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Original Article

Effect of footwear on standing balance in healthy young adult males

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Abstract

Objective: The present study aimed to evaluate the effect of footwear on standing balance in healthy young adult males. **Methods:** Thirty healthy male participants aged 20-30 years were tested for standing balance on the Balance Master on three occasions, including wearing a sandal, standard shoe, or no footwear (barefoot). The tests of postural stability include; "Modified Clinical Test of Sensory Interaction on Balance" (mCTSIB), "Unilateral Stance" (US), and the "Limits of Stability" (LOS). The balance scores (mCTSIB, US, and LOS) was analyzed. **Results:** There was a significant effect between footwear conditions for mCTIB with eye closed on a firm surface ($p=0.002$). There was a significant effect between footwear conditions for the US with eye open and closed ($p<0.05$). There was a significant effect between footwear conditions for LOS reaction time during forward movement ($p=0.02$). Similarly, there was a significant effect between footwear conditions for LOS reaction time during left side movement ($p=0.01$). **Conclusions:** Wearing sandals compared to bare feet significantly increased postural sway and reduced stability in healthy young adult males. However, wearing a standard shoe compared to bare feet did not significantly affect balance scores in standing.

Keywords: Balance, Footwear, Postural Sway, Barefoot, Stability

Introduction

Footwear has a vital role in improving well-being of any individuals. Previous study reported an association between footwear and disorders; therefore, considering footwear characteristics during management program is important[1]. Footwear facilitates sensory information to the foot and control postural stability through the touch and proprioceptive system[2,3]. The tactile stimulation is detected by the cutaneous mechanoreceptors of the plantar surface of the feet and gives information of plantar pressure distribution to the central nervous system[2]. Previous study reported an impaired standing balance, if plantar surface afferents are not intact[4]. Whereas, stimulation of the cutaneous mechanoreceptors can enhance postural stability[5-7]. The type of Footwear and their modifications, including foot orthoses, shoe inserts, and insoles can stimulate tactile as well as proprioceptive systems[8,9]. In addition, previous study reported increased thresholds of plantar cutaneous vibrotactile particularly in the elderly[7,10].

The maintenance of static and dynamic balance is a vital to reduce risk of injuries in any sports. Type of footwear may influence the sensory feedback quality from the feet[11]. Footwear often designed to give support and stability to the foot, therefore, potentially affecting balance and function of the foot[1]. However, previous study reported 42% of fall in a group of 106 older people during wearing walking shoes[12]. Another study reported postural instability in the elderly

Abbreviations
mCTSIB = Modified Clinical Test of Sensory Interaction on Balance
US = Unilateral Stance
LOS = Limits of Stability
COG = Center of Gravity

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Table 1. Comparison of balance scores between a sandal, standard shoe, or no footwear (barefoot) conditions.

Variables	Barefoot (BF) Mean ± SD	Standard shoe (SS) Mean ± SD	Sandal (S) Mean ± SD	ANOVA		BF vs SS	BF vs S	SS vs S
				F	p	p	p	p
mCTIB Firm - EO (deg/sec)	0.38 ± 0.19	0.41 ± 0.38	0.49 ± 0.14	1.784	0.17			
mCTIB Firm - EC (deg/sec)	0.31 ± 0.07	0.35 ± 0.18	0.52 ± 0.36	6.861	0.002	0.99	0.002	0.02
mCTIB Foam - EO (deg/sec)	0.67 ± 0.14	0.73 ± 0.18	0.78 ± 0.17	3.349	0.04	0.49	0.034	0.73
mCTIB Foam - EC (deg/sec)	1.29 ± 0.37	1.35 ± 0.40	1.62 ± 0.36	6.295	0.003	0.97	0.004	0.02
US - EO Left (deg/sec)	0.90 ± 0.21	0.98 ± 0.45	1.23 ± 0.65	3.904	0.02	0.89	0.03	0.14
US - EC Left (deg/sec)	2.46 ± 0.92	2.62 ± 0.80	3.08 ± 1.06	3.533	0.03	0.89	0.04	0.18
US - EO Right (deg/sec)	0.89 ± 0.25	1.08 ± 0.46	1.34 ± 0.88	4.293	0.02	0.70	0.01	0.27
US - EC Right (deg/sec)	2.54 ± 0.92	2.65 ± 0.94	3.17 ± 1.22	3.181	0.05	0.95	0.04	0.16
LOS - RT Forward (sec)	0.89 ± 0.30	0.89 ± 0.28	1.10 ± 0.36	4.344	0.02	0.88	0.04	0.04
LOS - RT Right (sec)	0.83 ± 0.29	0.87 ± 0.30	0.97 ± 0.28	2.028	0.14			
LOS - RT Back (sec)	0.77 ± 0.28	0.78 ± 0.32	0.90 ± 0.26	1.900	0.16			
LOS - RT Left (sec)	0.79 ± 0.27	0.88 ± 0.26	0.99 ± 0.28	4.429	0.01	0.56	0.01	0.31

mCTIB, Modified Clinical Test of Sensory Interaction on Balance; US, Unilateral Stance; EO, Eye open; EC, Eye closed; LOS, Limits of Stability; RT, Reaction time.

population who has poor footwear type and poor footwear characteristics[13]. In addition, Keegan et al.[14] reported an increased risk of a foot fracture from a fall in individuals using slip-on shoes and sandals. Furthermore, Murphy et al.[15] had suggested that the shoes were an important element in the development of human posture. Therefore, the present study aimed to evaluate the effect of footwear on standing balance in healthy young adult males.

