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Acute effects of an instructional movie on drop jump performance and lower limb kinematic and kinetic variables

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Objectives: Drop jump (DJ) is a typical exercise of plyometric training in which the state before takeoff (pre-set phase) influences the force exertion of the lower limbs during takeoff, as well as performance variables. This study aimed to examine the effects of watching an instructional movie during the pre-set phase on the performance and lower limb kinematic and kinetic variables during plyometric training.

Methods: Fourteen participants (age, 21.9 ± 2.1 years; height, 175.6 ± 2.6 cm; weight, 70.7 ± 4.9 kg) were enrolled in this study. Seven participants with a high rebound jump (RJ) index under normal conditions were classified into the high RJ-index group. Seven participants with a low RJ-index were classified into the low RJ-index group. DJs were performed under normal conditions and under the movie condition (DJ immediately after watching the instructional movie during the pre-set phase). Performance and kinematic and kinetic variables of the lower limb joints were measured.

Results: Compared with the normal condition, the movie condition was associated with a significantly high RJ-index, lesser degree of knee flexion ($p < 0.011$), and significantly larger concentric torque ($p < 0.018$) of the ankle. An interaction effect was observed for the eccentric torque ($p < 0.025$) and positive power ($p < 0.004$) of the ankle, which were significantly greater in the high RJ-index group under the movie condition.

Conclusion: Watching an instructional movie during the pre-set phase improves the movement and force production of the ankle and knee joint, which, in turn, improves the DJ performance. However, the effects may be more pronounced in participants with a high RJ-index.

KEYWORDS

plyometrics, stretch-shortening cycle, joint kinetics, joint kinematic, pre-set phase

1 Introduction

Basic movements, such as running and jumping, are executed by the stretch-shortening cycle (SSC) of the lower limbs (Komi, 2003). To improve sports performance, enhancing the ability of the lower limbs to perform SSC movements is important and has been achieved using plyometric training. A typical plyometric training method is the drop jump (DJ),

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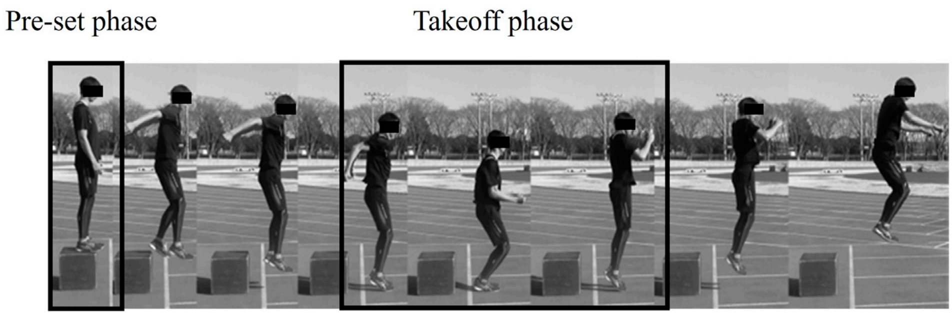

FIGURE 1
Phase structure in the drop jump.

which involves jumping off a platform at a certain height and jumping again immediately after landing (Bobbert, 1990; Byrne et al., 2010). When performing the DJ, to capture the large ground reaction force applied at the moment of ground contact after the drop from the platform, a well-timed landing based on the temporal and spatial predictions just before the ground contact is required (Taube et al., 2012). This enables the lower limb joints to exert a large force and power during the takeoff phase. Therefore, the DJ is a highly technical exercise that requires a large amount of power to be exerted within a limited time, which should be considered during plyometric training.

In the DJ, the activity of the muscle–tendon complex of the main active muscle group during takeoff is predicted before ground contact (Leukel et al., 2012). Therefore, vision plays an important role in the movement and force exerted by the main muscle group (Ko et al., 2022; Santello, 2005; Terada et al., 2016). In addition, regarding the DJ, the brain state during the phase in which the athlete is positioned on the platform (plyo box, *etc.*) before stepping off (pre-set phase, Figure 1) affects the DJ performance (Yoshida et al., 2016; Yoshida et al., 2018). Previous studies have suggested that a decrease in excitability of the inhibitory circuits in the motor cortex innervating the ankle plantar flexor muscle during the preset phase increases the stretch reflex evoked from the ankle joint muscles during the takeoff phase and the ankle joint force exertion during the same phase, affecting DJ performance (Yoshida et al., 2016; Yoshida et al., 2018). Therefore, when DJing in plyometric training, the pre-set phase is important to smoothly manipulate the various factors that affect performance and to elicit training effects. Additionally, in the field of training practice, efforts are being made to improve performance by having others demonstrate a target exercise or by watching an instructional movie. Previous studies have reported that combining a long-term plyometric training program with watching an instructional movie improves DJ performance (Battaglia et al., 2014; Keller et al., 2014). However, long-term interventions with videos were combined with routine training separately from the actual test performance in these studies. Therefore, it is unclear whether watching an instructional movie immediately before performing a DJ immediately improves performance. Moreover, The decrease in excitability of the inhibitory circuits in the motor cortex innervating the ankle plantar flexor muscle during the preset phase is more pronounced in athletes with a superior DJ performance (Yoshida et al., 2016), and the increase in excitatory in the motor cortex innervating the hand muscles of athletes with superior abilities is more pronounced when predicting performance (percentage of correct basketball free throws) after watching a movie illustrating the target exercise (Aglioti et al., 2008). Therefore, the acute effect of an instructional movie during the pre-set phase may be more pronounced in participants with a superior DJ performance than in those without it.

