The effect of ankle taping to restrict plantar flexion on ball and foot velocity during an instep kick in soccer.

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Short title: The effects of ankle taping on soccer instep kicks

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Abstract

Context: Posterior ankle impingement syndrome (PAIS) is a common disorder in soccer players and ballet dancers. In soccer players, it is caused by the repetitive stress of ankle plantar flexion due to instep kicking. Protective ankle dorsal flexion taping is recommended with the belief that it prevents posterior ankle impingement. However, the relationship between the ankle taping and ball kicking performance remains unclear.

Objective: To demonstrate the relationship between the restriction of ankle taping and performance of an instep kick in soccer.

Design: Laboratory-based repeated-measures study.

Setting: University laboratory.

Participants: Eleven male university soccer players.

Intervention: The subjects' ankle plantar flexion was limited by taping. Four angles of planter flexion (0°, 15°, 30°, and without taping) were formed by gradation limitation. The subjects performed maximal instep kicks at each angle.

Main Outcome Measures: The movements of the kicking legs and the ball were captured using 3 high-speed cameras at 200 Hz. The direct liner transformation method was used to obtain 3D coordinates using a digitizing system. Passive ankle plantar flexion angle, maximal plantar flexion angle at ball impact, ball velocity and foot velocity were measured. The data were compared among 4 conditions using repeated measures ANOVA and the correlations between ball velocity and foot velocity, and between ball velocity and toe velocity were calculated.

Results: Ankle dorsal flexion taping could gradually limit both passive plantar flexion and plantar flexion at the impact. Furthermore, limitation of 0° and 15° reduced the ball velocity generated by instep kicks.

Conclusion: Plantar flexion limiting taping at 30° has a potential to avoid posterior ankle

impingement without decreasing the ball velocity generated by soccer instep kicks.

Introduction

Soccer is one of the most popular sport in the world, with an estimated 300 million active players (as documented by the Fédération Internationale de Football Association: FIFA). In Japan, it is also the most famous sport; there were 953,740 registered players in the Japan Football Association in 2012.[1] It is important for human health and medical economy to prevent soccer related injuries because of the large number of soccer players all over the world. Posterior ankle impingement syndrome (PAIS), such as os trigonum syndrome, is a common sports injury in soccer players and ballet dancers.[2, 3] PAIS is characterized by posterior ankle pain with forceful plantar flexion. Soft tissues, bony processes, unfused ossicles, or osseous fragments entrapped between the posterior tibial plafond and the superior calcaneus can lead to symptoms.[2, 4] In soccer players, it is known to be caused by repetitive stress from ankle plantar flexion due to kicking (Figure 1).[3, 5] Because surgical treatment requires a recovery period of at least 5 weeks before returning to sports activity,[6, 7] conservative treatment is often considered initially. Protective ankle dorsal flexion taping is recommended with the belief that it prevents posterior ankle impingement.[2]

In soccer, the instep kick is one of the most typical techniques used when a faster ball speed must be generated while maintaining ankle plantar flexion. It is important to achieve a high ball velocity in soccer kicking, thus improving the chances of scoring. Because of the kinematic features of the ankle, the instep kick is believed to be a major risk factor for PAIS.[3, 5] A powerful instep kick needs a higher foot velocity because the ball velocity is dependent upon the foot velocity just before the ball impact. It is well known that positive correlations exist between the foot velocity and the ball velocity during the ball impact phase.[8, 9] A great foot velocity is generated by the lower limb movement during the instep kick that is expressed in the open kinetic chain. The motion pattern of kicking is generally accepted as a proximal (thigh) to distal (shank and foot) sequence of segmental motions.[10]

There is no consensus as to whether or not ankle support can interfere with normal function, instead of reducing the pain and dysfunction caused by sports injury.[11-13] While posterior impingement at the time of impact may be reduced by protective ankle dorsal flexion taping, performance, such as the instep kick, may be reduced because sufficient ankle plantar flexion movement becomes impossible due to the restrictive ankle taping.[13] However, to our knowledge, the relationship between the ankle taping and ball kicking performance remains unclear.

