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A study of Postural Sway according to the Wedge Direction during one Leg Standing

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Abstract

Background/Objectives: Equilibrium is the ability to maintain the Center Of Gravity (COG) in their Base Of Support (BOS) and the human body to maintain balance. The purpose of this study is to healthy adults when wearing medial/lateral wedge, ankle posture was to evaluate the effect of the dynamic balance. **Methods/Statistical Analysis:** This study elected a healthy adult male 14, female 26 people that have no physical balance due to musculoskeletal and neurologic abnormalities, ankle instability. Tetrax interactive balance system was maintained for 30 seconds on each surface (plane surface, lateral wedge, medial wedge) on the one leg standing position. Tetrax interactive balance system results through the General Stability Index (GST), Weight Distribution Index (WDI), weight distribution was collected. Data was analyzed the within surface in comparison paired t-test and the between surface in comparison one-way ANalysis Of VAriance (ANOVA). **Findings:** In the comparison between each floor, there were significant differences in weight distribution index ($p<.05$), in visual conditions change between the stability index was a significant difference ($p<.05$). Weight distribution difference of left and right were significant differences between the medial wedge and flat from the eyes open ($p<.05$), The eyes-closed state was a significant difference in medial wedge, flat and medial wedge, lateral wedge($p<.05$). Therefore, closing one's eye is considered during dynamic balance training to get the effect of improving result. **Application/Improvements:** Therefore, closing one's eye is considered during dynamic balance training to get the effect of improving result.

Keywords: Dynamic Balance, Lateral Wedge, Medial Wedge, One Leg Standing, Weight Distribution

1. Introduction

Balance is the ability of the human body to maintain the equilibrium and the Center Of Gravity (COG) in it is their own Base Of Support (BOS)[1]. It is a complex process which reacts to external movements that happen whenever the body has voluntary movement to keep the posture[2]. The safety degree to maintain balance of human body is defined as stability[3], and this stability is evaluated by the size of BOS, position and height of center of mass, but it is evaluated by slope angle of the Center Of Mass (COM) and the center of pressure nowadays[4]. Controlling body position in some space by maintaining direction and stability is called Postural balance. The direction of posture which maintains suitable relationship in body and environment is also known as kinetic balance which is the ability that returns body to it is equilibrium status[5,6]. Humans adjust the posture not only in still situation but also in kinetic situation to maintain the postural balance. Thus, it is the strategy which can change kinetic reaction by sensory information that constantly informs direction of body and environment[7].

The ability that maintains the center of gravity in the base of support is called as postural sway[8], it means being maintained in the range of stability[9], and this is the phenomenon that pertains to every human being without doesn't have any physical defeat and so it is seen as the expression of balance sensory system[10]. There are always subtle quakes even humans take in a neutral posture standing up straight. In other words, the center of gravity of human body repeatedly shows quakes in the direction

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of back and forth, left and right and the vibration comes from the quakes is irregular and complicated[11,12]. In case of a healthy adult, they get information and are controlled from the sensory input which is all-body sensory information that comes from the sole of a foot and connected which is contacted to the base of support[13,14]

One leg standing means holding the weight of to one leg and it is a posture that requires dynamic stability that is essential to humans to perform swing phase whenever they walk or go up and down the stairs[15-17]. As you see, one leg standing is suitable dynamic state to measure balance ability in various environments and so it complements the general balance measurement which has always operated in still state[18,19].

The main purpose of Wedge is to improve the condition of skeletal alignment whenever human stands up straight or walk[20]. For balance, the joint of ankle is the body part that shows posture-controlling strategy very firstly when the body is started to shake[21]. In addition, the joint of ankle has very important structure for its very first functions like absorbing shock and moving the body when humans walk. That keeps balance and walking[22,23]. Especially when human stands on wedge, the joint of ankle potentially shows the stiffness, and it is related to essential factors which are needed to improve the symmetry of posture which is needed by each person or to improve the stability of the human body. Wedge is also widely used as one of the treatments for deformation of the foot[24]. On previous researches, there was insufficient information about dynamic balance when the wedge is worn, because the researchers had only evaluated still fluctuation. Also, there is great deal of papers about one leg standing or wedge. However, there are only few papers about how the weight distribution and stability differ with the one leg standing posture, wearing wedge and different form of wedges. Therefore the purpose of this study is to explain how the wedge affects on human's posture when a healthy subject is standing with one leg to evaluate the dynamic balance.

