

Kinematic effects of skip drills on sprint ability in junior high school students

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Abstract

Problem Statement: Skip drills are commonly used as training methods to enhance running performance, yet their specific effects and underlying mechanisms remain incompletely understood. **Purpose:** This study aimed to investigate the influence of skip drills on sprint ability and accompanying kinematic changes in lower limb movements among junior high school students. **Approach:** Seventy-three male junior high school students (mean height: 165.2 ± 5.7 cm, mean weight: 54.7 ± 9.7 kg, age range: 14–15 years) participated in a 3-week skip drill program. Skipping and sprinting movements were recorded before and after the skip drill. Subjects who showed forward leg swing improvement during skipping were assigned to the frontside mechanics (FM) group ($n = 12$), while those with the opposite trend were assigned to the backside mechanics (BM) group ($n = 5$). Kinematic parameters, including speed, stride length, ground contact time, and knee joint angles were analyzed. **Results:** The FM group shorten in ground contact time of skipping and increased the stride frequency of sprinting and skipping and sprinting speed after the skip drill. In contrast, the BM group showed no significant changes in kinematic parameters. The FM group also demonstrated a smaller knee joint angle in the latter half of the stance phase during skipping and sprinting, suggesting increased leg stiffness and improved propulsive force. **Conclusion:** The results suggest that skip drills can enhance sprint ability by improving leg movement. This study provides a foundation for developing drills and training programs aimed at enhancing running ability.

Keywords: skipping, sprinting, kinematic analysis, knee joint angle, stance phase

Introduction

Skipping has been used as a rehabilitation exercise to transition between walking and running (Johnson et al., 2005) and is widely used as a general warm-up exercise for athletes across a variety of sports (Gamma et al., 2014, Somboonwong et al., 2015, McGowan et al., 2016). Skipping is also the most popular drill activity, especially for track and field coaches, with many different types of skipping used in training (Whelan et al., 2016). Sáez et al. (2012) noted that training to enhance sprint performance can be optimized using programs that incorporate greater horizontal acceleration movements (e.g., skipping, horizontal jumps). In addition, Whelan et al. (2016) pointed out that sprint drills to develop efficient running movements should be kinematically similar to sprinting (e.g., force production and timing). These findings support the possibility that skipping training can contribute to enhance running ability.

However, among the various types of sprint drills, the specific mechanism by which skipping is effective in enhancing running ability has not been clarified. McDonnell et al. (2017) reported that hip extension torque during the support phase of skipping was greater than that during running. In addition, Nakano et al. (2024) found that the peak value of hip extension angular acceleration during skipping occurred earlier in individuals with excellent running ability compared to those with poorer running ability in the support phase. Although these reports indicate that skipping and sprinting are closely related, they do not demonstrate the effectiveness of skipping as a drill. Skipping has also been used as a drill for running in physical education classes, with practical studies examining its effectiveness reporting that skipping drills enhance running movements and muscle strength (Ogata et al., 1988, Iwatake et al., 2008, Hasegawa et al., 2021). However, to date, no studies have examined whether skipping movements are improved by implementing skip drills and how they are transferred to running movements.

In a study focusing on lower limb movement during running, Derrick (2004) showed that increasing the stiffness of the lower limb muscles during contact and reducing knee flexion could increase overall leg swing velocity. Morin et al. (2007) and De Ruiter et al. (2013) reported that increasing leg stiffness contributes to achieving shorter ground contact time. Furthermore, Chu and Korchemny, (1989) and Kale et al. (2009) found that faster sprinters had a shorter contact time during the support phase than slower sprinters, generating greater

propulsive force in that shorter period. These findings support Weyand et al. (2010) and Miyashiro et al.'s (2019) proposal that shortening ground contact time is effective in improving running performance.

On the other hand, Sáez et al. (2012) conducted a meta-analysis on plyometric training and concluded that sprint-specific plyometric training shortens ground contact time during sprinting. Additionally, Rimmer and Sleivert (2000) reported that plyometric training, such as single-leg hops and alternate-leg bounds, reduced ground contact time during sprinting. Therefore, because skipping is also a plyometric movement (Sáez et al., 2012), skipping drills are expected to shorten ground contact time during skipping, leading to transfer of this movement to sprinting and improved performance. However, there is not enough scientific evidence of the skipping drills, compared to other training methods.