Therefore, we studied the relationship between the restriction of ankle taping and the performance of an instep kick in soccer. In particular, this study aimed to investigate what kind of taping not decrease the ball velocity, establishing 4 taping conditions to control ankle plantar flexion. Our hypotheses were as follows: (1) Ankle dorsal flexion taping could gradually limit both passive plantar flexion range of motion (ROM) and the maximal plantar flexion angle at the impact. (2) Excess limitation by ankle taping would reduce the ball velocity generated by an instep kick because of the decrease of the foot velocity.

Materials and methods

Design

The study was a repeated-measures design. The taping condition, that has 4 levels, was the independent variable, and the plantar flexion ROM, the angle of ankle plantar flexion, and the velocities of the ball and foot and toe were the dependent variables. Participants attended a 1-hour testing session at the university. Participants were tested on a single occasion and were tested across 4 taping conditions in a randomized order.

Participants

Eleven experienced male soccer players (Table 1), who had no history of major lower limb injury or disease, volunteered to participate in this study after providing written informed consent. They were assessed for leg dominance using Chapman's test,[14] and all of them were determined to be right leg dominant.

All procedures were approved by the Ethics Committee of the Graduate School of Health Sciences, Hiroshima University (ID: 1013).

Procedures

Taping technique. Four conditions of planter flexion angle (0°, 15°, 30°, and without taping) were formed by gradation limitation with ankle taping. The tape was applied to the subject's right ankle by an experienced physical therapist to avoid variability. Three types of tape, 38mm inelastic tape, 75mm hard elastic tape, and 50mm soft elastic tape were used for the taping (Nitreat CB-38, EB-75, EBH-50; Nitto medical Inc., Tokyo, Japan). Three 38mm inelastic anchors were applied to the skin beneath the heads of the gastrocnemius. Two inferior anchors were applied over the metatarsal head. The subject's ankle plantar flexion was limited by three 75mm elastic tapes. Finally, 50mm soft elastic wrapping tape was fixed in a figure eight shape and with a heel lock (Figure 2).

Measurement. The measurement of passive plantar flexion ROM was recorded using manual goniometry, according to the protocol of the Japanese Orthopedic Association, before the kicking experiment under each taping condition. As shown in Figure 3, to integrate passive plantar flexion torque, the region 15 cm apart from the medial and lateral malleolus was depressed by 40N using a hand held dynamometer (µTas F-1; Anima Inc., Tokyo, Japan). Based on the method of Krause et al., the magnitude of the applied force was determined through trial and error before the actual testing.[15] The investigators applied a "typical" force to the dorsal aspect of the foot with the dynamometer while the participant performed passive plantar flexion. As a result of this process, 40N was selected as the standard force for all subjects.

A FIFA-approved size five soccer ball (Jabulani Lusiada; Adidas; diameter = 22cm, mass = 0.43 kg) was used, and its inflation was fixed at 900 $g \cdot cm^{-2}$ throughout the experiment. The subjects performed five maximal instep kicks under each of the four taping conditions.

Three electrically synchronized high-speed cameras (FKN-HC200C; 4 Assist Inc., Tokyo, Japan) were used to capture the motion of the foot, the lower leg, and the ball during instep kicking. The sampling rate was set at 200 Hz to adequately analyze the foot and the ball behavior during the impact. Reflective markers were placed on the fibular head, the lateral malleolus, the base of the fifth metatarsal bone, the head of the fifth metatarsal bone, and on the surface of the ball.

A digitizing system (DIPP-Motion XD; Tokyo, Japan) was used to manually digitize the aforementioned body landmarks and three of the ball surface markers in the area where the deformation was relatively small during impact. The ball surface marker intervals were approximately 10 cm.[16] The direct linear transformation (DLT) method was then used to obtain the three-dimensional coordinates of each marker from 10ms before ball contact to 10ms after ball contact. The three-dimensional coordinates were expressed as a right-handed orthogonal reference frame, fixed on the ground, in which the X axis was horizontal and pointed to the goal, the Y axis was vertical and pointed upward, and the Z axis was perpendicular to the X and the Y axes. To calibrate the space around the ball impact area, a calibration frame (90 * 90 * 90 cm) with 8 control points was sampled before the trials. A 12 Hz fourth order Butterworth low-pass filter was used to smooth marker displacement data.[17]

The angle between the lines formed from the fibular head to the lateral malleolus and from the base to the head of the fifth metatarsal bone was calculated and expressed in degrees of ankle plantar flexion. The linear velocity of the ball during the first 10ms after the impact was calculated from the center of the ball defined by the ball surface markers. The linear velocities of the base of the fifth metatarsal marker (foot velocity) and the head of the metatarsal marker (toe velocity) during the last 10ms before the impact were calculated.

