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Is walking barefoot on different natural terrains effective to improve balance in older adults?

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Abstract
Objectives: To study the effects of barefoot walking on three different surfaces for balance, lower limb strength, and confidence in older adults.
Methods: 45 healthy subjects (mean age 65.08 ± 4.86) were randomly divided into three groups of different surfaces namely grass, sand, and soil. After the assessment, they were made to walk barefoot on either surface for 30 minutes/day, five days/week for six weeks. Data were analysed using the 'paired-t' test and One-Way ANOVA with α set ≤ 0.05 at a 95% confidence interval.
Results: All groups showed statistically significant improvement in balance, lower limb strength, and confidence post-intervention ($p<0.05$). However, the inter-group analysis showed no significant difference, indicating no one surface is better than the other ($p>0.05$).
Conclusion: Barefoot walking on all three surfaces is equally effective. It can be included in balance training and rehabilitation program to reduce the risk of falls in older adults.

Keywords: Surfaces, cutaneous proprioception, walking rehabilitation, fall prevention program, elderly

Introduction

India has the second-highest population in the world. According to the census 2021, 10.1% of people are above the age of sixty years (Older adults in India 2021, 2021). Aging is an irreversible physiological change that alters physical, functional, and psychosocial well-being. The growing population of older adults has placed high demands on healthcare due to various systemic changes with increasing age. One of the factors leading to a high rate of morbidity and mortality amongst this population is an event of fall. The prevalence of falls in older adults is reported to be 24.98% and it is often caused by multiple risk factors.[1] Most of the time falls experienced by them are a result of age-related deterioration of balance and muscle strength.[2]

Balance is the ability to maintain an upright posture. It mainly depends on three components: vision, equilibrium, and proprioception. It is needed to maintain posture, respond to voluntary movements, and react to external perturbations; failure of which can lead to fall.[3] Impaired balance is also associated with decreased lower limb strength.[4] This reduces their confidence in carrying out their daily physical and social activities which in turn impacts their quality of life. Reduced confidence due to fear of falling is an exaggerated concern observed in most of the older population. [5]

Several extrinsic and intrinsic factors impact balance attributing to the risk of falls in older people. Out of these, footwear is an extrinsic contributing factor. There is an association between wearing slippers and the rate of falls in community-dwelling older adults.[6] Footwear has an impact on balance by altering frictional conditions at the shoe-floor interface.[7,8] As footwear hampers kinesthesia, greater awareness of foot position and postural balance can be seen in barefoot conditions.[9]

The general interest in barefoot locomotion is fascinating and has attracted scientific focus.[10,11] It claims lesser restrictions for motion control, which increases the sensitivity of sensory receptors of the foot.[12] The human foot sole has 104 cutaneous mechanoreceptors.[13] Tactile information from these receptors sends afferent signals to the central nervous system (CNS) which helps to maintain posture and representation of the body in space. This in turn maintains the static as well as a dynamic balance of the person.[14,15]

Barefoot walking also improves muscle strength and joint flexibility in the legs which is important to correct balance loss.[16,17] Comparison of balance in single-leg standing with 5-toed socks, conventional socks, and bare feet showed that static balance was more compromised in both socks than bare feet.[18] Likewise, dynamic balance assessed during a single leg jump landing task was better in bare feet than in standard running shoes. This is likely due to less filtering of sensory input which usually results from additional material between the foot and the ground. Inputs from these receptors also help to detect the texture qualities of different surfaces.[19]

The effect of different terrains may be comparable to textured insoles that increase somatosensory input and postural stability during locomotion.[20,21] Walking barefoot in nature, on easily available surfaces is a type of earthing that can benefit a human body physiologically as well as psychologically.[22] However, there is limited literature that proves the direct effect of barefoot walking on natural terrain evaluating balance and rate of fall in the older population. Thus, this study aimed to find out whether

barefoot walking can improve balance, lower limb strength, and confidence in community-dwelling older adults. The authors also aimed to see a difference in the effect of barefoot walking on different surfaces like grass, sand, and soil.

Materials and methods

The study was a multi-arm, parallel-group, single-blinded, randomized trial. Post institutional ethics committee approval, 83 subjects were screened for the study. The sample size was calculated using G power (Version 3.1.9.4), which was based on the values obtained from the pilot study. The effect size was 0.62, α set ≤ 0.05 at 95% of the confidence interval. The sample size calculated was 45, with 15 subjects in each of the three groups. After screening for eligibility, 61 subjects were recruited. Written informed consent was obtained after making them aware of the purpose and procedure of the study. Healthy subjects of both genders between ages 60-75 years were included in the study. The exclusion was considered for subjects with known neurological balance and coordination issues, active musculoskeletal injury or abnormality of spine/ lower limb, any neuropathy, or chronic diabetes mellitus. Subjects were recruited from various community parks and residential societies in Pune city. They were divided into three groups via computer-generated randomization technique with allocation ratio 1:1:1 (Group A=grass; group B=sand; group C=soil).

