



Original Article

Athletic event-specific characteristics in floating toes during the static standing posture

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Abstract. [Purpose] We aimed to determine the cause of floating toe syndrome, along with methods for correction and prevention. [Participants and Methods] We recruited 93 Japanese male students. Participants were grouped, according to primary sport, as Sprinters (SPR), Swimmers (SWM), Gymnasts (GYM), Kendoists (KND) and Controls (CON). Degree of floating toe syndrome was measured according to whether any toe was not in full contact with the ground in a static standing posture—the Floating Toe Point (FTP). Two points were given for each toe that was not at the FTP. The sum of the FTP was defined as the Floating Toes Score (FTS), and was classified as follows: Normalcy (over 18 points), Incomplete Contact (between 10 and 17 points), and Floating Toes (Under 9 points). [Results] The mean FTS for all participants (10.40 ± 5.803) met the criteria for Floating Toes. Scores were highest for SWMs (13.46 ± 5.710), followed by GYMs (13.26 ± 4.505), and SPRs (12.00 ± 4.870), who all met the criteria for Incomplete Contact. Both KNDs (6.55 ± 5.409) and CONs (9.45 ± 4.824) met the criteria for Floating Toes. [Conclusion] SWMs had the highest FTSSs, followed by GYMs, and SPRs. KNDs had the lowest FTS. However, no group was classified as Normal. We suggest that athletes who practice or train with bare feet do not necessarily have higher FTSSs, if evaluated in the standing posture.

Key words: Floating toes, Floating toes score, Athletic event-characteristic

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INTRODUCTION

Floating toes are known as one of the deformities of the toe; where the toe does not contact the ground surface because of too much warping the toes. In general, recognition of floating toes is not high and it is not compared much with other incidences of foot syndromes, for example, hammer toes, hallux valgus, flatfeet, and others. The literature about the incidence of floating toes in children and younger adults by nature are reported mostly by Japanese researchers¹⁻³⁾, although there are some reports from the other countries as an aftereffect of Weil osteotomy in adults^{4, 5)}. Presently, it is not known whether floating toes, except for the after effect of surgery, are the Japanese specific, inherited or an effect of lifestyle or not⁶⁾. It was reported the incidence of floating toes in Japanese infants in 2000 was about 10 times that of the incidence in 1980⁷⁾ and, over 70% of Japanese 3 to 6 years old infants were also reported to have at least one “floating toe”⁸⁾. In adults, about 65% of males and 75% of females were reported to have floating toe at least in one of their toes⁹⁾.

Foot segments are the only part that functions as the interface to the outside of body during posturing in standing and bipedal locomotion like walking and running. Therefore, the morphologies and/or functions of the foot segments may affect

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on the performance of these physical activities.

Some researchers had reported the dysfunctions concerning floating toes^{10, 11}. For example, lowered toe grip strength in floating toes children compared with normal toes children are reported⁶. Similarly, a decrease in toe grip strength is thought to be one of the factors causing floating toes in adults¹³. Furthermore, the ability to keep stabilize the standing posture would be weakened in floating toes because it is necessary to grasp the ground surface with their toes during the standing posture⁶.

Floating toes are also reported to affect the gait pattern, kinetics, or kinematics of the proximal joints. In fact, disability in dynamic balance, decreased step length, and speed during walking are also reported as a result of floating toes¹⁴. Moreover, excessive dorsiflexion¹⁵, developed in the metatarsal-phalangeal (MP) joints, or lack of plantar flexion¹⁶ force are also reported as cause of floating toes. Because propulsive force during walking and running are developed during the latter half of the ground contact phase, the MP joint is thought to contribute a developing force. However, body weight must be supported at only two points, heel and thenar in the floating toes condition, although it is supported at three points, for at toe in addition to these two points in non-floating toe condition. Therefore, it may be thought that insufficient propulsive force was developed because there was no contact at toes in the floating toes condition, whereas in the non-floating condition, the MP joint develops enough propulsive force.

During walking, windlass mechanism¹⁶ is active during passive first MP joint extension. The medial longitudinal arch begins to rise almost immediately with passive first MP joint extension, though there is another type which demonstrate a significant delay of initiation of the windlass mechanism, a greater magnitude of rear foot eversion during walking¹⁷. Then, floating toes was thought to attenuate a person from obtaining the work of the windlass mechanism and restrict the forward movement¹⁶. Besides, it makes walking inefficient as a result of lowering the rigidity in the foot segment¹⁸. It is not only in standing and walking but also other motions in some athletic events too, it is thought that toes play an important role to stabilize the posture to develop force in some direction in the foot.