2. Method

2.1 Subjects

Subjects are healthy women and men who had been instructed about the purpose of the study and the method of study before being part of the study and made an agreement. They are total 40; 14 men and 26 women. Their physical characteristics are just the same with Table 1.

The criteria for selection are: 1. Person who has the operation ranges of the ankle, knee and hip joint in normal level, 2. Person who doesn't have any deficiency of the visual, auditory senses and the body balance by musculoskeletal or neurology disorder, and 3. Person who has never gone through knee or ankle surgery. The criterion for exclusion has set as person who can't keep on standing with one leading leg on foothold or wood wedge. A leg which can kick the ball when the ball is rolled has settled as leading leg.

Table 1. The usual properties of the subjects (N=40)

Characteristics	Female(n=26)	Male(n=14)
Age	19.64±1.15	19.23±1.69
Height(cm)	162.2±5.35	175±3.58
Weight(kg)	55.2±4.67	68.07±7.05

2.2 Study Method

This study was conducted with single group. A balance measuring instrument was used to measure posture flexibility and balance ability. A balance measuring instrument reflects movement of pressure change and center of pressure; this is measurable because it is composed with four footholds to place each of the heels and the whole surface of foot. In order to measure in one leg standing position, a wood block sized 30cm for lengths, 3.5cm for heights has placed exactly at the center of four footholds and to make the weight distributed equally, slip protection pad has been attached. The center of wood block is indicated with a pen in order to place one foot[25] (Figure1). The wood wedge sized 75mm for breadth 250mm for height 10 degrees for angle was made for measuring posture[26] (Figure 2). A subject place barefoot to the exact center of the foothold. One experiment has conducted by two subjects. One subject was in direct one leg standing experiment and the other stood behind or beside of the subject to protect her/him from getting hurt from a fall.

Plane Surface (PS), 10 degrees Lateral Wedge (LW), 10 degrees Medial Wedge (MW), on these three surface one leg standing experiment was performed with Eyes Opened (EO) and Eyes Closed (EC) (Figure3).

For EC, subjects raised and bent their opposite leg with 90 degrees for knee and 45 degrees for hip joint when it is said like, 'Please raise your one leg but not leading leg', and they kept that posture for 30 seconds each.

A horizontal stick that almost reached the waist line was in front of subjects to let their fingers to be placed lightly without weight to prevent the body from leaning on one side with one leg standing posture[27]. Subjects got 2 minutes rest after a measurement for each surface to prevent the stress (Figure 4 and 5).

Figure 1. Foot plate for one leg standing
(Lt: Above of foot plate, Rt: Below of foot plate)

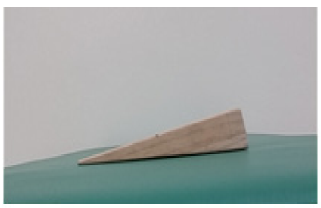

Figure 2. The 10 degree wedge that induces ankle position

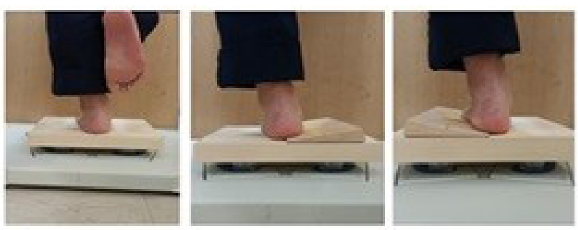

Figure 3. Wedge shape (plane, lateral wedge, medial wedge)

2.3 Balancing Ability

Items to be measured in this study include General Stability Index (GST), Weight Distribution Index (WDI) and weight distribution.

2.3.1 General Stability Index (GST)

General stability index measures posture quake and shows general degree of stability. If the stability is high, it means the weight on four force plate, the front side and back side of the feet is placed, doesn't have much changes. Controlling the changes and compensation skill of subject's posture is evaluated. Stability level is shown with minimum of 0 point to maximum of 100 points and lower the points are, higher the stability of balancing ability is[16,28].