Baseline evaluation was done by a blinded assessor with the help of the following outcome measures A) timed up and go test (TUG),[23] B) four square step test (FSST),[24] C) 30-second chair stand test (30sCST),[25,26] and D) activity specific balance confidence scale (ABC).[27]

On day one, subjects were given a trial on their respective surface. They were also informed about the initial discomforts and were asked to approach the intervener as per their necessity. Subjects walked bare feet for 30 minutes a day, five days a week for six weeks on their respective grouped surface (Figure 2, Figure 3, Figure 4).[28] Subjects were supervised by the intervener in the first week, and later the supervision was done twice a week. For the rest of the days in a week, communication was maintained via text messages. The post-intervention assessment was done at the end of the 6th week.

Statistical Analysis

Data analysis was done using a statistical package for social sciences (SPSS) version 26 (IBM Inc, USA). Baseline matching and post hoc analysis for age and BMI were done using the One-Way Analysis of Variance (ANOVA) test. Normality testing was done using Kolmogorov Smirnov and Shapiro Wilk test. Parametric testing for intragroup analysis was done using the 'Paired-t' test. Non- parametric testing for intragroup analysis was done using the Wilcoxon Signed-Rank test. Intergroup and post hoc analysis for parametric data was done using One Way ANOVA and for non-parametric data was done using the Kruskal Wallis test.

Results

The present study included a total of 61 subjects from which a total of 45 subjects completed a six-week intervention (Figure 1). The demographic data and clinical characteristics of the participants were matched at baseline (Table 1). There was no statistically significant difference among baseline parameters of dropout subjects as well as subjects who remained in the study till 6 weeks. Intra-group analysis of all three groups reported statistical significance for balance, lower limb strength, and confidence post-intervention ($p<0.05$) (Table 2). Inter-group analysis of the three surfaces reported no statistical significance for balance, lower limb strength, and confidence ($p>0.05$) (Table 3).

Table 1: Demographic Data and Baseline Matching

Parameters	Grass group	Sand group	Soil group	P value	Total
Number of participants	20	20	21		61
Age	65.95 ± 5.22	64.8 ± 5.46	64.52 ± 3.95	0.62	65.08 ± 4.86
BMI	24.80 ± 2.46	25.44 ± 3.58	23.92 ± 2.38	0.23	24.72 ± 2.80
Gender	10: 10	16: 4	14: 7		40: 21

Note- Values are mean ± SD; BMI= Body Mass Index; SD= Standard Deviation

Table 2: *Intra –Group Analysis*

	Groups	Pre (Mean ± SD)	Post (Mean ± SD)	Within group p value
Balance using TUG (sec)	Grass	11.50 ± 1.69	9.80 ± 1.20	0.00*
	Sand	9.69 ± 1.53	8.20 ± 1.37	0.00*
	Soil	10.63 ± 2.18	8.74 ± 1.42	0.00*
Balance using FSST (sec)	Grass	11.80 ± 2.05	9.50 ± 1.12	0.00*
	Sand	10.80 ± 1.77	8.80 ± 1.25	0.00*
	Soil	12.07 ±1.63	9.63 ± 1.34	0.00*
Strength using 30 sec CST (no. of repetitions)	Grass	11.46 ± 3.08	13.66 ± 4.38	0.00*
	Sand	15.86 ± 5.06	19.63 ± 6.30	0.00*
	Soil	13.53 ± 4.45	16.76 ± 4.82	0.00*
Confidence using ABC scale (%)	Grass	77.15 ± 13.96	87.53 ± 8.74	0.00*
	Sand	79.61 ± 14.57	88.09 ± 10.65	0.00*
	Soil	85.41 ± 12.50	89.86 ± 11.44	0.00*

Note- SD= Standard Deviation; '*' indicates statistical significance, denoted as $p<0.05$

Table 3: Inter Group Analysis

Outcome	Groups	Mean difference ± SD	CI		P value	Post hoc test	P value
			Lower	Upper			
TUG	Grass	1.70 ± 1.08	1.10	2.30	0.64	Grass & Sand	0.84
	Sand	1.49 ± 1.00	0.93	2.04		Grass & Soil	0.90
	Soil	1.89 ± 1.35	1.13	2.64		Sand & Soil	0.63