Statistical analysis

Data analysis for significant differences was carried out using SPSS 20.0 for Windows Statistics version 20.0 (IBM Japan Co. Ltd., Tokyo, Japan).

The mean values and standard deviations were calculated for each condition. One-way repeated measures analysis of variance (ANOVA) was used to test for differences in the passive ROM, maximal plantar flexion angle at ball impact, ball velocity, foot velocity and toe velocity among the four conditions. When the main effect was statistically significant, post hoc analyses were carried out with Bonferroni-adjusted paired t-tests. For each taping condition, paired t-test was used to analyze the difference between passive ROM and the maximal plantar flexion angle on impact.

The Pearson product-moment correlation was also used to determine the relation between ball velocity and foot velocity, and between ball velocity and toe velocity.

The intra-class correlation coefficient (ICC (1, 5)) was also calculated to investigate the within-subject reliability of each variable. The alpha level used for all analyses was $P<.05$.

Results

Figure 4 shows the passive ROM and maximal plantar flexion angle at the ball impact. Passive ROM for the 0°, 15°, 30° taping and without taping were 0.1±2.0°, 14.4±1.8°, 28.8±1.5° and 55.3±3.2°, respectively. There were significant differences among all conditions (P<.05). Compared with the condition without taping, 0°, 15°, 30° taping resulted in restriction of 55.2° (99.8%), 40.9° (74.0%) and 26.5° (47.9%)

The maximal plantar flexion angles at ball impact were 19.5±10.3°, 27.6±7.8°, 33.3±9.9° and 41.6±10.8°, respectively. There were significant differences among all conditions (P<.05). Compared with the condition without taping, the angles with the 0°, 15°, 30° taping were more restricted by 22.1° (53.1%), 14.0° (33.7%) and 8.3° (20.0%).

Figure 5 shows the ball and foot and toe velocity of instep kicking for each taping condition. The ball velocities for 0°, 15°, 30° taping and without taping were 20.4±2.1, 21.7±2.0, 22.5±1.9 and 23.1±1.3 m/s, respectively. There were significant differences between the two taping conditions (0°, 15°) and without taping (P<.05). Compared with the condition without taping, the ball velocities for 0°, 15° and 30° taping were reduced by 2.7m/s (11.7%), 1.4m/s (6.1%) and 0.6m/s (2.6%).

The foot velocities for 0°, 15°, 30° taping and without taping were 14.8±1.4, 15.0±1.2, 15.1±1.1 and 15.0±1.3m/s, respectively. There were no significant differences among the taping conditions. By contrast, the toe velocities for 0°, 15°, 30° taping and without taping were 14.4±1.4, 15.2±1.3, 15.5±1.0 and 15.7±1.5m/s, respectively. There were significant differences between the 0° and 30° taping (P<.05).

Table 2 shows the correlations between the ball velocity and foot velocity, and between the ball velocity and toe velocity. There were moderate to strong correlations between the ball velocity and foot velocity and between the ball velocity and toe velocity (r = 0.685 to 0.863, P<.05).

The ICC (1, 5) values of the impact angle, ball velocity, foot velocity and toe velocity were 0.978, 0.926, 0.841 and 0.821, respectively.

Discussion

PAIS is recognized as chronic pain in athletes, such as soccer players.[2, 3] It is known to be caused by repetitive stress from ankle plantar flexion due to kicking.[3, 5] As a conservative treatment, protective ankle dorsal flexion taping is recommended with the belief that it prevents posterior ankle impingement. However, whether or not this taping really avoids excessive ankle plantar flexion at the ball impact and what kind of effect this has on soccer kicking performance remain unknown. Therefore, this study aimed to investigate what kind of taping could restrict excess ankle plantar flexion without decreasing the ball velocity, by using 4 precise taping conditions to control ankle plantar flexion. Based on our results, taping was able to gradually restrict the maximal plantar flexion angle at ball impact for each of the 4 taping conditions, and excess restriction, such as 0° and 15° taping, decreased the ball velocity. Many independent researchers have investigated the instep kick in soccer,[10, 18-20] and the effect of ankle taping,[11-13, 21]. However, the relationship between restriction of ankle taping and ball velocity as a result of soccer kicking remains unclear. Thus, this is the first investigation to report how the kicking skills vary with the different degrees of restriction by ankle taping.