Materials and methods

Participants

Thirty healthy adult male aged older than18 years were recruited from the college of applied medical sciences, King Saud University, Riyadh. The present study was approved by the institution ethics committee, Rehabilitation Research Chair, King Saud University, Riyadh, Saudi Arabia. Each participant provided a written informed consent prior to the experiment. Individuals were excluded if they had a history of neurological disorders that can affect balance.

Procedures

Participants' demographic data such as age, height, weight, and body mass index (BMI) were recorded prior to testing. The Balance Master (NeuroCom Balance Master®; Natus Medical Incorporated, CA, USA) was used to measure the Postural stability[16]. The Balance Master utilizes a force platform to locate the center of gravity (COG) and provides various tasks for challenging balance. For all the tests, the participants were tested with three occasions, including wearing a sandal, standard shoe, and no footwear (barefoot). The tests of postural stability include; "Modified Clinical Test of Sensory Interaction on Balance" (mCTSIB), "Unilateral Stance" (US), and the "Limits of Stability" (LOS). The mCTSIB includes 4 conditions: eye open on the firm surface, eye closed on the firm surface, eyes open on the foam, and eyes closed on the foam[17]. The mCTSIB tests measure subject's "sway velocity" (degree/sec) from 3 trials of 20 s duration for each of the four given conditions[18]. The US assessed the postural stability during single leg standing (right and left) in 2 conditions: eye open and eye closed. The US test measure subject's "sway velocity" (degree/sec) from 3 trials of 20 s duration for each of the given conditions[19,20]. The LOS assessed the subject's stability limits without losing balance in a given directions. The LOS measures the "movement reaction time" (sec) and "movement velocity" (degrees/sec) from 3 trials of 20 s duration for given directions[21,22]. In all the test conditions, the participants asked to stand in the marked position on the Balance master, with their hands positioned on the iliac crests[23]. Participants had given a 15-second rest period between each trial and asked to perform a 5-m walk between each test condition. The order of all the test condition was randomized to minimize learning effect.

Statistical analysis

SPSS version 21 was used to analyze the data. The balance scores (mCTSIB, US, and LOS) between wearing a sandal, standard shoe, or no footwear (barefoot) was analyzed using the "repeated measures analysis of variance" with "Bonferroni's correction". A $p<0.05$ was considered as statistically significant.

Table 2. Comparison of balance scores between eyes open and closed conditions.

Footwear conditions	Balance outcome	Eyes open	Eyes closed	t-test	
				t	p
Barefoot (BF)	mCTIB on firm surface	0.38 ± 0.19	0.31 ± 0.07	1.948	0.06
	mCTIB on foam surface	0.67 ± 0.14	1.29 ± 0.37	-7.991	<0.001
	US on left leg	0.90 ± 0.21	2.46 ± 0.92	-9.970	<0.001
	US on right leg	0.89 ± 0.25	2.54 ± 0.92	-10.862	<0.001
Standard shoe (SS)	mCTIB on firm surface	0.41 ± 0.38	0.35 ± 0.18	0.734	0.47
	mCTIB on foam surface	0.73 ± 0.18	1.35 ± 0.40	-7.757	<0.001
	US on left leg	0.98 ± 0.45	2.62 ± 0.80	-13.895	<0.001
	US on right leg	1.08 ± 0.46	2.65 ± 0.94	-8.704	<0.001
Sandal (S)	mCTIB on firm surface	0.49 ± 0.14	0.52 ± 0.36	-0.394	0.69
	mCTIB on foam surface	0.78 ± 0.17	1.62 ± 0.36	-13.835	<0.001
	US on left leg	1.23 ± 0.65	3.08 ± 1.06	-11.765	<0.001
	US on right leg	1.34 ± 0.88	3.17 ± 1.22	-11.235	<0.001

mCTIB, Modified Clinical Test of Sensory Interaction on Balance; US, Unilateral Stance.

Results

The 30 male participants with mean (SD) of age, weight, height, and BMI were 23.1 (2.12), 71.1 (13.8), 1.69 (.05), and 24.69 (4.61), respectively. Table 1 presents the comparison of balance scores between a sandal, standard shoe, or no footwear (barefoot) conditions. Table 2 presents the comparison of balance scores between eyes open and closed conditions.