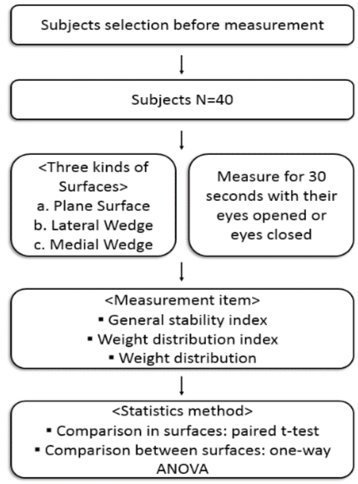

Figure 4. Study flow diagram

Figure 5. One leg standing position
(Lt.: Front , Rt.: Side view)

2.3.2 Weight Distribution Index (WDI)

Weight distribution index shows the percentage (%) of the degree of weight distributed to four footholds and each foothold is equal 25%. By converting weight distribution to points, the posture isn't flexible if the points are as low as 0, 4~6 points means normal and weight distribution ability is low if the points are over 6. As weight distribution changes a lot, the body condition is bad[29].

2.3.3 Weight Distribution

Balance measuring instrument showed weight distribution between left and right feet, toes and heels, but in this study, it was able to measure by one leg standing by using four pads instead of toes and heels. When the foothold was divided horizontally into two left and right shows weight distribution on Lateral part and Medial part and divided into three in vertical way, front and back side of the feet showed weight distribution on each toe and heel. 50% of weight is on left, right, heel and toe. Compare weight distribution difference of back and forth, left and right and weight distribution which has measured by four footholds when the subject was doing one leg standing by each surface and condition of visions.

2.4 Statistical Analysis

All measured values are converted to statistics by using windows program called SPSS ver 22.0. Compared the differences among measured value of GST, WDI and weight distribution on Plane surface, Lateral wedge and medial wedge with eyes closed and eyes opened. Paired T-test was used to compare the data inside of the surfaces and one-way ANOVA was used to compare the data between surfaces. Statistical significance was set at p <.05.

3. Results

3.1 General Stability Index

The result of comparing each surfaces is that there was no significant difference neither on Plane surface, lateral wedge or medial wedge with eyes opened (p>.05). However, EO and EC were 14.64±6.68 and 17.06±9.66 on PS, 14.20±6.86 and 17.31±9.01 on LW and 14.95±8.44 and 17.15±9.96. There was significant difference between condition of visions inside of each surfaces (p<.05) (Table 2).

3.2 General Stability Index

Weight distribution index showed significant difference between surfaces with the value of 5.06±3.01 for PS, 5.26±2.41 for LW and 7.63±3.66 for MW with EO (p<.05), and 5.77±3.39 for PS, 5.38±2.84 for LW and 8.52±3.71 for MW with EC (p<.05). For condition of visions, however, there were significant differences. EO and EC each showed 5.06±3.01 and 5.77±3.39 on PS, 7.63±3.66 and 8.52±3.71 for MW (p<.05) (Table 3).

3.3 Weight Distribution Andweight Distribution Difference

The significant difference of weight distribution between left and right, and toe and heel means that body weight tends to lean on a certain side. The weight distribution difference between heel and toe was significant only on PS (p<.05), and there was no significant difference between

Table 2. The different GST according to different surface and visual condition (N=40)

	Vision	Surface			f	post-hoc
		PS[a]	LW[b]	MW[c]		
GST	EO	13.64 ± 6.68	14.20 ± 6.86	14.95 ± 8.44	.319	a=b=c
	EC	17.06 ± 9.66	17.31 ± 9.01	17.15 ± 9.96	.022	a=b=c
	t-value	-3.347*	-2.674*	-1.791		

*aaverage ± standard deviation

*GST: General stability, EO: Eyes open, EC: Eyes close, PS: Plane surface, LW: Lateral wedge, MW: Medial wedge.

Table 3. The different WDI according to different surface and visual condition (N=40)

	Vision	Surface			f	post-hoc
		PS [a]	LW [b]	MW [c]		
GST	EO	5.06 ± 3.01	5.26 ± 2.41	7.63 ± 3.66	. 8.665*	a=b, a<c, b<c
	EC	5.77 ± 3.39	5.38 ± 2.84	8.52 ± 3.71	10.589*	a=b, a<c, b<c
	t-value	-2.418*	-.396*	-2.828*		

*aaverage ± standard deviation

*WDI: Weight distribution, EO: Eyes open, EC: Eyes close, PS: Plane surface, LW: Lateral wedge, MW: Medial wedge.