The SSC ability of the lower limbs is assessed using the reactive strength index (Young et al., 1999; Jarvis et al., 2021) and rebound jump (RJ) index (Miura et al., 2010; Zushi et al., 2022) of the DJ or RJ, which are vertical jumping motions performed with both legs. Both aforementioned indices can be obtained by dividing the jump height by the contact time during the jump. The RJ-index is related to athletic activities, such as sprinting (Barr and Nolte, 2011; Furlong et al., 2021) and changing directions (McCormick et al., 2014). Therefore, it is important to utilize the RJ-index to properly assess the lower limb for SSC ability (Flanagan and Comyns, 2008; Jarvis et al., 2021). Further, in recent years, when evaluating lower limb SSC ability using RJs and DJs, performance and kinetic variables of the three lower limb joints have been added (Yoshida et al., 2018; Zushi et al., 2022). Previous study suggested that each variable related to the ankle joint affects contact time, whereas variables related to the hip and knee joints affect jump height (Bobbert et al., 1987; Marshall and Moran, 2013; Zushi et al., 2022). Therefore, by clarifying the changes in the kinetic variables of the three lower limb joints in conjunction with changes in the performance variables resulting from watching an instructional movie during the preset phase, it is possible to indicate an evaluation perspective when performing plyometric training combined with an instructional movie. Moreover, the effects of such interventions on improved performance and activation of brain states vary depending on the performance level, training experience, and other factors (Aglioti et al., 2008; Olsson et al., 2008). Therefore, it is inferred that the acute effect of the instructional movie improves ankle and knee joint motion, torque, and power, which are considered to affect the RJ-index during the takeoff phase, but more significantly in subjects with superior RJ-index.

This study aimed to examine the effects of watching an instructional movie during the pre-set phase on the DJ performance variable, the torque production characteristics of the three joints of the lower limbs during the DJ, and the individual characteristics of the three joints of the lower limb. These results will contribute to the development of plyometric training methods that use sensory information, such as vision. In this study, we hypothesized that the influence of the instructional movie would differ depending on the participant's level of lower limb SSC ability (RJ-index), and that movement and force exertion during takeoff would be immediately improved, especially in participants with superior RJ.

2 Materials and methods

This study was approved by the appropriate research ethics committee (tai 019-18). The participants were informed of the benefits and risks of the investigation before obtaining written informed consent for study participation. This study conformed with the principles set forth in the Declaration of Helsinki.

2.1 Participants

Fourteen healthy male university students (age, 21.9 ± 2.1 years; height, 175.6 ± 2.6 cm; weight, 70.7 ± 4.9 kg) who were participants of a university track and field club were subdivided into high RJ-index and low RJ-index groups, each comprising seven participants with a high or low RJ-index based on the mean value under the normal condition, respectively. An *a priori* power analysis (Faul et al., 2007) with an assumed type 1 error of 0.05 and a type 2 error rate of 0.20 (80% statistical power) was conducted for RJ-index of DJ. The results showed that 7 participants in each group would be sufficient to find the statistically significant main effects of 'instructional movie'. The participants were medically screened and had no injuries of any type before the study commenced. They were informed of the test and were allowed to practice DJs sufficiently in advance.