There were no significant effects between footwear conditions for mCTIB with eye open on firm surface (p=0.17). However, there were significant effects between footwear conditions for mCTIB with eye closed on firm surface (p=0.002). Post-hoc analyses indicate a significant differences in mCTIB between barefoot and sandal (p=0.002), and between standard shoe and sandal (p=0.02), but not between barefoot and standard shoe (p=0.99). In addition, there were significant effects between footwear conditions for mCTIB with eye open and closed on foam surface (p=0.04 and p=0.003, respectively). Post-hoc analyses indicate a significant differences in mCTIB with eye open between barefoot and sandal (p=0.03), but not between standard shoe and sandal (p=0.73), and between barefoot and standard shoe (p=0.49). However, there were significant differences in mCTIB with eye closed between barefoot and sandal (p=0.004), and between standard shoe and sandal (p=0.02), but not between barefoot and standard shoe (p=0.97).

There were significant effects between footwear conditions for US on left foot with eye open and closed (p=0.02 and p=0.03, respectively). Similarly, there were significant effects between footwear conditions for US on right foot with eye open and closed (p=0.02 and p=0.05, respectively). Post-hoc analyses indicate a significant differences in US on left foot with eye open and closed between barefoot and sandal (p=0.03 and 0.04, respectively), but not between standard shoe and sandal (p=0.14 and p=0.18, respectively), and between barefoot and standard shoe (p=0.89 and p=0.89, respectively). Similarly, there were significant differences in US on right foot with eye open and closed between barefoot and sandal (p=0.01 and 0.04, respectively), but not between standard shoe and sandal (p=0.27 and p=0.16, respectively), and between barefoot and standard shoe (p=0.70 and p=0.95, respectively).

There were significant effects between footwear conditions for LOS reaction time during forward movement (p=0.02). Post-hoc analyses indicate a significant differences in LOS reaction time during forward movement between barefoot and sandal (p=0.04), and between standard shoe and sandal (p=0.04), but not between barefoot and standard shoe (p=0.88). Similarly, there were significant effects between footwear conditions for LOS reaction time during left side movement (p=0.01). Post-hoc analyses indicate a significant differences in LOS reaction time during left side movement between barefoot and sandal (p=0.01), but not between standard shoe and sandal (p=0.31), and between barefoot and standard shoe (p=0.56). In addition, there were no significant effects between footwear conditions for LOS reaction time during backward and right side movement (p=0.14 and p=0.16, respectively).

There were insignificant differences in the postural sway measured by mCTIB on firm surface when tested in eyes closed condition compared to eyes open test conditions in all the three footwear conditions (p>0.05). There were significant differences in the postural sway measured by mCTIB on foam surface and US on left and right leg when tested in eyes closed condition compared to eyes open test conditions in all the three footwear conditions (p<0.001).

Discussion

The present study aimed to evaluate the differences between wearing a sandal, standard shoe, or no footwear (barefoot), in relation to postural stability measured by mCTSIB, US, and the LOS in healthy young adult males. The findings of the present study indicates that the wearing a sandal compared to bare feet significantly affect balance scores in mCTSIB with eye closed on firm surface, mCTSIB with eye open and closed on foam surface, US on left and right foot with eye open and closed, and the LOS reaction time during forward and left side movement. However, wearing a standard shoe compared to bare feet did not significantly affect balance scores in standing.

A previous study noted significantly increased medio-lateral and antero-posterior sway in eyes-closed testing in all footwear types compared to bare feet[24]. Another study reported less sway in bare feet quiet standing compared to wearing own shoes and other footwear conditions[25]. In addition, AP sway was increased in older adults wearing athletic footwear compared to bare feet[26]. The tactile postural control mechanisms which transfer required updated sensory information to the CNS for the maintenance of balance can be altered by footwear[24].

In the present study, there were increased postural sway and reduced stability when tested in eyes closed condition compared to eyes open test conditions in all the three footwear conditions. Similarly, previous studies reported increased postural sway and reduced stability when tested in eyes closed condition compared to eyes open test conditions[26,27]. The importance of vision in postural control is reported in the previous study[28].

In the preset study, there were increased postural sway and reduced stability when tested with standard shoes compared to sandal. Previous study reported that the poor footwear characteristics of sandal such as minimal heel counter stiffness and poor motion control resulting negative effect on balance[24].

The present study had some potential limitations. As this was a comparative study the small number of participants minimizes the generalizability of the results. The result of present study is limited to only healthy young adult males. Future research of footwear's effect on balance in young adult males who require stability (such as, acute ankle injuries, or lower extremity orthopedic conditions) would give further knowledge about the importance of footwear on balance in the younger adult population.

The present study concludes that the wearing a sandal compared to bare feet significantly increased postural sway and reduced stability in healthy young adult males. However, wearing a standard shoe compared to bare feet did not significantly affect balance scores in standing.

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Ethics approval and consent to participate

The study was approved by the ethics committee of the College of Applied Medical Sciences, King Saud University. The participants were asked to sign a written informed consent form approved by the institution ethics committee of King Saud University.

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Authors' contributions

SA: Corresponding author, participated in the design of the study, participated in the data collection, drafted the manuscript and finished the manuscript. AA: participated in the design of the study, helped in ethics applications and revised the manuscript critically. HZ: participated in the design of the study, developed the protocol, and revised the manuscript critically. All authors read and approved the final manuscript.

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