A previous study of amateur soccer players showed that the maximal plantar flexion angle and velocity on ball impact were 47.6° and 24.3 m/s, respectively.[18] Although there were some methodological differences, these results are consistent with the present findings.[19, 20] In addition, ICC (1, 5) values showed an almost perfect degree of reliability.[22] Therefore, our results of instep kicking are considered to have good validity and reliability.

In this study, enforced taping was used to establish a 0° taping condition in which the passive plantar flexion angle would be 0° by taping, and the 15° taping condition and the 30° taping condition were set up in a similar manner. Consequently, the taping restricted the angle near the target, i.e., 0.1±2.0° with the 0° taping condition, 14.4±1.8° with the 15° taping condition, and 28.8±1.5° with the 30° taping condition. Since taping conditions can be established with an objective indicator, i.e., the passive range of motion, our method of establishing the reproducibility of the results of taping may become useful. There were significant differences in the passive ankle plantar flexion angle among all taping conditions, and it was shown that gradual restriction of the ankle plantar flexion angle by taping is possible. The three taping conditions were specified by the angle at the time of establishing the ankle plantar flexion using the same force. In previous studies of the effect of taping, the description "the same taper enforced all" is used in many cases.[11, 21] However, to the best of our knowledge, this is the first report of a method specifying two or more taping conditions with a specific restriction angle.

From the result of the maximal plantar flexion on ball impact, consistent with our hypothesis, we confirmed that the maximal plantar flexion angle at ball impact could be restricted gradually. PAIS is characterized by posterior ankle pain with forceful plantar flexion. van Dijk et al. reported that dancers exhibited a normal range of motion: dorsiflexion/ plantar flexion 20°/50° on both sides.[23] By contrast, Calder et al. remarked that the range of motion of the ankle joint may or may not be affected.[6] At any rate, as long as the terminal position of ankle plantar flexion is avoided, ankle pain caused by PAIS may not occur. While it is necessary to properly assess the patients' range of ankle plantar flexion, which is defined by PAIS symptoms, our results might help the choice of moderate restriction of ankle taping that does not interfere with instep kicking performance as much as possible.

With respect to the ball velocity, the 0° and 15° taping conditions exhibited a degree of incongruity in the case of a kick among many of the subjects. In particular the ball velocity decreased significantly by 2.7 m/s (11.7%; 20.4±2.1 m/s vs. 23.1±1.3 m/s) for 0° and without taping, respectively. Thus, in a match situation, a drop in the velocity of 11.7% may make the difference between victory and defeat. The instep kick produces a great ball velocity by an open kinetic chain that continues from the proximal to distal segment.[10] Excessive restriction, such as that achieved with the 0° and 15° taping conditions, inhibited this kinetic chain, and it was perceived that ball velocity decreased. Indeed, there were some correlations between ball velocity and foot velocity, and between ball velocity and toe velocity. In particular, the correlations between ball velocity and toe velocity for the 0° and 15° taping conditions were strong. However, Nunome et al. reported the foot motion was assumed to not have a substantial influence on the leg swinging motion during kicking.[24] In our findings, there were a few significant differences in foot velocity and toe velocity among the 4 taping conditions, with the exception of the significant toe velocity difference between 0° and 30° taping. Therefore, decreasing of the ball velocity with the 0° and 15° taping may not be explained by simply decreasing of the foot velocity and toe velocity. Asami et al. mentioned that rigidity of the foot is important for a powerful kick, and that this became impaired when the ball was struck by the forefoot.[25] Thus, there is the possibility that decreasing of the foot velocity and toe velocity as well as changes of the impact site are intricately interrelated in the decline of the ball speed through inhibition of the kicking kinetic chain due to excess restriction with ankle taping. While reduction of foot and toe velocity may be inevitable due to the restriction of the ankle plantar flexion, patients may be able to adjust to changes in the impact site by practicing in the taping condition.