For example, sprint runners need to develop the propulsive force with their foot to run faster. It is reported that faster male sprinters experience higher maximal rates of MP joint extension¹⁹. Kendo athletes are characterized wearing heavy protective guards and taking a step forward with the left foot from the ready position standing on tiptoe, where left Achilles tendon rupture occurs more frequently²⁰. Moreover, kendo athletes are needed to stabilize the posture not only forward, but also backward and lateral direction, with bare feet. They have a habit to train specifically in Kendo with bare feet, it may enable their toes to be free, and prevent any foot related injuries. Gymnasts need to stabilize their posture on the softer and springy floor, with barefoot or very flexible exclusive shoes. In gymnastic events, lower extremity injuries occur most commonly during landings, tumbling, vaulting and dismounts. Common injuries include ankle sprain equal to knee ligamentous injuries such as anterior cruciate ligament tears or ankle fractures²¹. In contrast, swimmers spend their time in the water not standing with their feet. Thus, they are not affected by the gravity, during most of their training.

Recently, the extent of floating toes was evaluated by scoring how much the toes contact the surface using footprint images in a previous study^{13, 18}. A higher score was gained if the toes are float less in these studies. However, it is not known whether a person with high motor ability, like athletes, have a higher floating score or not. Although it is reported that floating toes person have a tendency for lower function in the lower limbs.^{6, 14, 22-24}. To obtain the cause of floating toes, or hints to prevent or correct floating toes, we compared the incidence of floating toes in athletes of several athletic events whose way of use of toes are different. We postulated that the floating toe score during static standing posture would differ by specific athletic event, especially the incidence of floating toes being lower in barefoot or unshod athletes like those in kendo and gymnastics. Moreover, the incidence of floating toes in weight bearing locomotive athletic like sprint running would be lower. In contrast, it will be higher in the events that do not have body-bearing weight like swimming. Because the necessity and way of supporting and stabilizing the body weight with feet is different event by event, we anticipate there is an athletic event difference in the incidence of floating toes.

In the previous studies²², it has already been mentioned that it is necessary to evaluate and classify floating toes considering, namely static condition, the functional aspects, namely dynamic condition. Even though, the significance of investigating event specificity in floating toes are that it might be useful to assess of floating toe condition in static may become the indices of conditionings of athletes, and/or growth and development of children.

PARTICIPANTS AND METHODS

The participants were 93 Japanese male university students (20.5 ± 1.21 years, 170.9 ± 7.21 cm, 67.2 ± 8.02 kg). Of these, 82 were athletes who regularly trained at specific athletic events, including some representative of Japan in each event in former Olympic games or Universiade games. The 11 remaining participants were non-athletes, namely they did not do regular sports training, although their major in the university was sports sciences.

The participants were each grouped into their specialty athletic event. The breakdown of their sports event was 15 sprint runners (SPR), 13 swimmers (SWM), 23 gymnasts (GYM) and 31 kendo athletes (KND). The other 11 participants who do not have any specialty events were grouped as control (CON). The physical characteristics of the participants were indicated in Table 1.

All participants were informed about the experimental procedure and the purpose of the study prior to study onset. Written consent was obtained from all participants. The methods and all procedures used in these experiments accorded with current

Table 1. The physical characteristics of the participants

Group	N	Age (years)	Height (cm)	Weight (kg)
ALL	93	20.48 (1.212)	170.93 (7.214)	67.19 (8.022)
KND	31	20.06 (1.209)	171.04 (4.538)	68.37 (7.161)
SWM	13	20.23 (0.832)	176.11 (6.073)	71.73 (7.350)
GYM	23	20.30 (1.185)	163.17 (5.249)	59.40 (5.636)
SPR	15	21.00 (1.254)	176.51 (6.420)	70.37 (5.195)
CON	11	21.64 (0.674)	173.15 (5.376)	70.42 (8.269)

Mean (\pm SD).

KND: kendo athletes; SWM: swimmers; GYM: gymnasts; SPR: sprint runners; CON: control.

local guidelines and Declaration of Helsinki and were approved by the local Ethics Committee for Human Experiments of School of Health and Sports Science, Juntendo University (approval code: JU_SPO_Eth_No.27-20).

Pictures of the soles of the feet were taken using a commercially available specially made foot scanner (FootLook2, FootLook Corp., Fukuoka Japan), which modified the commercially available flat-bedded scanner for PC. The participants stood on the scanner with both feet, and postured static standing, leaving the width of both feet the same as their shoulder's width. They looked at the marker put on the front wall at each participant's eye height, 2-meters apart from them during scanning. The scanning time was about 2 seconds. Participants kept static while scanning.

