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Kinetics Analysis during Stance Phase of Fore Foot Contact versus Rear Foot Contact in Running

The purpose of this study was to compare and analyze the difference of the ankle joint movements during landing. Seven adult males voluntarily participated in the study and the average foot size of the subjects was 269.8 mm. Image analysis equipment and the ground reaction force plate (landing type) was used to measure th kinetic variables. As a result of this study, it was confirmed that the vertical ground reaction force peak point appeared once in the barefoot with forefoot, while two peak points appeared in the barefoot and functional shoe foot with rear foot landing. About ankle angle, fore foot landing ankle angle, the average with bare foot landing was −10.302° and the average with functional shoe foot landing was −2.919°. Also about rear foot landing, ankle angle was 11.648° with bare foot landing and 15.994° with functional shoe landing. The fore foot landing, ankle joint force analysis produced 1423.966N with barefoot and 1493.264N with functional shoes. But, the rear foot landing, ankle joint force analysis produced 1680.154N with barefoot and 1657.286N with functional shoes. This study suggest that the angle of ankle depends on the landing type and bare foot running/functionalized shod running, and ankle joint forces also depends on landing type.

Key words: *Motion Analysis; GRF; Injury; Joint Force; Running*

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INTRODUCTION

Running is a form of walking. It is the most basic locomotion for human, and it is easy to operate and there are few limit factors such as place and athlete suit. For this reason, running is a representative aerobic exercise that has been ongoing since the inception of human upright walking. In particular, recent health awareness has increased and many people are participating in the running exercise as a preventive measure for adult diseases such as obesity and hypertension.

The interest in this kind of running has developed in terms of exercise effect and functionality of running, and interest in functional shoes has also increased. Particularly, in relation to the increase of the exercise effect and the efficient operation performance, the study on the contribution and the function of the running to the running shoes has been actively carried out. Nigg [1] reported that functional shoes absorb the impact force to protect the joints of the human body including feet and prevent injury.

Functional shoes generally increase the height of the heel of the shoes and adjust the hardness of the outsole and the insole to prevent the injury by shock absorption and increase the efficiency of the exercise. Romkes et al. [2] and Nigg et al. [3] found that unstable shoes with a higher heel had positive effects on lower extremity muscles. However, Lieberman et al. [4] showed that the design of the heel of the functional shoes causes the rear foot contact in the stance phase, that the dysfunctions of functional shoes were more likely to cause injury than barefoot running in the form of fore foot contact and that the alternative method is more effective.

Tibia rotation due to rear foot eversion causes patella femoral pain, achilles tendon pain and shin splint in the support phase before running toe off interval(Clement et al. [5], Smart et al. [6], Tiberio [7],

Vitasalo and Kvist [8]. Nordin and Frankle [9] Suggest this: Rear foot landing causes foot eversion. On the other hand, the fore foot landing has the time to adapt to irregular ground conditions, so that it flexibly moves the foot and effectively absorbs impact from the ground. Therefore, The purpose of this study was those analyze the difference of the ankle joint movements during landing by using the image analysis equipment and the ground reaction force plate (landing type) and provide basic data to prevent injuries of the lower extremity joints by analyzing the kinematic variables related to injuries between landing types.

METHODS

Subjects

The subjects of this study were seven normal adult males who were lived in Seoul, Korea, and were not injured in the lower limb for the past year.The subjects were informed in writing and agreed with the experimental procedure before the start of the experiment. And they have been pretrained in the behavior required for the experiment. The mean height of the subjects was 179.4 cm, weight was 70.2 kg, and the mean age was 22.1 (Table 1). The average foot size of the subjects directly measured was 269.8 mm.

Before the experiment, anthropometrical variables, such as height, weight, foot length, and foot width, were measured. Foot lengths were measured at the longest point when viewed from the side and foot widths were measured horizontally at the widest point of the foot [10,11]. To implement the full-body musculoskeletal models of individual subjects, reflective markers were attached to 16 points on the upper extremities, 19 points (Helen Hayes marker set) on the lower extremities and the images were taken [12]). A 3D motion analyzer consisting of two force-measuring boards (600 mm×900 mm, Kistler Ltd., Swiss), eight infrared cameras (Eagle 4, Motion Analysis Ltd., USA), 10-mm reflective markers, a data processor, and a PC was used as a measurement tool.

Table 1. Characteristics of subjects (n=7)

Gender	Height(cm)	Weight(kg)	Age(yr)	Foot size(mm)
M(SD)	179.428(5.94)	70.285(6.29)	22.142(1.68)	269.857(7.69)

Exercise Methods

he mission to be performed by the subjects is as follows. Running in two different conditions: landing type and barefoot / functionalized wear(produced by N, model: free run distance) running, and tested according to the landing type at intervals of 2 weeks. The first experiment was performed with familiar Rear-foot landing running, which was performed under two conditions: barefoot and functionalized. After the end of the Rear-foot landing experiment, subjects were provided with images and information about fore-foot landing. In order to increase the proficiency of the fore-foot landing, the subjects performed an experiment with a 2-week practice period. Before the experiment, the subjects performed light stretching and practice running.

