balance, comparing it with barefoot walking considering its use for rehabilitation purpose for first time and choice of preference. Even though minimalist footwear shows results, still footwear recommendation for fall prevention is unclear. Here we focus on training intrinsic factors such as foot muscle strength and balance in elderly using an extrinsic tool. This approach seems to have the potential to train the individual making them stronger to have better control and walking in their own choice of footwear in which they are accustomed. 'Paduka' is one such footwear which will strengthen the foot muscles by constantly engaging the muscles in holding footwear, challenge balance to a step higher from conventional training, training foot muscles and balance in more functional activity which will increase the compliance of the patients. Furthermore, non restrictive, slip resistance rough wooden surface makes it relatively safe. Hard surface over the thin, soft and flexible surface of minimalist footwear, can give stronger sensory feedback simulating barefoot walking giving faster results as compared to any other footwear.

Clinical Implications

'Paduka' footwear can be used for foot muscles strengthening in more functional activity as a progression to conventional foot muscle exercises such as short foot exercise and toe curls. Giving balance training wearing challenged footwear again gives a further scope of improvement at a faster rate with higher compliance. This will help in fall prevention strategy to train individual using a challenged footwear and improve their control in the conventional footwear to reduce the risk of fall drastically. Furthermore, we do not recommend 'Paduka' for daily life and use for longer duration due to lack of evidence where this study being the first of its kind, thus limiting its use under therapist supervision.

Future direction

Biomechanical implications and gait parameters can be assessed and

further studied. Cost effectiveness, Environmental factors and footwear preference over minimalist footwear for training can be considered.

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