In summary, restriction, such as that achieved with a 30° taping condition, will not influence ball velocity, but the contribution of the angle at the time of the impact leading to a posterior ankle impingement might be avoidable. As stated previously, PAIS in soccer players is believed to be due to repetitive excessive ankle plantar flexion at the time of impact.[3, 5] Therefore, we demonstrated that it is likely to reduce excess posterior ankle entrapment between the posterior tibial plafond and the superior calcaneus with ankle taping restriction on ball impact.

This study has some limitations. The inclusion of only healthy participants limits the ability to generalize these results to soccer players with symptoms. It is necessary to confirm how instep kicking performance would change in PAIS participants when they are controlled by ankle taping. A second limitation is related to the possibility of reduced effectiveness of restriction by ankle taping when performing soccer actions that include not only kicking but also jumping, running and stopping. [12, 26] In a future study, we will determine whether the effect of ankle plantar flexion restricting taping persists when subjects perform repeated sports tasks, including instep kicking.

Conclusion

This study examined the effectiveness of protective ankle dorsal flexion taping to the dynamics of instep soccer kicking. The results suggest that excess restrictions, i.e., 0° and 15° taping, can decrease the ball velocity, because of inhibition of the kicking kinetic chain due to excess restriction with ankle taping. However appropriate restriction, i.e., 30°, could reduce excess ankle plantar flexion that is considered a cause of posterior ankle impingement with no negative effect on instep kicks in soccer.