In the preliminary study, when we observed the skipping of elite junior sprinters of the same age as general junior high school students, we found that in approximately 87% (20/23 people) of the elite junior sprinters, the take-off leg overtook the opposite leg after the first hop. In contrast, such leg movement was only observed in about 14% (10/73 people) of general junior high school students. Furthermore, as the ten students who had an overtaking movement were either members of the track and field club or had high overall athletic ability, the movement of the take-off leg overtaking the opposite leg during the forward swing of the skipping leg is thought to be related to sprinting ability.

In this study, we aimed to examine whether skipping movements themselves can be improved and how skipping transfers to sprinting movements. After the general junior high school students completed the skip drill, subjects who were able to demonstrate this movement were assigned to the frontside mechanics (FM) group, and subjects who showed the opposite tendency were assigned in the backside mechanics (BM) group. We then conducted a kinematic analysis of the lower limb movements of skipping and sprinting in both groups to compare them. Understanding these kinematic characteristics will contribute to developing training programs and sprint drills that effectively enhance running ability.

Materials & methods

Participants

Participants were 73 male junior high school students (165.15 ± 5.7 cm, 54.73 ± 9.65 kg, aged 14–15 years). The participants were fully informed of the purpose of the study, the experimental procedures, and safety measures and agreed to participate in the experiment. This study was approved by the Aichi University of Education Research Ethics Committee (AUE20220901HUM).

Procedure

Participants completed a 30 m skip and a 50 m sprint at 100% subjective effort before and after the skip drill period. The trials were conducted on a clay surface of school yard on January 31, 2023 and February 17, 2023 and were recorded via video camera. To record the movements, a video camera (CASIO, EX-100F) was used with a frame rate of 120 Hz and exposure time of 1/1000 sec. To capture the skipping motion, the camera was set 25 m to the left from the starting point, and calibration marks were set at 1 m intervals from 22 to 28 m to convert to actual length. To capture the sprinting motion, the camera was set 43 m to the left from the starting point, and calibration marks were set at 1 m intervals from 40 to 46 m to convert to actual length. The skip drill consisted of five repetitions of 30 m skips performed as quickly as possible at a frequency of twice a week (six times in total). During the skipping drills, participants were instructed to move "forward and quickly."

Data collection

The 50 m sprint times were recorded manually via a hand-held stopwatch. The movement of the take-off leg overtaking the opposite leg during the forward swing of the skipping leg is thought to be related to sprinting ability. In order to clarify the relationship between the difference in the change in skipping motion, subjects who were able to demonstrate this movement were assigned to the FM group ($n = 12$), and subjects who showed the opposite tendency were assigned to the BM group ($n = 5$), as shown in Figure 1. The movies were digitized via the video motion analysis system Frame-DIAS VI (DKH, Japan), and 23 points of the body and four calibration markers were converted into 2D 4-point actual length.

Sprinting movements were analyzed from the time one foot touched the ground until the other foot touched the ground. The skipping motions were analyzed from the time one foot touched the ground (first step) until the same foot touched the ground again (second step). The sprinting and skipping speeds were defined as the average horizontal movement speed of the greater trochanter in each analysis section. Stride length of running was defined as the distance from the ground contact of one foot to that of the opposite foot. Stride frequency of running was calculated as the inverse of the time from when one foot touched the ground to when the other foot touched the ground.

Running contact time was defined as the time from the landing of one foot to the take-off of the same foot, and the running aerial time was defined as the time from the take-off of one foot to the landing of the opposite foot. Stride length of skipping was defined as the distance from the point where one foot touched the ground until the ipsilateral foot touched the ground again.