2.2 Procedures

All subjects were instructed to refrain from resistance training the day before the experiment. Before the experiment, they had to perform 15 min of low-intensity jogging, including dynamic stretching. Before the experiment, the participants practiced to ensure that they could perform the trials correctly, according to the instructions of the author, who was familiar with the experimental protocol. The practice of DJs in advance was to minimize the change in performance due to the learning effect occurring during measurement and suppress variations in jumping techniques (Bergmann et al., 2013). Thereafter, they performed 3 DJs using a 0.3 m box. All subjects were given 2 min of rest after the warm up. The experimental exercise consisted of a DJ from a drop height of 0.3 m with two force plates (9287C; Kistler, Winterthur, Switzerland). The participants were instructed to shorten their contact time as much as possible and to jump as high as possible. At that time, the participants were asked to step on the force plates using one leg at a time to measure ground reaction forces on both legs separately. Considering that participants in this study typically train using arm swings, in all the trials, free swinging was used without any restrictions on the swinging motion of the arms to avoid variability in jumping technique. Under the movie condition, the participants performed the DJ immediately after watching a simulated movie (RJ-index, 4.33; jump height, 0.641 m; contact time, 0.148 s) during the pre-set phase. During the preset phase, the arms were extended next to the hips on the platform and the legs were upright to standardize the posture during the pre-set phase. Immediately after watching the instructional movie, the participant placed one leg forward from the platform and then jumped off the platform to perform the DJ. The instructional movie was projected onto a large screen placed 5 m in front of the participant on the platform, and the video began playing when a signal was given by the measurer. The time spent watching the movie was the same as that used by Yoshida et al. (Yoshida et al., 2016), who measured brain states during the preset phase. Under the normal condition, the participants were instructed to perform DJs without watching the movie. The movie and normal conditions were performed in randomized order. The predefined order of jumps was used for each participant. The jumps of three trials under each condition were statistically analyzed by calculating the mean of the performance, kinematics, and kinetic variables. A failed attempt was defined as a foot sticking out of two force plates at the time of crossing and leaving the ground. The rest period between trials was 300 s (5 min) to account for the effects of fatigue (Comyns et al., 2011) and immediate effects of the last trial. Adequate rest time was allowed between trials to minimize the effects of fatigue as much as possible. Participants were not provided any feedback regarding their performance.

2.3 Data analysis

The three-dimensional coordinates of 13 retro-reflective markers (diameter, 14 mm) fixed to the body were collected using a Vicon T20 system with 10 cameras operating at 250 Hz. Auto-labeling was used to measure the body coordinates. During the preliminary experiment, it was expected that the coordinates of the left and right hip joint markers would be swapped during the measurement; hence, a dummy marker was attached to one of the thighs to address the problem. If swapping of the coordinates of the hip joint marker occurred during the trial, then the swapped coordinates were interpolated. The reflective marker was fixed around the periphery with kinesiology tape (NITREAT Kinesiology Tape; Nitto Group Company, Osaka, Japan) and remained firmly attached during the measurement.

The ground reaction force was measured using two force platforms (Kistler 9287C; 0.9 m × 0.6 m; Kistler) at 1,000 Hz. The kinematic data were smoothed using a fourth-order low-pass Butterworth filter with optimal cutoff frequencies of 7.5 and 15.0 Hz (Wells and Winter 1980). The data were time-synchronized using Vicon Nexus software (Nexus 2; Vicon Motion Systems, Ltd., Los Angeles, CA, United States) for subsequent inverse dynamic analyses. The kinematic and kinetic variables of the dominant leg were used for the data analysis. The ground contact and flight times were calculated at the point where the vertical ground reaction force was <10 N (Bosco et al., 1983), and the jump height was calculated using the following free-fall formula (Bosco et al., 1983; Taube et al., 2012):

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$$jump\ height = \left(g \cdot tair^{2}\right)^{8^{-1}}$$

with g being the gravitational acceleration with a value of 9.81 m/s^2. The RJ-index was calculated by dividing the jump height by the contact time (Yoon et al., 2007; Miura et al., 2010; Zushi et al., 2022).

The coordinate system used to calculate the joint torque and angle was the same as that described previously (Zushi et al., 2022). Twelve representative body points were used for each participant (1, right toe; 2, right heel; 3, right ankle; 4, right knee; 5, right greater trochanter; 6, right shoulder; 7, left toe; 8, left heel; 9, left ankle; 10, left knee; 11, left greater trochanter; 12, left shoulder), and one dummy marker was attached to the left thigh. The vector from the ankle joint to the toe was the Z-ankle axis, the vector from the knee joint to the ankle joint was the auxiliary vector S-ankle axis, and the outer product of the *Z*-axis was the Y-ankle axis. The outer product of the Y-ankle and Z-ankle axes was the X-ankle axis, and the coordinate system consisting of the X-ankle, Y-ankle, and Z-ankle axes was termed the ankle joint movement coordinate system. The vector from the knee joint to the ankle joint was the *Z*-axis, and that from the greater trochanter to the knee joint was the auxiliary vector S-knee axis. The outer product of the Z-knee and S-knee axes formed the Y-knee axis. The outer product of the Y-knee and Z-knee axes was the X-knee axis, and the coordinate system consisting of the X-knee, Y-knee, and Z-knee axes was the knee joint movement coordinate system. The vector from the hip joint to the knee joint was the Z-hip axis, and that from the knee joint to the ankle joint was the auxiliary vector S-hip axis. The outer product of the Z-hip and S-hip axes formed the Y-hip axis. The outer product of the Y-hip and Z-hip axes was the X-hip axis, and the movement coordinate system consisting of the X-hip, Y-hip, and Z-hip axes was termed the hip joint moving coordinate system. The vector moving from the center of gravity to the midpoint of the left and right shoulders was defined as the *Z*-axis, and the vector running from the midpoint of the left abductor and left shoulder to the midpoint of the right abductor and right shoulder was defined as the auxiliary vector S-trunk axis. The outer product of the Z-trunk and S-trunk axes formed the Y-trunk axis, and that of the Y-trunk and Z-trunk axes formed the X-trunk axis. The coordinate system consisting of the X-trunk, Y-trunk, and Z-trunk axes was referred to as the trunk movement coordinate system.