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Figures

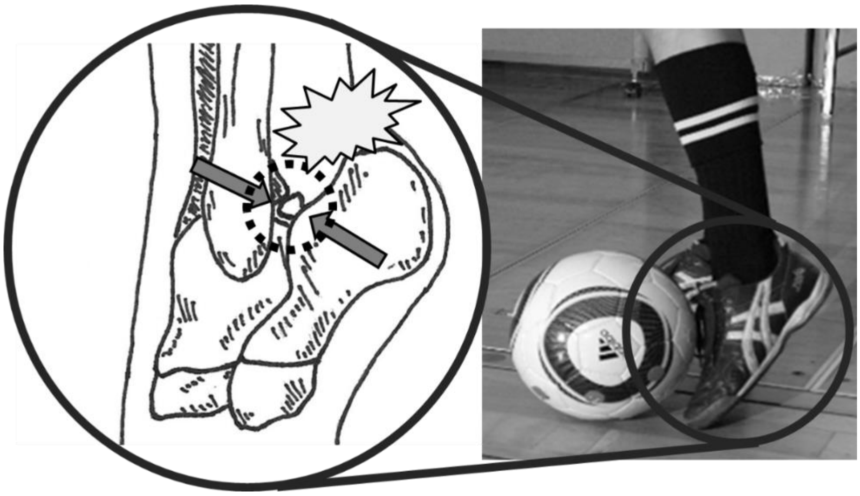

Figure 1. Mechanism of PAIS in soccer

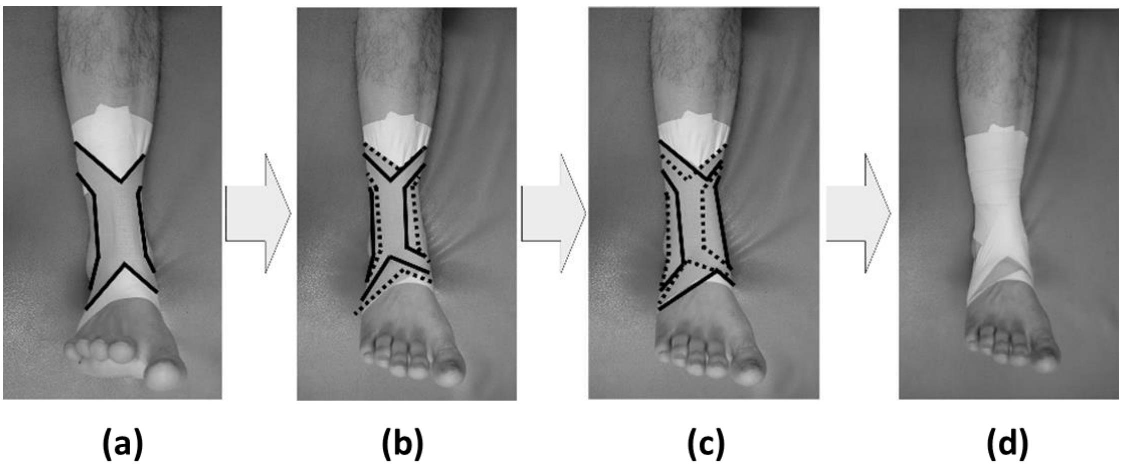

Figure 2. Ankle plantar flexion limiting taping

(a) 1st split taping; (b) 2nd split taping; (c) 3rd split taping; (d) Wrapping

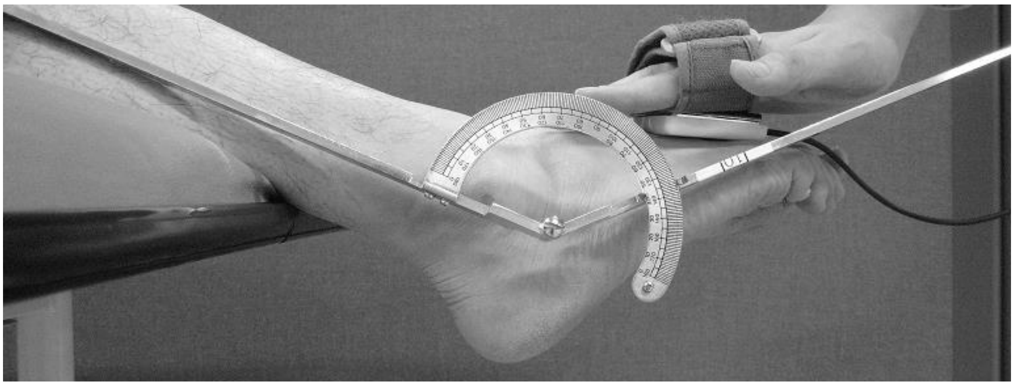

Figure 3. Measurement of the passive plantar flexion of the subject's ankle by using hand held dynamometer

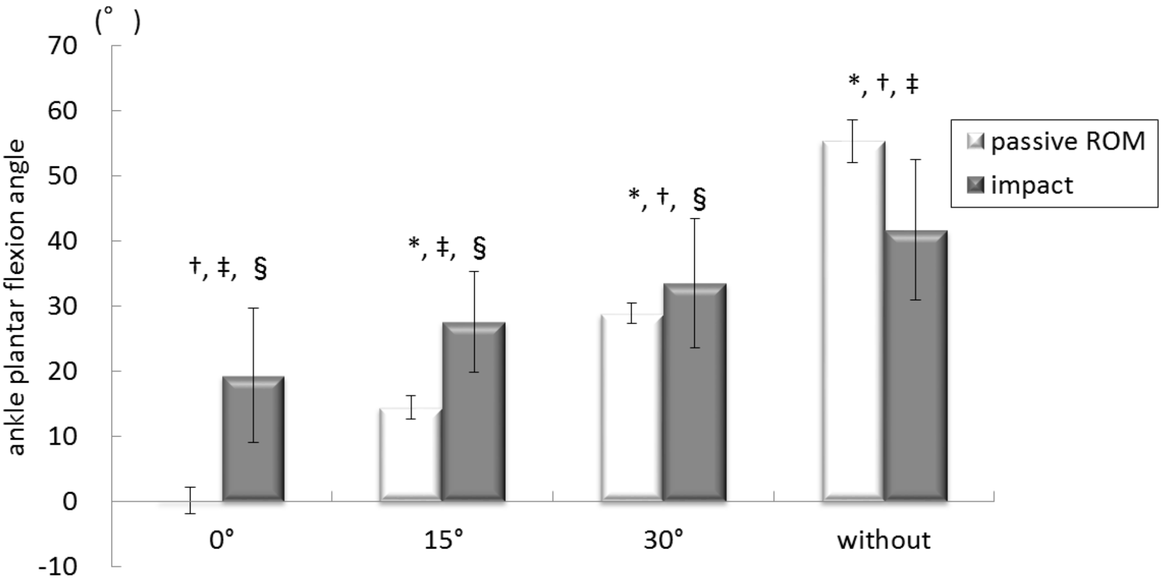

Figure 4. The difference of angle of ankle plantar flexion among various taping conditions

0°: 0° taping; 15°: 15° taping; 30°: 30° taping; without: without taping.