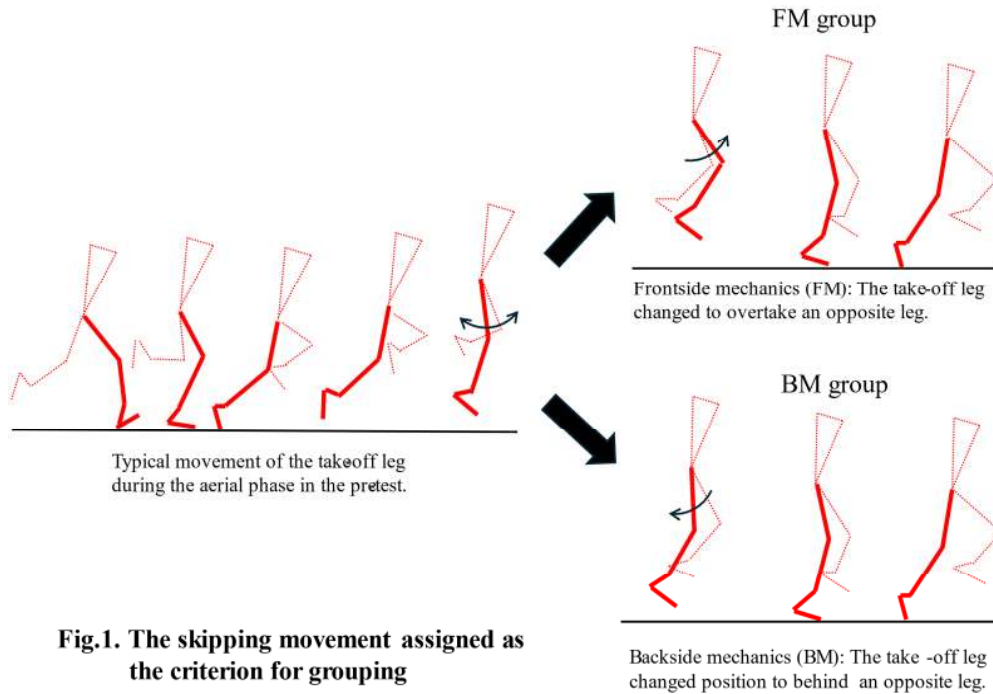


Fig.1. The skipping movement assigned as the criterion for grouping

Skipping contact time was defined as the time from touching down to taking-off of one foot, and skip aerial time was defined as the time from taking-off of one foot to touching down again of the same foot. In sprinting and skipping, the knee joint angle was calculated from contact to take-off. In addition, to examine changes in the knee joint angle, the movement during the support phase was expressed as the time lapse from the moment of contact (0%) to just before take-off (100%).

Statistical analyses

Correlations between moving speed and other variables were examined by calculating Pearson's product-moment correlation coefficient. In addition, the significance of differences between groups was examined using paired t-tests. All data were distributed ($p < 0.05$).

Results

Table 1. Kinematic variables of skipping in the FM and BM groups.

	Frontside mechanics group		Backside mechanics group	
	Pre-test	Post-test	Pre-test	Post-test
Speed (m/s)	5.30 ± 0.44	5.79 ± 0.43*	5.42 ± 0.51	5.43 ± 0.40
Contact time (s/stp)	0.18 ± 0.01	0.16 ± 0.02*	0.17 ± 0.01	0.17 ± 0.02
Stride length (m/stp)	1.90 ± 0.19	2.08 ± 0.19*	1.94 ± 0.10	2.00 ± 0.32
Flight time (s/stp)	0.24 ± 0.03	0.23 ± 0.08	0.27 ± 0.02	0.25 ± 0.08

Values are mean ± SD. * $p < 0.05$ vs. Pre-test.

Table 1 shows the kinematic indices of skipping before and after the skip drill in the FM and BF groups. The skipping speed of the FM group increased after the skip drill but did not change in the BM group. Stride length of skipping in the FM group was longer after the skip drill but did not change in the BM group. Contact time of skipping in the FM group was shorter after the skip drill but did not change in the BM group. The aerial time of skipping did not change after the skip drill in either group.

Table 2. Kinematic variables of sprinting in the FM and BM groups.

	Frontside mechanics group		Backside mechanics group	
	Pre-test	Post-test	Pre-test	Post-test
Speed (m/s)	7.08 ± 0.69	7.46 ± 0.71*	7.04 ± 0.79	7.06 ± 0.81
Stride frequency (Hz)	4.09 ± 0.28	4.26 ± 0.26*	3.91 ± 0.28	4.05 ± 0.25
Contact time (s/stp)	0.13 ± 0.01	0.13 ± 0.02	0.14 ± 0.03	0.15 ± 0.03*
Stride length (m/stp)	1.73 ± 0.13	1.75 ± 0.10	1.80 ± 0.13	1.74 ± 0.10
Flight time (s/stp)	0.12 ± 0.02	0.11 ± 0.01*	0.12 ± 0.02	0.10 ± 0.02*

Values are mean ± SD. * $p < 0.05$ vs. Pre-test.