The coordinates were smoothed using a fourth-order, zero-lag, low-pass Butterworth filter with optimal cut-off frequencies of 7.5–15 Hz, which were determined using the residual method (Wells and Winter 1980). Estimations of the center of mass and inertial parameters were based on the body segment parameters of Japanese athletes (Ae et al., 1996). The global coordinate system was defined using the jumping directions of the participants in the *X*-axis (mediolateral direction), *Y*-axis (anterior–posterior direction), and *Z*-axis (vertical direction). The ankle joints were analyzed for plantar flexion and dorsiflexion, and the knee and hip joints were analyzed for extension and flexion. The ankle joint angle was defined as the line segment connecting the ankle with the knee and that connecting the ankle with the toe. The knee joint angle was defined as the line segment connecting the knee with the greater trochanter and that connecting the knee with the ankle. The hip joint angle was defined as the angle formed by the line segment connecting the greater trochanter with the shoulder and that connecting the greater trochanter with the knee. Angular velocity was calculated as the average negative and positive values of each joint; flexion velocity was considered a negative value, and extension velocity was considered a positive value.

Joint kinetics were divided into the first (eccentric [Ecc] phase) and second (concentric [Con] phase) halves of the takeoff phase based on the lowest point of the center of gravity. The joint torque was calculated using an inverse dynamics approach. The joint torque at each joint was transformed into a joint coordinate system. The joint power was computed as the dot product of the joint torque and joint angular velocity, and the average values of the negative and positive powers caused by the extension torque during the takeoff phase were calculated. These data were determined based on the positive extension–negative flexion (positive plantarflexion–negative dorsiflexion) axis around the ankle, knee, and hip joints.

2.4 Statistical analyses

Intraclass correlation coefficients were calculated to determine the intermeasurement reliability of the measured variables. All data are presented as the mean ± standard deviation. A two-way (two conditions × two groups) analysis of variance (ANOVA) with repeated measures was used to test for significant differences, with pairwise comparisons evaluated by Bonferroni *post hoc* analysis. Effect sizes using eta square, Cohen and Hedges' g were obtained for any significant pairwise comparisons and interpreted using the following scale: <0.2, trivial; 0.2–0.5, small; 0.5–0.8, medium; 0.8–1.3, large; and >1.3, very large (Cohen, 1992). The alpha level was set to 0.05. Statistical analyses were performed using IBM SPSS Statistics version 25 (IBM Corp., Armonk, NY, United States).

3 Results

The intermeasurement reliability of the RJ-index in this study was high for both the normal (0.918) and movie (0.901) conditions. The reliability of the RJ-index was examined using the Shapiro–Wilk test, with a statistic of normal (0.24) and movie (0.10). Results of the performance variables (RJ-index, jump height, and contact time) for each condition and between groups are presented in Table 1. The results of the two-way ANOVA showed no interaction for either variable, but a main effect of the RJ-index and jump height was found for the condition and group. Furthermore, a main effect of the contact time was found for the condition. The results of the Bonferroni *post hoc* analysis indicated that the movie condition was associated a significantly higher RJ-index and jump height and significantly shorter contact time compared to that in the normal condition (Effect size: 0.36). In both conditions, the high RJ-index group had a significantly higher RJ-index than the low RJ-index group (effect size = normal: 2.62, movie: 3.03). The high RJ-index group also had a significantly higher jump height than the low RJ-index group (effect size = normal: 1.61, movie: 1.78). For contact time, the high RJ-index group was significantly shorter than the low RJ-index group in the movie condition (effect size = normal: 0.49, movie: 0.73).

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TABLE 1 Drop jump performance variables of each condition.