FSST	Grass	2.30 ± 1.62	1.40	3.20	0.69	Grass & Sand	0.84
	Sand	2.00 ± 1.23	1.31	2.68		Grass & Soil	0.96
	Soil	2.44 ± 1.37	1.68	3.20		Sand & Soil	0.63
30 sec CST	Grass	2.2 ± 2.63	0.73	3.66	0.28	Grass & Sand	0.33
	Sand	3.76 ± 3.25	1.96	5.56		Grass & Soil	0.47
	Soil	3.23 ± 2.16	2.03	4.43		Sand & Soil	0.85
ABC	Grass	10.37 ± 8.46			0.21		
	Sand	8.47 ± 7.15					
	Soil	4.45 ± 3.07					

Note- SD= Standard Deviation; CI= Confidence Interval

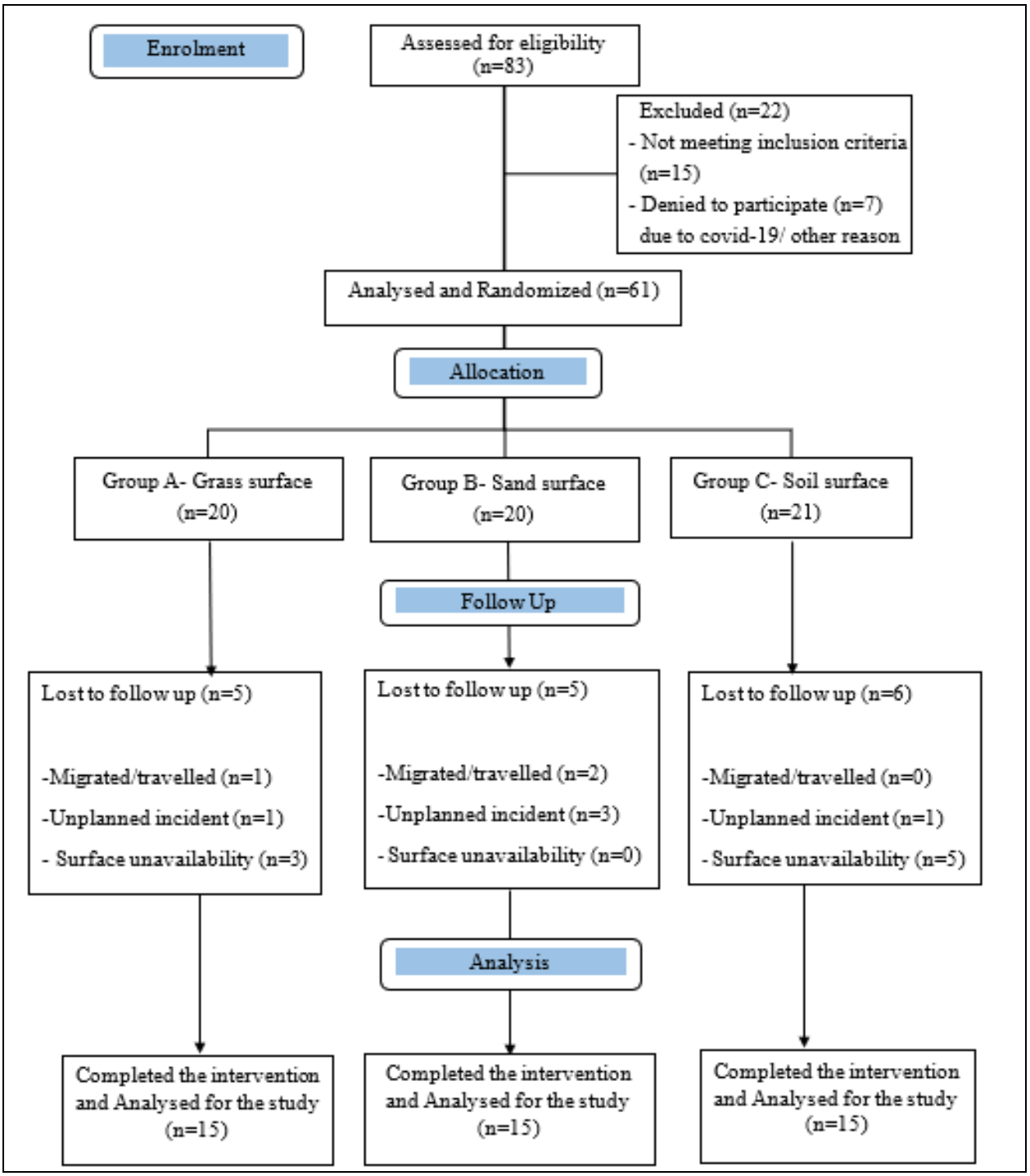

Fig 1: CONSORT flow chart

Fig 2: Subjects walking barefoot on grass

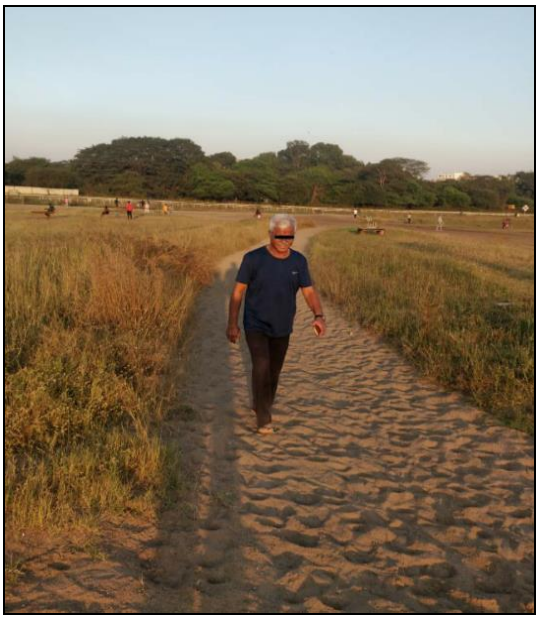

Fig 3: Subjects walking barefoot on sand

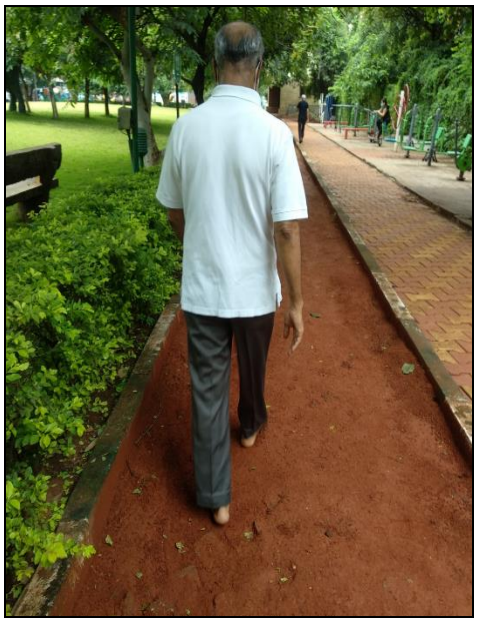

Fig 4: *Subjects walking barefoot on soil*

Discussion

According to the existing literature, this could be the first study to compare the effects of barefoot walking on three different surfaces namely grass, sand, and soil. Although there were studies quoting benefits of barefoot walking in nature on our mind, body, and health, there was a dearth of literature establishing its effect on balance, lower limb strength, and confidence, especially in older adults.[29] With aging, proprioception and tactile sensitivity reduces as a result of a decrease in translational velocity by nerve fibres.[30] This is mostly associated with atrophied axons and decreased response of muscle spindles.[31]

In this study, the balance was significantly improved in people who practiced barefoot walking on grass. This is because grass has a soft texture of leaves which stimulates the sensory receptors in the feet. Skin innervation by mechanoreceptors includes myelinated A and unmyelinated C afferent fibres. Tactile C fibres conduct impulses as slowly as 1 m/s. The free nerve endings of these fibres react in a slowly adapting manner to stimuli that are in the "light touch" range.[32] Plantar muscles correct posture as a response to sensory perception.[33,34] Walking barefoot on grass also improved participants' lower limb strength and confidence. Despite having a smooth leafy texture, the grass surface has an uneven ground where it is challenging for small and large groups of lower limb muscles to maintain balance.[35] Hence walking intervention improved the lower limb strength of older people in this group. These factors in turn improved their confidence.