Experiments were carried out five times under each condition, and the running speed was 3.3 ~ 3.7m / s (Kaneko et al. [13]). Data of the best attitude was selected.

RESULTS

Ground reaction force

The ground reaction force(GRF,N) according to landing type and bare foot / functional wear in the support phase is shown in Fig.1. Of the four graphs, the (a), (b) two graphs with one peak point represent the fore foot landing GRF. The (c), (d) two graphs (c), (d) indicate the rear foot landing GRF and have two peak points. The first peak point of the rear foot landing GRF graph is associated with the impact from the ground.

Ankle Angle

The ankle angle according to the bare foot / functional wear and landing type are shown in Table 2. In fore foot landing condition, the ankle angle of barefoot running was −10.312° while functionalized shod running was −2.919°. In rear foot landing condition, the ankle angle of barefoot

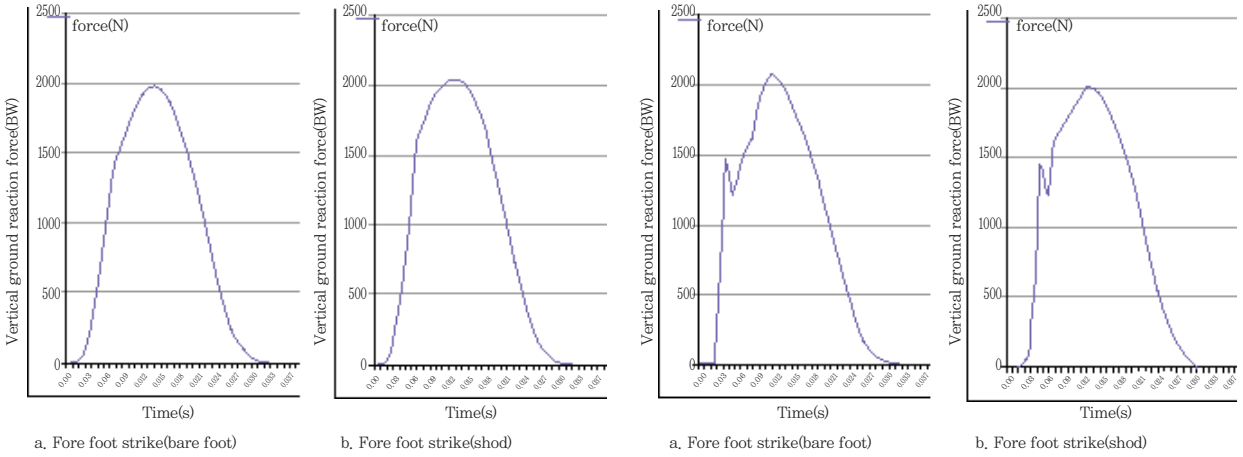

Fig. 1. Ground reaction force (GRF) according to the 4 different conditions.

running was 11.648° while functionalized shod running was 15.994°. Table 3 is the result of two-way ANOVA conducted to determine whether there is interaction with the main effects of landing type and bare foot/functional wear. The analysis showed that there was statistically significant difference in ankle angle according to landing type ($p<.05$). On the other hand, there was not significant difference in ankle angle between barefoot and functional wear ($p<.05$). There is no interaction between two independent variables.

Table 2. Ankle angle (unit:deg)

Factor				
Landing type	Bare/Shod	N	M	SD
Fore foot landing	Bare	7	-10.31	9.65
	Shod	7	-2.91	9.89
Rear foot landing	Bare	7	11.64	7.08
	Shod	7	15.99	4.55

Bare=bare foot running, Shod=functionalized shod running

Table 3. Ankle angle two-way ANOVA results (unit:deg)

Group	Sum of squares	DOF	Mean square	F	P
Landing type	2923.697	1	2923.697	44.594	.000
bare/shod	241.187	1	241.187	3.679	.067
Landing type*bare/shod	16.246	1	16.246	.248	.623

Bare=bare foot running, Shod=functionalized shod running

Table 4. Ankle joint force (unit: N)

Factor				
Landing type	Bare/Shod	N	M	SD
Fore foot landing	Bare	7	1423.96	224.54
	Shod	7	1493.26	258.79
Rear foot landing	Bare	7	1680.15	301.18
	Shod	7	1657.28	243.95

Bare=bare foot running, Shod=functionalized shod running

Table 5. Ankle joint force two-way ANOVA results (unit: N)

Group	Sum of squares	DOF	Mean square	F	P
Landing type	309008.987	1	309008.987	4.619	.042
bare/shod	3772.530	1	3772.530	.056	.814
Landing type*bare/shod	14865.546	1	14865.546	.222	.642

Bare=bare foot running, Shod=functionalized shod running

Ankle Joint Force

The ankle joint force according to the bare foot / functional wear and landing type are shown in Table 4. In fore foot landing condition, the ankle joint force of barefoot running was 1423.966N while functionalized shod running was 1493.264N. In rear foot landing condition, the ankle joint force of barefoot running was 1680.154N while functionalized shod running was 1657.286N. Table 5 is the result of two-way ANOVA conducted to determine whether there is interaction with the main effects of landing type and bare foot / functional wear. The analysis showed that there was statistically significant difference in ankle joint force according to landing type ($p<.05$). On the other hand, there was not significant difference in ankle angle between barefoot and functional wear ($p<.05$). There is no interaction between two independent variables.