Table 2 shows the kinematic indices of the sprints before and after the skip drill for the FM and BF groups. The sprinting speed of the FM group was faster after the skip drill but did not change in the BM group. Stride frequency of sprinting was higher in the FM group after the skip drill but remained unchanged in the BM group. Contact times of sprinting in the FM group did not change after the skip drill, but those of the BM group became longer. The aerial time of sprinting in each group was shortened by the skip drill. Stride length of sprinting in each group did not change with the skip drill.

Figures 2–5 show the displacement of the knee joint angle during the stance phase of skipping and sprinting in both groups. The knee joint angle in the FM group tended to be smaller in the latter half of the stance phase after the skip drill in both skipping and sprinting. On the other hand, the knee joint angle in the BM group tended to be larger during the stance phase after the skip drill in both skipping and sprinting.

Discussion

We conducted skip drills on junior high school students and kinematically investigated the effects of the drills on sprint running. The results indicated that the skip drills we used may have contributed to enhancing sprint ability.

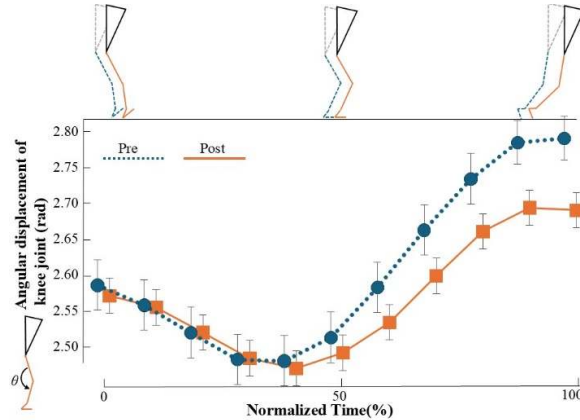


Fig.2. Angular displacement of knee joint angle during the stance phase in skipping (FM group)

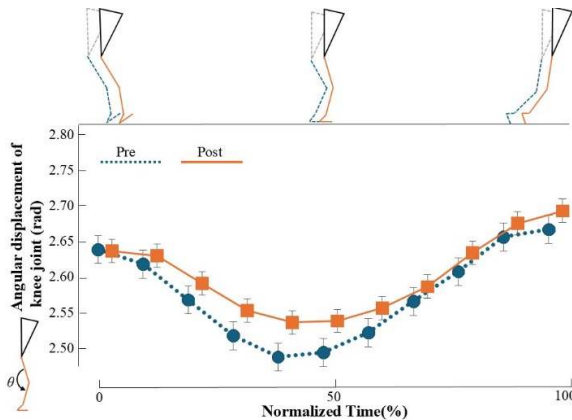


Fig.3. Angular displacement of knee joint angle during the stance phase in skipping (BM group)

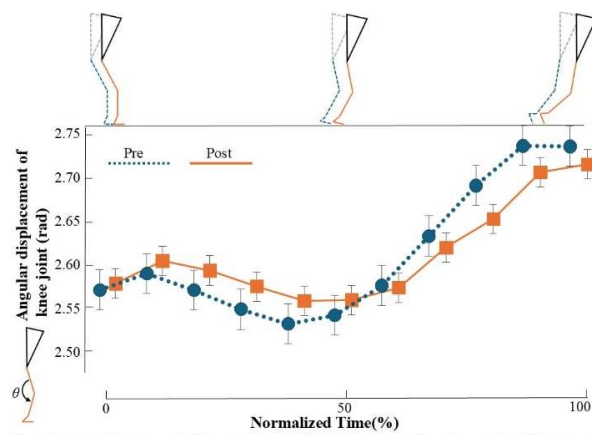


Fig.4. Angular displacement of knee joint angle during the stance phase in sprinting (FM group)