Walking barefoot on sand also showed similar results. During the transition of stance to swing phase, resistance is imposed by sand. When the heel of the foot strikes the ground, it sinks into the sand. Intrinsic foot muscles as well as large muscle groups of leg work extra hard to push through the toe-off phase and move forward. Hence walking barefoot on sand improves lower limb muscle strength.[36] Somatosensory mechanism with the help of active postural adjustments is necessary for detecting body orientation while walking on irregular surfaces. Self-organization is crucial to define the most suitable walking pattern while adapting to environmental changes.[37] Gait training on the unstable ground requires diverse movement in the ankle joint as well as large muscle strength. This induced proprioception and increased balance ability.[38,39] This was

explained by Tae-Ho Kim by comparing the walking ability of chronic stroke patients with barefoot gait training on sand versus firm ground. The study concluded that sandy ground training is more effective at enhancing gait endurance.[27]

Results of this study also revealed a significant difference in pre and post scores in the soil group. A variety of soils are found in different regions. A typical texture of soft organic material along with small rock particles is usually seen along the walking track in community parks. The specialty of this texture is that it creates an acupressure effect when walking bare feet on it. A study conducted on the effect of acupressure for dynamic balance in older adults proposed that acupressure improves balance control by increasing regional circulation. Improved blood circulation aids afferent nerves' movement from the organ terminals to the CNS which in turn enhances CNS control over motor control.[40] A study by Azarpaikan *et al*. documented that the somatosensory function of the feet and ankles is considered the most important sensory source for postural control in older people.[41]

In a comparison of the three groups with each other, the soil group showed the highest improvement in balance. Although the difference was not significant between the three groups, the greater mean difference in the soil group can be because of the consistency of soil containing small rock particles. This gives an effect of acupressure overpowering the effect of somatosensory stimulation by the light touch of grass and an effect of ankle proprioception due to sand.

In this study, the mean difference for the strength of lower limb muscles was found to be higher in the sand group. Walking on sand requires greater plantarflexion during the stance phase along with more flexed knee and hip joints during the swing phase. These changes in walking kinematics on sand suggest an increased complexity to perform locomotion. This requires the increased need for postural control to achieve dynamic stability and to improve lower limb strength.[42] The cost of energy expenditure after walking on sand is higher as compared to flat ground or grass. The uneven texture of sand consumes more energy in a push-off phase while walking and this requires a greater amount of mechanical work from foot and leg muscles.[37]

The mean difference between the groups for the confidence of the subjects showed a higher percentage in the grass group. Walking in nature, being connected to the earth's surface has psychological effects on a person's body and mind. Walking on the green surface of grass stimulated a sense of freshness and calmness. This could have helped them feel relaxed, less anxious and in turn, might have distracted their mind from the fear of falling.

On analysing between-group data by comparing all three surfaces, results for balance, strength, and confidence were not significant. A possible reason can be that grass surfaced ground has some bumps and soil at root level which might have given mixed results. All three surfaces pose a challenge to the postural control system of the body by the effect of tactile stimulation, proprioception, and acupressure.[31,38,37] Although the mechanisms are different, the resultant effect might be similar to have shown improvements in balance, strength, and confidence without a clinically significant difference. Another possibility can be that irrespective of the surface textures, the amount of shift in the body's centre of mass (COM) for all uneven surfaces can be the same. CNS lowers the height of COM to increase the dynamic stability during gait to reduce the chances of falls.[34,43] As the between-group difference is not significant, any easily available surfaces can be recommended as a strategy to improve balance in older adults.

Participants of this study also shared their experiences subjectively. These findings were reduced blood pressure, body pain, pedal edema, and varicosities. The reason behind this is the grounding effect of barefoot walking which gives analgesic, anti-inflammatory benefits to the human body, improves blood flow, and lymphatic/venous return to the heart. Some participants also experienced reduced stress levels and improved sleep quality because of the enhanced cortisol circadian profile.[28,44]

On contrary, barefoot walking increases the chance of getting injured or infections. Keeping this in mind, safety was considered to avoid foot injuries and trips over any obstacles. Foot hygiene was considered to prevent bacterial or fungal infections. Weather conditions like rainy seasons, too hot or too cold environments were considered.[3]

The limitations of this study were that it only focused on parameters like balance, lower limb strength, and confidence. But falls in the older population can also be associated with a few other factors like conditions related to vision, increased reaction time, delayed reflexes, inability to use ankle or hip strategies efficiently, reduced range of motion of joints, increased body mass index, behavioural changes like depression, etc. which were not measured. The terrain of different textures varies in height, thickness, density which affect spatial and temporal parameters, kinetics, kinematics of gait, plantar pressure, and one's energy expenditure differently which was not measured in this study.[45,46,47]

Conclusion

A significant difference was found within the group in all three groups for balance, strength, and confidence parameters. This means that grass, sand, and soil surface improve balance, lower limb strength, and confidence in older people. However, there was no statistically significant difference found between the groups. This concludes that no surface is better than the other. All three surfaces improved balance, strength, and confidence equally.

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