Variables	All				High RJ-index group				Low RJ-index group			
	Normal		Movie		Normal		Movie		Normal		Movie	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
RJ-index (m/s)	2.39	0.49	2.57	0.53	2.78	0.21	3.01	0.19	2.01	0.36	2.14	0.36
Jump height (m)	0.44	0.09	0.46	0.08	0.50	0.06	0.51	0.08	0.39	0.08	0.40	0.07
Contact time (s)	0.19	0.03	0.18	0.03	0.18	0.02	0.17	0.02	0.19	0.03	0.19	0.03

Interactions				Effect size (η^2)	Difference	Effect size (d) (between the condition of each group)	Effect size (g) (between the group of each condition)
Variables	*Factor*	*F-value*	*p-value*				
RJ-index (m/s)	Condition	27.551	0.000[a]	0.70	Normal < Movie	All: 0.36	Normal: 2.62 Movie: 3.03
	Group	29.318	0.000[a]	0.71	Lower < Higher	Higher: 1.10	
	Condition × Group	2.312	0.154	0.16	n.s	Lower: 0.35	
Jump height (m)	Condition	4.892	0.047[b]	0.29	Normal < Movie	All: 0.16	Normal: 1.61 Movie: 1.78
	Group	10.268	0.008[a]	0.46	Lower < Higher	Higher: 0.21	
	Condition × Group	0.012	0.915	0.00	n.s	Lower: 0.19	
Contact time (s)	Condition	4.871	0.048[b]	0.29	Normal > Movie	All: 0.24	Normal: 0.49 Movie: 0.73
	Group	1.358	0.266	0.10	n.s	Higher: 0.43	
	Condition × Group	1.006	0.336	0.08	n.s	Lower: 0.11	

[b]$p < 0.05$.
[a]$p < 0.01$.
n.s., not significant; RJ, index, rebound jump index; SD, standard deviation.

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TABLE 2 Kinematic variables during the takeoff of the drop jump under each condition.

		All				High RJ-index group				Low RJ-index group			
		Normal		Movie		Normal		Movie		Normal		Movie	
Variables	*Joint*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Joint flexion (deg)	Hip	4.27	3.97	3.91	4.92	2.07	2.54	1.99	3.76	6.47	4.04	5.83	5.45
	Knee	22.03	7.12	18.92	9.59	18	5.58	13.79	8.88	26.05	6.4	24.05	7.68
	Ankle	23.13	6.99	23.68	6.9	24.87	5.28	25.8	5.71	21.39	8.42	21.56	7.75
Joint extension (deg)	Hip	36.8	10.32	36.59	9.8	37.79	10.36	37.39	11	35.82	11.01	35.79	9.23
	Knee	54.4	8.68	52.45	9.31	54.78	8.39	50.71	10.33	54.01	9.62	54.19	8.59
	Ankle	54.71	5.76	54.77	5.42	53.45	4.88	53.61	3.58	55.95	6.68	55.93	6.23

Interactions					Effect size (η^2)	Difference	Effect size (d) (between the condition of each group)	Effect size (g) (between the group of each condition)
Variables	*Joint*	*Factor*	*F-value*	*p-value*				
Joint flexion (deg)	Hip	Condition	0.518	0.518	0.04	n.s	All: 0.08	Normal: 1.30 Movie: 0.82
		Group	3.789	0.075	0.24		Higher: 0.18	
		Condition × Group	0.614	0.614	0.02		Lower: 0.02	
	Knee	Condition	9.054	0.011*	0.43	Normal > Movie	All: 0.44	Normal: 1.34 Movie: 1.24
		Group	6.014	0.030*	0.33	Lower > Higher	Higher: 0.76	
		Condition × Group	1.156	0.303	0.09		Lower: 0.31	
	Ankle	Condition	0.846	0.376	0.07	n.s	All: 0.09	Normal: 0.50 Movie: 0.63
		Group	0.410	0.534	0.09		Higher: 0.03	
		Condition × Group	1.124	0.310	0.03		Lower: 0.16	
Joint extension (deg)	Hip	Condition	0.067	0.800	0.01	n.s	All: 0.01	Normal: 0.18 Movie: 0.16
		Group	0.105	0.752	0.01		Higher: 0.03	
		Condition × Group	0.800	0.827	0.00		Lower: 0.00	
	Knee	Condition	3.849	0.073	0.24	n.s	All: 0.23	Normal: 0.09 Movie: 0.37
		Group	0.078	0.785	0.01		Higher: 0.49	
		Condition × Group	4.576	0.054	0.28		Lower: 0.02	
	Ankle	Condition	0.012	0.914	0.00	n.s	All: 0.02	Normal: 0.43 Movie: 0.42
		Group	0.656	0.434	0.05		Higher: 0.04	
		Condition × Group	0.020	0.890	0.00		Lower: 0.00	

[a]$p < 0.05$.
[b]$p < 0.01$.
SD, standard deviation.

Table 2 shows the results for flexion and extension of the three lower limb joints of the groups under both conditions. The results of the two-way ANOVA showed significant effects of condition and group on the amount of knee joint flexion. The Bonferroni *post hoc* analysis also showed that the degree of knee flexion was significantly smaller in the movie condition than in the normal condition (Effect size: −0.44). The degree of knee joint flexion was also significantly smaller in the high RJ-index group than in the low RJ-index group in both conditions (effect size = normal: 1.34, movie: 1.24).