Table 4. Left, right and heel, toe of the weight distribution (%) (N=40)

Visual	Plate	Surface			f	post-hoc
		PS^{a}	LW^{b}	MW^{c}		
EO	Left	49.28 ± 3.16	49.93 ± 3.45	48.04 ± 3.62	3.162*	a=b, a=c, b>c
	Right	50.72 ± 3.16	50.07 ± 3.45	51.96 ± 3.62	3.161*	a=b, a=c, b<c
	t-value	-1.448	-.132	-3.432		
	Heel	56.43 ± 8.87	58.34 ± 6.85	63.49 ± 8.98	7.768*	a=b, a<c, b<c
	Toe	43.57 ± 8.87	41.66 ± 6.85	36.51 ± 8.98	7.768*	a=b, a>c, b>c
	t-value	-1.838	.740	-3.248		
EC	Left	49.08 ± 3.18	50.37 ± 3.19	48.08 ± 3.75	4.640*	a=b, a=c, b>c
	Right	50.92 ± 3.18	49.63 ± 3.19	51.93 ± 3.75	4.640*	a=b, a=c, b<c
	t-value	-1.838	.740	-3.248		
	Heel	57.45 ± 10.28	58.36 ± 7.97	64.41 ± 10.72	6.049*	a=b, a<c, b<c
	Toe	42.55 ± 10.28	41.64 ± 7.97	35.59 ± 10.72	6.049*	a=b, a>c, b>c
	t-value	4.583*	6.632	8.502		

^{*a}Average ± standard deviation

* Left and Right means when it divides wooden plate into equal parts vertically. Heel and Toe means posterior part when it divides wooden plate into equal parts transversely.

* For comparing Left-Right and Heel-Toe, We did compared T-test and for comparing surface, we did one-way after normality test is done.

*EO: Eyes open, EC: Eyes close, PS: Plane surface, LW: Lateral wedge, MW: Medial wedge.

Table 5. Comparison between the weight distribution difference according to direction (N=40)

Direction	Visual	Surface			p	Direction	Visual	Surface			p
		I	J	I-J				I	J	I-J	
Left-Right	EO	PS	LW	-1.27	.106	Heel-Toe	EO	PS	LW	-3.46	.218
			MW	-2.00*	.011				MW	-12.54*	.000
		LW	PS	1.27	.106			LW	PS	3.46	.218
			MW	-0.74	.343				MW	-9.09*	.001
		MW	PS	2.00*	.011			MW	PS	12.54*	.000
			LW	0.74	.343				LW	9.09*	.001
	EC	PS	LW	-0.14	.859		EC	PS	LW	0.65	.841
			MW	-1.77*	.026				MW	-11.91*	.000
		LW	PS	0.14	.859			LW	PS	-0.65	.841
			MW	-1.63*	.041				MW	-12.56*	.000
		MW	PS	1.77*	.026			MW	PS	11.91*	.000
			LW	1.63*	.041				LW	12.56*	.000

* Left-Right: The average weight distribution difference of the between left and right. Heel-Toe: The average weight distribution difference of the between heel and toe., I-J: The difference beteewn compared two average weight distribution.

* WDI: Weight distribution, EO: Eyes open, EC: Eyes close, PS: Plane surface, LW: Lateral wedge, MW: Medial wedge.

*If the difference between surfaces is bigger, the wedge affects left&right or heel&toe direction in weight distribution a lot.

left and right, heel and toe inside of surfaces on LW and MW (p>.05) (Table 4).

Comparing weight distribution on left side under EO condition along left, right, toe and heel, there was no significant difference between PS and LW, PS and MW (p>.05), LW was significantly higher between LW and MW (p>.05). For the weight distribution on right side under EO condition, there was no significant difference between PS and LW, PS and MW (p>.05), MW was significantly higher between LW and MW (P<.05). For weight distribution on heel under EO condition, there was no significant difference between PS and LW (p>.05), it was significantly high on MW between PS and MW, LW and MW (p<.05). For weight distribution on toe under EO condition, there was no significant difference between PS and LW (p>.05) but on PS between PS and MW, and on LW between LW and MW were significantly high (p<.05). For the weight distribution on left under EC condition, there was no significant difference between PS and LW, PS and MW (p>.05), it was significantly high on LW between LW and MW (p<.05). For the weight distribution on right under EC condition, there was no significant difference between PS and LW, and PS and MW (p>.05), it was significantly high on MW between LW and MW (p<.05). For the weight distribution on heel, there was no significant difference between PS and MW (p>.05), it was significantly high on MW between PS and MW, and LW and MW both (p<.05). For the weight distribution on toe, there was no significant difference between PS and LW (p>.05) and everything was higher than MW between PS and MW, and LW and MW (p<.05) (Table5).