Passive ROM: passive ankle plantar flexion ROM; impact: maximal plantar flexion angle on ball impact.

* versus 0°; † versus 15°; ‡ versus 30°; § versus without ($P < .05$).

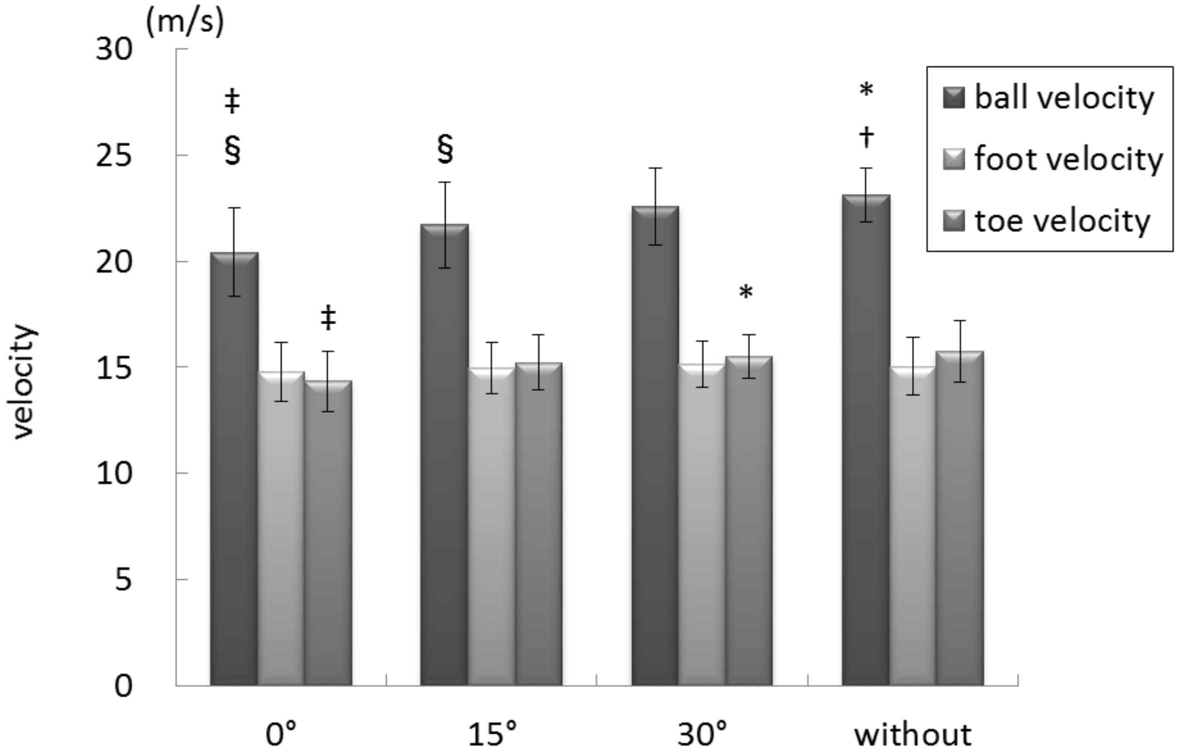

Figure 5. The difference of ball, foot and toe velocity among various taping conditions

0°: 0° taping; 15°: 15° taping; 30°: 30° taping; without: without taping.

* versus 0°; ‡ versus 30°; § versus without ($P < .05$).

Tables

Table 1. Subject Characteristics, Mean ± SD

Age (y)	Height (cm)	Weight (kg)	Career (y)
20.8±1.1	175.0±4.0	67.2±4.9	10.1±3.0

Table 2. Summary of correlation coefficients between ball velocity and foot velocity, ball velocity and toe velocity

	Ball - Foot		Ball - Toe	
	r	P value	r	P value
0°	0.705*	.015	0.863**	.001
15°	0.842**	.001	0.835**	.001
30°	0.587	.057	0.732*	.010
without	0.546	.082	0.685*	.020

Ball-Foot: Correlation between ball velocity and foot velocity; Ball-Toe: Correlation between ball velocity and toe velocity. *: $P < .05$; **: $P < .01$.