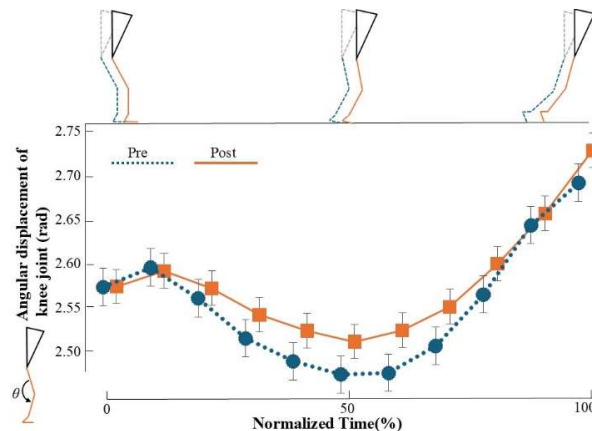


Fig.5. Angular displacement of knee joint angle during the stance phase in sprinting (BM group)

After the skip drill, the skipping speed of the FM group improved, but there was no change in the BM group. This indicates that the change in take-off leg motion resulting from skip drills is related to an improvement in skipping speed. After the skip drill, the contact time in skipping was shortened in the FM group, but there was no change in the BM group. Sprint-specific plyometric training has been reported to shorten contact time in sprinting (Rimmer & Sleivert, 2000, Sáez et al., 2012). Therefore, it is possible that in the FM group, the skipping movement changed during the drill to become more plyometric, leading to shortened contact time. Furthermore, the skip drill helped to increase the stride length of skipping, but the aerial time of skipping remained unchanged in the FM group. On the other hand, there was no change in the stride length and aerial time of skipping in the BM group after the drill. These results suggest that the FM group was able to convert ground reaction force into propulsive force more quickly and efficiently during the stance phase, which resulted in an increase in skipping speed.

After the skip drill, the sprinting speed in the FM group improved, whereas no change was observed in the BM group. Furthermore, the contact time of sprinting did not change, but the stride frequency of sprinting significantly increased in the FM group. This suggests that the improvement in sprint ability was mainly influenced by increased stride frequency in the FM group. After the skip drill, the contact time of skipping in the FM group was shortened, whereas that of sprinting did not change. This may be because the contact time of sprinting is basically shorter than that of skipping, making the change less noticeable. Furthermore, the skip drill helped to shorten the aerial time of sprinting, but the stride length of sprinting remained unchanged in the FM group. This indicates that the aerial speed of sprinting increased in the FM group. Aerial time and speed of sprinting are thought to depend on the ground reaction force and its direction at take-off (Haugen et al., 2019). Therefore, although the contact time did not change in the FM group, it is possible that participants were able to convert ground reaction force into propulsion more efficiently.

The knee joint angle of skipping and sprinting after the skip drill was smaller in the FM group, especially in the latter half of the stance phase, whereas the opposite tendency was observed in the BM group. An effective method to increase the swing speed of the leg is increasing the stiffness of the lower limb muscles during contact and reducing the flexion of the knee (Derrick, 2004). It has also been pointed out that in order to exert forward power during sprinting, knee flexion should be kept to a minimum (Chelly & Denis, 2001). Furthermore, high leg stiffness at ground contact in sprinting is not only essential for short contact time and large vertical force but is also an important ability for faster thigh extension during the stance phase (Clark et al., 2020). Therefore, the smaller knee joint angles in the latter half of the stance phase in skipping and sprinting in the FM group after the

skip drill may be due to the increased leg stiffness resulting from the employed drill, reflected in faster hip extension leading to an increase in propulsive force. These findings suggest that for participants who were able to make take-off leg overtaking the opposite leg after the skip drills, improvements in lower limb movement during the stance phase led to improved propulsion, subsequently improving sprint ability.

Although the mechanism behind the appearance of the take-off leg overtaking the opposite leg is unclear, it is possible that the movement of extending the knee joint until before take-off is linked to the movement of extending the hip joint, delaying the timing of the hip flexion just after take-off. It is also possible that faster sprinting initiates hip flexion at an earlier moment during the stance phase.

Conclusions

This study suggests that skip drills are an effective training method. In particular, those who were able to overtake the opposite leg during the forward swing of the take-off leg after the skip drill showed improved movement speed and shorter ground contact time in both skipping and sprinting. Additionally, in individuals who demonstrated the ability to overtake, the knee joint angle in the latter half of the stance phase was smaller in both skipping and sprinting, which may have improved leg stiffness, leading to increased propulsive force. These findings provide basic data for designing skipping drills to enhance running performance.

Conflicts of interest

There are no conflicts of interest to declare.

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