The pressure force of foot contact was estimated in 16 gradations using scanner bundled computer software. The theory of force estimation by the software was as followed. Namely, the color of skin of the human sole is pink despite race and age, as a capillary effect at adding no pressure force under normal conditions. If the higher-pressure force was applied, the whiter the color of sole will be as an effect of pushing out the blood from the capillary. This software distinguishes the color of skin as changing the pressure force and expresses it as the strength in the pressure force by the 16-gradations.

We had set the threshold of the pressure force at the 3rd level of gradation. Based on the pressure force, floating condition of toe fingers was evaluated in 3 kinds as followed. The 12th scale was defined as "fully contacted", between 4th and 11th scale was "half contacted", and under 3rd scale was "no contacted". Their degree of floating toes was scaled at 2-points full mark for each finger and defined as floating toes point (FTP).

Each toe finger was numbered as 1st, 2nd, 3rd, 4th, 5th toe finger from thumb to 5th, respectively, and right and left toe fingers were grouped as R or L, respectively. Namely, right thumb and Left 4th finger was indicated as R1 and L4, respectively.

The sum of FTP in both feet were defined as FTS of 20-points full marks based on Fukuyama et al¹⁰⁾. Moreover, over 18 points were judged as "Normal toes (NT)", between 10 and 17 points were "Incomplete contact (INC)", and less than 9 points were "Floating toe (FT)". However, it was applicable to NT, in the case that when FTP in each thumb are not fully contacted, even if it had over 18 points.

All statistical analyses were conducted using computer software (ORIGIN[®] 2019b ver. 12, OriginLab Corp., Northampton, MA, USA), and data were expressed as mean \pm standard deviation (SD), however, the mean and SD reported are not representative of the statistics due to the paired nature of the analyses. Therefore, the effect size was 0.99705. Number of toe finger, FTP, FTS, Kind of Sports Event were obtained and analyzed. Two-way analysis of variance (ANOVAs) were used to determine between-group difference in FTP at different toe fingers. When significant interactions were found, independent t-test for comparisons of means for each dependent measure were used and post-hoc analysis was performed using Tukey-Kramer test to compare the differences between the event groups and toe fingers. The significant level of the analyses was set at 5%.

We determined the reliability with the intraclass correlation coefficient (ICC). The ICC indicates the error in measurements as a proportion of the total variance in scores. As a rule, we considered an ICC over 0.90 as high, between 0.80 and 0.90 as moderate and below 0.80 as insufficient¹²⁾.

RESULTS

Table 2 indicated the FTP shown by event group and toe digit, respectively. In each group, the points in 5th toe fingers in both right and left were under 1.0, except for SWM. On the other hand, FTP in thumb and 2nd, 3rd fingers on both sides were over 1.0 in all groups, except KND. Only SPR and GYM had over 1.0 points in 4th toe fingers.

Main effects were observed both in fingers and sports events, though there is no interaction among the variables. Post-hoc test revealed KND had significant differences with SPR, SWM, and CON. Moreover, significant differences in FTP in L5 were observed between L1, L2, L3, and L4, respectively. Similarly, significant differences in FTP were observed between L5 and L1, L2, L3, and L4 and between R4 and R2 and R1.

Table 3 indicates the FTS among sports event groups. Mean value in all participants (10.40 ± 5.803) was classified as FT. SWM marked highest FTS (13.46 ± 5.71), and GYM (13.26 ± 4.505) and SPR (12.00 ± 4.870) followed it, though no group were classified as NT, when looking at mean values. Both KND (6.55 ± 5.409) and CON (9.45 ± 4.824) were classified as FT.