4. Discussion

The study was to find out influence to healthy adult that ground & inner, outer wedge affect on postural sway while taking on leg standing. It was to measure, GST, WDI and Weight Distribution and find difference among them under the situation of opening eyes or closing them after taking one leg standing in order to dynamic status. Based on the result, in case of GST, comparison between ground surfaces doesn't have significant difference and it shows significant difference between visible conditions in every ground surface. And in case of WDI, inner wedge has high significance than other 2 ground surfaces in comparison between ground surfaces. In terms of weight distribution difference significant, significant difference between every surface would be placed in between ground surface and inner wedge and there is weight distribution difference between the biggest front and rear in inner wedge than other 2 ground surfaces.

Ganesan and others (2014) reported that, targeting a normal person, wearing of inner side and outer side has relation with reduction of posture sway from inside and outside when just maintaining static posture, taking a look at front above both kinds of outside and inside wedges[30]. Advanced study about visual information emphasized importance of various sense stimulation such as proprioceptive sense, visual and vestibular sense in a way to postural control when having two leg standing[31]. Also, based on the result that evaluates movement area and speed of pressure center point by each sense stimulation applied with imbalance motivation on vestibular sense, proprioceptive sense, and visual condition, it was reported that balance training is helpful on various condition even in one leg standing[32]. But when proprioceptive sense disturbance and it was disclosed that when visual disturbance were applied in two legs standing and one leg standing respectively. Proprioceptive sense disturbance gives more effect to two legs standing than visual disturbance whereas visual disturbance gives more effect to one leg standing than proprioceptive sense disturbance[33]. The comparison result of stability index per visual condition when on ground and wearing of wedge outside and wedge inside in this study found that when on ground and wearing outer wedge, measurement in eyes close makes GST score increase significantly than opening up eyes. This means significant decrease of stability and implies that information through visual plays a important role to keep pertaining balance as organ which maintains and provides information about balance maintenance[34]. However, unlike comparison between visual conditions, there wasn't significant difference on comparison between ground surfaces. Complicated move of a body for controlling balance is measures by a machine directly when an object touches two feet and stands on a machine in a characteristic of a measuring equipment using a theory that less weight change on 4 ground reaction force equipments, more stability but, in this study, it is considered that weight change on individual 4 ground reaction force equipment won't be huge, not measuring delicately than movement body controlled because of not disconnected footplate between an object and an equipment in order to measure one leg standing.

Tropp and others spoke that if reaction on ankle joint exists, location change of ankle joint will affect more on postural sway[35]. In this study, WDI was measured based on change of weight distribution divided in 4 plates (2 toes, 2 heels) and regardless of visual condition, when wearing inner wedge is more significant than ground and when wearing outer wedge ($p<.05$). Many advanced study reported that outer wedge gives change on biochemical factors related with balance maintenance like moving moment of subtalar articulation and knee joint from center of weight to be far end[36]. However, a reason that WDI doesn't show significant difference between ground and inner wedge is that there is no enough time to be adopted in sudden balance environment change[37], it isn't a shape of insole that wedge has incline on back axis[38], and foot entire length (250 mm) is wooden material. Because of it, it is considered that ground and wearing inner wedge became a factor to reduce difference of ankle posture.

When the wearing of inner wedge is compared with ground and the wearing of outer wedge respectively, significant increase of WDI is that weight distribution change above inner wedge is the largest in significant level. Since measuring in one leg standing used with footplate directly produced an equipment to measure 2 legs standing in this experiment, it can't translate morbidity but analyze result by wearing inner wedge. According to Ahn and others (2005), inner/outer wedge can cause inner spread in ankle joint[39], in addition to that, Bate and others (1979) reported that the wearing inner wedge made outer spread decrease in ankle joint[40]. According to Tae Bum Yoo and others (2008), when walking, inner spread of inner wedge improved stability on ankle shape and center of pressure moved to higher position of incline since a walker stepped most highest spot in most highest place for smooth walk[35]. However, in case of this experiment, a measurement while maintaining one leg standing shape not consecutive move like a walk, as this pressure center movement result, it is considered that WDI is higher when wearing inner wedge than ground and wearing outer wedge.