Table 3 shows the results of the trials for each condition and the torques of the three lower limb joints (ankle, knee, and hip) compared between groups. The results of the two-way ANOVA showed a significant effect of condition on the ankle joint torque of the Ecc and Con phases. Additionally, an interaction effect was observed in the ankle joint torque of the Ecc phase. The Bonferroni *post hoc* analysis also showed that the movie condition was associated with significantly larger ankle joint torque of the Ecc and Con phases compared to that in the normal condition (Effect size: 0.28). Additionally, the movie condition was associated with a significantly larger ankle joint torque of the Ecc phase compared to that in the normal condition in the high RJ-index group (Effect size: 0.46).

Table 4 shows the results of the trials and power of the three lower limb joints under each condition. The results of the two-way ANOVA showed a significant effect of condition on the negative and positive mean powers of the ankle joint and a significant effect of group on the negative and positive mean powers of the knee joint. Additionally, an interaction effect was observed for the positive mean power of the ankle joint. The Bonferroni *post hoc* analysis also showed that the movie condition was associated with significantly larger negative and positive mean powers of the ankle joint compared to that in the normal condition (Effect size = negative: −0.26, positive: 0.44). The negative mean power of the knee joint was significantly smaller (Effect size = normal: 1.18, movie: 1.49) and the positive power of the knee joint was significantly larger in the high RJ-index group than in the low RJ-index group (Effect size = normal: 1.27, movie: 1.26). Additionally, the movie condition was associated with significantly larger positive mean power of the ankle joint compared to that in the normal condition in the high RJ-index group (Effect size: 0.62).

4 Discussion

The changes in the performance variables of the RJ index, jump height, and contact time of the DJ task revealed that the RJ-index and jump height were higher and the contact time was significantly shorter under the movie condition than under the normal condition. The relationship between jump height and contact time, which constitute the RJ-index, was not strong, although these were reported to be independent variables (Young et al., 1999; Zushi et al., 2022). Therefore, our findings indicated that factors affecting the jump height and contact time were immediately improved by the incorporation of an instructional movie during the pre-set phase, resulting in a higher RJ-index. Incorporating long-term interventions, such as watching an instructional movie and reviewing jump height in real time into a routine plyometric training program, can improve DJ performance (Battaglia et al., 2014). The results of the present study suggest that watching an instructional movie during the pre-set phase immediately improves DJ performance. Studies have also suggested that reduced excitability of intracortical inhibitory circuits during the pre-set phase may facilitate stretch reflexes during the takeoff phase, resulting in greater torque in the agonist muscles of the lower limbs and ultimately affecting the RJ-index (Yoshida et al., 2016; Yoshida et al., 2018). These results suggest that the inclusion of an instructional movie during the pre-set phase, which improves various factors affecting the performance during the takeoff phase, leads to a significant increase in the RJ-index.

The analysis of flexion and extension of the three lower limb joints during the takeoff phase showed that the degree of flexion of the knee joint was smaller under the movie condition than under the normal condition (Table 2). Conversely, regarding the characteristics among the groups, the amount of flexion was significantly smaller in the high RJ-index group than in the low RJ-index group (Table 2). In a previous study, a bounce-type DJ, which included a short ground contact and the highest jump possible (as in the DJ experimental test of the present study), showed a larger knee joint angle during takeoff (the phase when the knee joint changes from flexion to extension) than a countermovement type of DJ, during which the participants jumped as high as possible (Marshall and Moran, 2013). In other words, in order to shorten the contact time, it is necessary to reduce the amount of knee joint flexion during takeoff. Therefore, these results suggest that watching an instructional movie during the pre-set phase reduces knee joint flexion during the takeoff phase and influences contact time reduction. When elite basketball players were provided a basketball free-throw instructional movie, they were able to predict outcomes faster and more accurately than individuals who had never played basketball (Aglioti et al., 2008). Additionally, elite basketball players showed greater excitability in brain regions controlling the agonist muscle groups during transcranial magnetic stimulation than non-elite basketball players. In a functional magnetic resonance imaging study of brain activity during the imagination of the takeoff motion of the high jump by novices and athletes, novices exhibited activations mainly in visual brain areas, whereas athletes showed activation mainly in motor areas (Olsson et al., 2008). Motor areas, such as the premotor cortex and cerebellum, were directly involved in the planning and execution of the movement, and that these areas were mainly activated during the imagination of the high jump by athletes at higher competitive levels. In the present study, the high RJ-index group was associated with a higher SSC motor execution ability than the low RJ-index group. Therefore, the reason for the improvement of knee joint flexion during takeoff during DJs under the instructional movie condition for the higher group may be attributed to the better ability of this group to achieve a well-timed landing based on the temporal and spatial predictions of ground contact, as shown in the instructional movie watched during the pre-set phase.