Table 2. The Floating toe points shown by event group and toe fingers

	L5	L4	L3	L2	L1	R1	R2	R3	R4	R5
All	0.27 (0.813)	1.13 (0.907)	1.20 (0.867)	1.60 (0.877)	1.47 (0.768)	1.60 (0.761)	1.73 (0.842)	1.53 (0.896)	1.20 (0.923)	0.27 (0.787)
	*L5 vs. L1, L2, L3, L4.								*R4 vs. R2, R1. *R5 vs. R3, R2, R1.	
KND	0.32 (0.748)	0.65 (0.877)	0.65 (0.877)	0.90 (0.944)	0.87 (0.763)	0.87 (0.763)	0.81 (0.873)	0.81 (0.946)	0.45 (0.768)	0.23 (0.617)
SWM	1.00 (1.000)	0.85 (0.987)	1.46 (0.660)	1.54 (0.877)	1.85 (0.376)	1.69 (0.630)	1.69 (0.751)	1.62 (0.768)	0.92 (0.954)	0.85 (0.987)
GYM	0.39 (0.783)	1.26 (0.864)	1.61 (0.583)	1.43 (0.788)	1.57 (0.662)	1.70 (0.559)	1.74 (0.541)	1.61 (0.656)	1.22 (0.951)	0.74 (0.864)
SPR	0.27 (0.704)	1.13 (0.834)	1.20 (0.862)	1.60 (0.737)	1.47 (0.743)	1.60 (0.632)	1.73 (0.458)	1.53 (0.743)	1.20 (0.862)	0.27 (0.704)
CON	0.36 (0.809)	0.91 (0.944)	1.09 (0.944)	1.27 (0.786)	1.27 (0.786)	1.27 (0.786)	1.18 (0.982)	1.00 (1.000)	0.82 (0.982)	0.27 (0.647)

*KND vs. SPR.

*KND vs. SWM.

*KND vs. GYM.

*KND vs. CON.

Mean (\pm SD).* $p < 0.05$.

KND: kendo athletes; SWM: swimmers; GYM: gymnasts; SPR: sprint runners; CON: control.

Table 3. The Floating Toes Scores among sports event groups

	FT SCORE
All	12.00 (5.803)
KND	6.55 (5.409)
SWM	13.46 (5.710)* vs. KND
GYM	13.26 (4.505)* vs. KND
SPR	12.00 (4.870)* vs. KND
CON	9.45 (4.824)

Mean (\pm SD).* $p < 0.05$.

KND: kendo athletes; SWM: swimmers; GYM: gymnasts;

SPR: sprint runners; CON: control.

DISCUSSION

In this study, we investigated the event-related differences in the incidence of floating toes in male college athletes in different athletic events. As results of mean values in all participants, it was identified that the FTP was lower especially in 4th and 5th toes, namely outside toes, and higher incidence of floating toes were observed. It was also identified that the lower FTP was observed in not only outsides, but insides toes in KND, and comparably higher floating toes scores were observed in SPR, GYM and SWM. We should have attention that full marks in floating toe means that all toe fingers attached to the ground. Therefore, most of the toe fingers in KND were observed floating from the ground.

At the beginning, we anticipated that a barefoot lifestyle would prevent the incidence of floating toes. Matsuda et al.²³⁾ mentioned that floating toes was the results of lifestyle depending on disuse of shoes. It was indicated that floating toes were frequently observed especially in 4th and 5th toes in their study. It was speculated that people were apt to relying on the shoe function and did not need to use toes for the same function. Therefore, we had anticipated the incidence of floating toes would be lowest in KND and GYM. We also anticipated as higher incidence of it in SWM compared with other over ground events, even if they were barefoot, because of lower effects of gravity in the water. However, the results of present study completely defied our anticipated results, namely many floating toes were observed in KND, and a lower number of floating toes were observed in SWM. Therefore, the incidence of floating toes may have almost no relation with barefoot lifestyle and loads of gravity on the foot.

Participants in most of the previous reports concerning floating toes were Japanese^{6, 11, 13, 14, 23–25, 28)}, so the speculation by Matsuda et al.²³⁾ that barefoot life style prevents the incidence of floating toes may not be applicable because Japanese people have habits of spending most of the time barefoot inside of the house. In the present study, many incidences of floating toes were observed in KND, despite them practicing and training with bare feet. This may imply the notion that the longer spending with bare feet does not lower, prevent, and/or improve floating toes. Conversely, the notion that wearing shoes causes floating toes was not borne out.

It was reported that floating toes might affect some motor function^{6, 13, 14, 26, 27)}. In the present study, FTS in CON, who do not have habitual training in competitive sports, were lower than any other athletes except for KND, and were significantly

lower than SWM and GYM. It can be possible that floating toes may have some relation with motor function in foot and/or lower limbs. Some previous studies have mentioned toe grip strength, that is the strength that flexes the toes, is as one of the motor functions concerning floating toes^{6, 13}). Therefore, it may be reasonable that the toe grip strength in floating toes patients are lower because floating toes is the symptom of toe fingers that tend to be dorsiflexed. It was reported that toe grip strength has a correlation with sprint running time. Moreover, strength training of toe-gripping was reported to improve not only muscle strength, but movement performance, for example 50-m dash time, vertical jump height etc²⁹).