Based on the measurement result about weight distribution difference among left and right, a heel and a toe from each ground surface, weight distribution between a heel and a toe has significant difference from all visual condition and ground surface. Compared with it per each ground surface, the difference of weight distribution was shown very huge on above inner wedge (Table 5). Also, in advance study, inner wedge made vertical force reduce at the front area of a foot than ground, and vertical force at the back area didn't have any difference with ground. Outer wedge reduced vertical force at the front area of a foot than ground and increased vertical force of foot back area than ground. But this experiment resulted opposite like vertical force was reduced at the back side of a foot than ground. This was considered that, in case of advanced study, with manufacturing wedge a shape of shoe insole which had incline at the back axis only, vertical force was increased at the back side of a foot relatively in order to maintain inner spread, but in case of this study, vertical force was reduced because pressure was widely spread at the front and the back, not to be increased since it is distributed at the back side of a foot by wedge produced with entire length of a foot.

Weight-bearing on subtalar articulation pronation movement was caused by outer spread of calcaneus, collection of malleolus, sole fold and inner circling of tibiofibular joint, and non-weight-bearing was movement caused by inner spread and open of calcaneus and dorsiflexion[18]. Schamberger and others (2002) spoked that pronation on a foot increased tension level of leg inner structure, inner-rotating knee joint axis, and valgus of knee joint. On the other hand, foot supination increased tension level of leg outer structure, outer-rotating knew joint axis, and varus of knee joint[41,42]. In this study, taking a look at run-out of left and right and front and back between 2 ground surfaces, in closing eyes and opening eyes, inner wedge and outer wedge, inner wedge and ground are significant. But in case of seeing weight distribution difference between left and right under closing eyes, leaning the weight to left against inner wedge and to right against outer wedge showed significant gap, so, just for this case, weight leaned to each other opposite side.

Sometimes unstable ground surface is constructed in order to lead balance maintenance difficult in various ways to make level of difficulty up for balance training starting from on stable surface ground. Unstable ground surface to be experienced with small tool like balance pad gets instability higher dramatically than ground since small tool inside is filled with air. If this study result is applied to balance training, using foot entire length wedge in one leg standing takes big weight distribution change rather than ground to direction of left and right, front and back, etc. Especially, application of inner wedge is presented to big change than application of outer wedge and when closing eyes get more unstable. Therefore, application of wedge enables an object to take an training in circumstance which increases change of weight distribution at the same with stable ground surface like harden flat ground rather than using soft small tool.

This study isn't generalized since object samplers are limited to 20s ages healthy adult. Weight distribution and stability are not sufficient to explain giving own sense information with allowing both hands support and bio-chemical body in order to control compensation exercise when having one leg standing. Moreover, it has limitation that characteristics such as Pes valgus, Pes varus, deformity of an object wasn't considered. For later on, a study that is able to provide information to confirm walk pattern change applying with wedge making ankle angle change and foot aid should be continued as suggestion. Also, this study will provide solution for not only optimized condition while operating delicate goal-directed subject but also improvement of shape balance wearing foot aid to change ankle shape of patient who has disabled function on balance control. And it guides development possibility of shoes for individual balance problem.

5. Conclusion

Purpose of this study is to find out the effect of ankle position on affect dynamic balance when wearing a healthy adult wears wedge.

Firstly, When GST was compared, there was no significant difference between surfaces (p>.05), but there was significant differences under condition of visions inside of each surfaces only (p<.05).

Secondly, WDI was significantly highest on medial wedge compared to the other surfaces (p<.05).

Thirdly, Related to Weight distribution difference between Left and right, heel and toe, condition of visions had no affect on lateral wedge and medial wedge. For comparison between surfaces, weight was more on right heel side on medial wedge than lateral wedge and on the lateral wedge, the weight was more on left, toe side. The significant difference among each surface was only shown between plane surface and median surface, and there was a large weight distribution difference between front side and back side on medial wedge compared to lateral wedge and plane surface.

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