The overall results of the average torques of the three lower limbs joints revealed that participants produced significantly greater Con torque during the Ecc and Con phases, positive power at the ankle joint, and positive power at the knee joint under the movie condition than under the normal condition (Table 3). Bounce DJs, during which participants jump with the shortest contact possible and highest jump possible, have been shown to exert more power at the ankle and knee joints than at the hip joint (Bobbert et al., 1987; Marshall and Moran, 2013; Zushi et al., 2022). Another study also reported that the force exertion of the ankle and knee

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TABLE 3 Joint torque variables during the takeoff of the drop jump under each condition.

Variables	*Joint*	*Phase*	All				High RJ-index group				Low RJ-index group			
			Normal		Movie		Normal		Movie		Normal		Movie	
			Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Mean joint torque (N/kg)	Hip	Ecc	2.71	1.38	2.56	1.63	2.55	0.98	2.21	1.13	2.88	1.76	2.91	2.06
		Con	1.05	0.34	1.08	0.32	1.01	0.25	1.12	0.36	1.09	0.42	1.04	0.31
	Knee	Ecc	2.04	0.38	2.12	0.38	1.92	0.30	2.03	0.38	2.17	0.43	2.20	0.40
		Con	1.96	0.29	1.96	0.30	1.90	0.29	1.89	0.34	2.01	0.30	2.03	0.25
	Ankle	Ecc	2.19	0.50	2.33	0.56	2.27	0.52	2.50	0.57	2.11	0.51	2.16	0.53
		Con	2.17	0.39	2.26	0.36	2.30	0.45	2.37	0.44	2.05	0.30	2.15	0.25

Interactions					Effect size (η^2)	Difference	Effect size (d) (between the condition of each group)	Effect size (g) (between the group of each condition)
Joint	*Phase*	*Factor*	*F-value*	*p-value*				
Hip	Ecc	Condition	0.787	0.389	0.06	n.s	All: 0.11	Normal: 0.23 Movie: 0.42
		Group	0.404	0.537	0.03		Higher: 0.35	
		Condition × Group	1.146	0.306	0.09		Lower: 0.02	
	Con	Condition	0.127	0.728	0.01	n.s	All: 0.09	Normal: 0.22 Movie: 0.22
		Group	0.000	0.993	0.00		Higher: 0.42	
		Condition × Group	0.852	0.374	0.07		Lower: 0.11	
Knee	Ecc	Condition	1.159	0,303	0.09	n.s	All: 0.19	Normal: 0.67 Movie: 0.45
		Group	1.206	0.294	0.09		Higher: 0.36	
		Condition × Group	0.321	0.581	0.03		Lower: 0.08	
	Con	Condition	0.041	0.844	0.03	n.s	All: 0.02	Normal: 0.36 Movie: 0.46
		Group	0.597	0.455	0.05		Higher: 0.03	
		Condition × Group	0.339	0.571	0.03		Lower: 0.07	
Ankle	Ecc	Condition	15.466	0.002[a]	0.54	Normal < Movie	All: 0.28	Normal: 0.29 Movie: 0.62
		Group	0.768	0.398	0.06		Higher: 0.46	
		Condition × Group	6.596	0.025[b]	0.37	Higher: Normal < Movie	Lower: 0.08	
	Con	Condition	7.520	0.018[b]	0.39	Normal < Movie	All: 0.02	Normal: 0.66 Movie: 0.62
		Group	1.458	0.251	0.11		Higher: 0.16	
		Condition × Group	0.243	0,631	0.02		Lower: 0.35	

[b]$p < 0.05$.
[a]$p < 0.01$.
Con, concentric; Ecc, eccentric; n. s., not significant; SD, standard deviation.

TABLE 4 Joint power variables during the takeoff of the drop jump under each condition.

Variables	*Joint*	*Phase*	All				High RJ-index group				Low RJ-index group			
			Normal		Movie		Normal		Movie		Normal		Movie	
			Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Mean joint power (W/kg)	Hip	Negative	−8.86	8.14	−8.26	7.41	−6.20	5.63	−5.78	6.01	−11.52	9.77	−10.74	8.28
		Positive	4.01	2.03	4.41	1.60	3.91	1.67	4.61	1.44	4.10	2.48	4.21	1.83
	Knee	Negative	−10.99	5.71	−10.40	4.85	−8.04	2.87	−7.47	3.29	−13.94	6.48	−13.33	4.49
		Positive	10.19	2.24	10.30	2.02	11.41	2.05	11.39	2.29	8.97	1.79	9.20	0.90
	Ankle	Negative	−10.69	6.41	−12.38	6.87	−13.40	7.07	−15.84	7.46	−7.99	4.66	−8.91	4.31
		Positive	12.41	2.46	13.49	3.13	13.20	2.96	15.04	3.36	11.61	1.69	11.93	2.08