It is known that people with floating toes have a tendency to be lower in the ability of postural control and in dynamic balance^{26, 27}). First finger in toes, namely thumbs are said to play an important role of “the action of supporting” the shifted body weight, and 2nd to 5th fingers in toes are said to play a role in the action of returning the shifted body weight to center of mass²⁵). Floating toes in the 4th and 5th toes in most participants were observed in the present study, and a lower number of floating toes were observed in 1st toes. Therefore, it can be said that the action to return the body weight to the original position might be weak in these participants in any of the events, or not necessary to return body weight in these events.

Men’s gymnastics are composed of the horizontal bar, the parallel bar, the floor exercise, the vault, the rings, and the side horse. Although most of them are events depending on the upper limbs, it is necessary to balance and land by feet in the final phase of every event. In the results of our present study, it was indicated that gymnastics and sprint were the only events that was over 1.0 point in the 4th toe. This enables us to explain the importance of toe function in gymnastics and the importance of contacting the toe on the floor.

It was also observed the higher incidence of floating toes in KND in the present study. Although it is necessary to control the posture with barefoot during KND, it is also necessary to shake the posture both around and laterally for timing to attack and feint. Therefore, it may be possible to say that in kendo, toes tend to dorsiflex to balance off rather than grasping the ground to maintain balance. This may be the reason why a highly rate of floating toes was observed in KND in the present study. Although Judo was selected in the previous study²⁵) as the same barefoot event as Kendo, incidences of floating toes in Judo was small on the other hand. In another study concerning judo athletes³⁰), the toe flexor strength relative to total muscle thickness in Judo athletes was reported as significantly larger compared with controls. Therefore, it can be speculated that thumbs in judo play a more important role to postural control dynamically compared with kendo. And it is known that the position and role of right and left leg in kendo is quite different. Namely, right and left leg is always positioned in front and rear, respectively. We postulate that the front leg works as the lead leg and the rear leg plays a supporting role for the body and generates the propulsion force. Although these events are both barefoot events, it is interesting that they are completely different in terms of having floating toes. It is necessary for Judo athletes to maintain strong postural control and balance for success^{30, 31}). Judo athletes are in contact with the opponent’s body throughout the competition. Thus, it is necessary for them to balance with their toes grasping the tatami mat, against a minor sway in alternate offense and defense. Therefore, it was speculated that roles of the toes between Kendo and Judo must be completely different.

In the previous study investigating the relation of floating toes and the ability of locomotion like walking and stepping, it was suggested the higher this ability of forward stepping, the higher the “floating toe” scores³²). In the present study, we observed that SPR had higher floating toes points compared with the other event groups in the 1st and 2nd toes. Krell and Stefanyszyn¹⁹) reported that faster male sprinters experienced higher maximal rates of MP joint extension, though no significant relation was observed between maximal extension angle and 100-m sprint time. Therefore, the MP joint must make a significant contribution to developing higher force during running. However, in our study, it was also observed that the FTP of thumb was higher, although the MP joint in the outside toe was lower. Therefore, the degree of contribution and function of inner vs. outer toe may be different in sprint running.

It was unexpected that the FTP in SWM was comparably higher, because swimmers spend so much time in the water, in an unloaded environment from gravity. Swimming was the only sports event of any in this study which scored FTP over 1 point in the 4th toes even if in only right side. It is possible that swimmers receive the water pressure in toes during the swimming kick. Although swimmers do not receive any ground reaction force during training, they must do physical training on the ground. Therefore, we speculated that making a streamline in the water is effective to avoid floating toes.

The assessment of floating toes was conducted only in a static standing posture in the present study. This was the limitation point of this study. Concerning with this point, a case was reported of non-floating toes in the dynamic situation like walking, even if they were judged as floating toes in the static situation²²). Therefore, even though Kendo, was judged as floating toes in a static situation, we did not check the case of floating toes in the dynamic situation. In addition, we did not check the cause of floating toes from the viewpoint of neuromuscular dysfunction. Therefore, we can say that this may be another limitation of our study.

Furthermore, although Judo as the representative of barefoot sports event had already been reported in a previous study²³), our present study was the first study (known up to date) that clarified the athletic event differences in the incidence of floating toes score for multiple sports events. Although it was the data that was collected in a static posture situation (with no dynamic situation), we suggest this is valuable data investigate the relation between FTS and motor ability. Moreover, it was suggested that the incidence of floating toes may be nothing to do with barefoot lifestyle.

In the present study, SWM marked the highest FTS, followed by GYM and SPR, and KND marked the lowest FTS. However, no group was classified as Normal in this study. Our study suggests that athletes who practice or train with bare feet do not necessarily have higher FTS by evaluation in the standing posture.

Funding and Conflict of interest

None.

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