The ankle joint force according to the landing type was lower in the fore foot landing than the rear foot landing, and statistically significant difference was observed($p<.05$). Also, in the fore foot landing condition, the functionalized shod running joint force value was higher than bare foot running condition and the bare foot running joint force was higher in the rear foot landing condition than the functionalized shod running($p<.05$).

DISCUSSION

This study was performed on seven normal adult males. 3D motion analyzer and force plate were used to obtain the vertical ground reaction force of the contact phase and kinematic analysis of the joint was performed. The results were as follows; The angle, the moment, and the joint force which are the kinematic variables according to landing type and barefoot/functional shoed were compared and analyzed.

Ground Reaction Force

As a result of this study, there are two types of graphs of ground reaction force according to landing type and barefoot · functionalization shod. The two ground reaction force graphs that have performed fore foot landing among the four graphs have only one peak point related to the active impact force. On the other hand, the two ground reaction force graphs with the rear foot landing have two peak points. The 1st peak of the two peak points is the peak associated with the passive impact force and is closely related to the injury as suggested by Nigg et al. [3], Munro, Miller and Fuglevand1[4] and Lieberman et al. [4] respectively. This can be attributed to the fact that the Ankle angle is plantar-flexion by using the fore foot during initial contact, resulting in more flexion

of the knee. In other words, fore foot landing is considered to be advantageous for prevention of injuries because there is no 1st peak related to impact force in prevention of injury.

Ankle Angle

The main effect of ankle angle according to landing type was plantarflexion in fore foot landing and dorsiflexion in rear foot landing. Especially in fore foot landing condition, bare foot was more plantarflexion than functionalized shod. In the rear foot landing condition, the functionalized shod was more dorsiflexed than the bare foot. The study of Ground reaction forces in distance running by Peter, et al. [15] showed that plantarflexion in initial contact was higher in fore foot langing than in real foot landing, which reduced vertical GRF. And Squadrone and Gallozzi[16] reported that the fore-foot landing was more plantarflexion than the rear foot landing, the load factor was smaller, and the values of other kinematic variables were changed. Not only landing type but also between bare-foot and functionalized shod group comparisons showed differences.

Fore foot landing can be said to be advantageous from the occurrence of injury due to the absence of ankle and foot abduction.

Ankle Joint Force

Ankle joint force due to landing type showed lower value in fore foot landing than rear foot landing. In the fore foot landing condition, the functionalized shod ankle joint force value was higher than the bare foot, and the bare foot ankle joint force was higher than the functionalized shod in the rear foot landing condition. There was no significant difference in Ankle joint force between bare foot and functionalized shod group. This implies that the impact on the human body by Simon et al. [17] varies depending on the shoe, the speed of movement, the landing method, and the exercise performance.

We compared the differences between four groups of bare foot fore foot landing(FB), functionalized shod fore foot landing(FS), bare foot rear foot landing(RB), and functionalized shod rear foot landing(RS). There was no difference between bare foot and functionalized shod wearing group in each landing type conditions.

The reason for this is thought to be due to the angular difference of the angular joints according to the landing type rather than to the bare foot and functionalized shod wear.

The fore foot landing is advantageous from the injury caused by this because the ankle and foot abduction do not occur. It is considered to be advantageous to the load generated by the impact force due to the 1st peak point. Nigg [1] reported that GRF graph presented two peaks, and first peak was concerned with impulse. Simon et al. [16] reported that the impulse was related to injuries and showed high correlations with the occurrence of injuries in running. Therefore, the fore foot landing using the front of the foot is advantageous from the injury caused by this because the ankle spur and foot abduction do not occur. It is considered to be advantageous to the load generated by the impact force due to the primary peak point.

CONCLUSIONS

In the support phase, the difference between the results of the bare foot running and the functionalized shod running was small. The graph shows that the number of peak points varies depending on landing type. Ankle angle was different according to landing type and bare foot running/functionalized shod running. Ankle joint forces were significantly different depending on landing type, and there were few differences between bare foot running and functionalized shod running. When the landing type was different, there was no primary peak value related to impact force in fore foot landing, and the angular change of the lower limb flexed the knee more and flexed the ankle in the fore foot landing condition. The results are similar to those of the previous study, and it was found through the motion analysis that the fore foot landing is advantageous to absorb the impact. In the fore foot landing, joint angle is lower than rear foot landing, fore foot landing is effective to prevent injuries.

The result of the analysis shows that the fore foot landing joint force is lower than that of the rear foot landing, it is considered that less stressful to the ankle running method is the fore foot landing.

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