Interactions					Effect size (η^2)	Difference	Effect size (d) (between the condition of each group)	Effect size (g) (between the group of each condition)
Joint	*Phase*	*Factor*	*F-value*	*p-value*				
Hip	Negative	Condition	1.280	0.260	0.10	n.s	All: 0.07	Normal: 0.67 Movie: 0.69
		Group	1.261	0.227	0.11		Higher: 0.07	
		Condition × Group	0.118	0.737	0.01		Lower: 0.08	
	Positive	Condition	1.696	0.217	0.12	n.s	All: 0.29	Normal: 0.09 Movie: 0.24
		Group	0.011	0.919	0.00		Higher: 0.42	
		Condition × group	0.916	0.357	0.07		Lower: 0.04	
Knee	Negative	Condition	1.092	0.317	0.08	Lower > Higher	All: 0.10	Normal: 1.18 Movie: 1.49
		Group	6.292	0.027*	0.34		Higher: 0.20	
		Condition × group	0.001	0.970	0.00		Lower: 0.10	
	Positive	Condition	0.099	0.758	0.01	Lower < Higher	All: 0.05	Normal: 1.27 Movie: 1.26
		Group	6.336	0.027*	0.35		Higher: 0.01	
		Condition × group	0.138	0.716	0.01		Lower: 0.13	
Ankle	Negative	Condition	11.225	0.006*	0.48	Normal < Movie	All: 0.26	Normal: 0.90 Movie: 1.14
		Group	3.744	0.077	0.24		Higher: 0.35	
		Condition × group	2.247	0.160	0.16		Lower: 0.20	
	Positive	Condition	12.674	0.004**	0.51	All: Normal < Movie	All: 0.44	Normal: 0.66 Movie: 1.11
		Group	2.979	0.110	0.20	Higher: Normal < Movie	Higher: 0.62	
		Condition × group	6.279	0.028*	0.34		Lower: 0.19	

[a]$p < 0.05$.
[b]$p < 0.01$.
n.s., not significant; RJ-index, rebound jump index; SD, standard deviation.

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joints increased with an increase in the RJ-index and jump height when plyometrics was applied (Alkjaer et al., 2013). Therefore, it is possible that watching the instructional movie during the pre-set phase increased the exertion of the muscle groups associated with ankle and knee joints, which increased the final RJ-index in this group.

The negative power of the knee joint was lower and the positive power of the knee joint was greater in the high RJ-index group than in the low RJ-index group under both conditions. Knee joint power influences jump height (Alkjaer et al., 2013). This study showed a lesser degree of knee joint flexion in the high RJ index group than in the low RJ-index group. Therefore, the high RJ-index group could potentially reduce the degree of knee joint flexion, gaining more power in the forward direction of the knee joint, through well-timed landings based on temporal and spatial predictions compared to that in the low RJ-index group.

Conversely, an interaction effect was observed between the torque during the Ecc phase and positive power of the ankle joint, and a significant increase was observed under the movie condition compared to that in the normal condition in the high RJ-index group only. These results indicate that the Ecc torque and positive power of the ankle joint are explicitly increased in the high RJ-index group because of the incorporation of the instructional movie during the pre-set phase. During bounce DJs, the ankle muscle group exerts the greatest power among the lower limb joints (Bobbert et al., 1987; Marshall and Moran, 2013). Additionally, the ankle joint torque during the takeoff phase affects contact time and jump height (Kovács et al., 1999). Positive ankle joint power has the greatest influence on the RJ-index and is related to the jump height and contact time of DJs and RJs (Zushi et al., 2022). Furthermore, a decrease in the excitability of intracortical inhibitory circuits in the ankle plantar flexors during the preset phase may stimulate the stretch reflex during the takeoff phase, thus increasing the torque of the ankle joint and primary working muscle group and ultimately affecting the RJ-index (Yoshida et al., 2016; Yoshida et al., 2018). Therefore, watching an instructional movie during the pre-set phase may significantly increase the torque and positive power of the ankle joint during the Ecc phase, thus affecting both the jump height and contact time of the DJs and significantly increasing the RJ-index of the high RJ-index group.

As a limitation of the study, the sample size in this study was relatively small although the number of participants was met on the sample size test. Therefore, a larger number of participants should be considered when conducting related studies in the future.

5 Conclusion

The DJ performance variables, and parameters of kinematics and kinetics related to the ankle and knee joints during the takeoff are increased by watching an instructional movie during the pre-set phase. However, these improvements are more pronounced in the group with high SSC ability in the low limb than in the group with lower SSC ability, increasing ankle joint torque and positive power during the Ecc phase.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by Research Ethics Committee for Faculty of Health and Sport Sciences, University of Tsukuba. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

YT and ZA provided substantial contributions to the conception or design of the manuscript. YT, ZA, YY, MH, OS, and TS were responsible for the acquisition, analysis, and interpretation of the data. All authors have participated in drafting the manuscript, and all authors revised it critically. All authors read and approved the final version of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frvir.2023.1198511/full#supplementary-material

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