A LONGITUDINAL INVESTIGATION ON DROP JUMP PERFORMANCE-FOCUSING ON BRAIN CONDITION DURING PRE-SET, STRETCH REFLEX AND JOINT KINETICS DURING TAKE-OFF

Takuya Yoshida[1], Kazutaka Takahashi[2], Masamichi Okudaira[2], Seita Kuki[2] Amane Zushi[2], Fusako Kawahara[2], Kodayu Zushi[2], Satoru Tanigawa[1]

Faculty of Health Sciences, University of Tsukuba, Tsukuba, Japan[1]
Graduate School of Comprehensive Human Sciences, Tsukuba, Japan[2]

The purpose of this study was to investigate the change in drop jump (DJ) performance with a training process that focused on the state of the brain during the pre-set phase, the stretch reflex during the take-off phase, and the joint kinetics of lower extremities during take-off phase. Three male sprinters performed DJ from a drop height of 0.6 m. We measured variables for state of the brain during the pre-set phase, stretch reflex, and kinetics of lower extremities during take-off. The results revealed that the brain showed disinhibition during the pre-set phase, and stretch reflex facilitation, and an increase in force development of the ankle joint were observed during the take-off phase. Therefore, we propose that the mutual enhancement on component of performance in each phase may be effective in improving DJ performance during a training course.

KEY WORDS: DJ-index, pre-set phase, time-series relationship, ankle joint torque

INTRODUCTION: Explosive power output of the lower extremities is essential for improving performance in several sports. Drop jump (DJ) is not only used as a training method for improving explosive power in numerous types of sports but it is also a method of evaluation. Previous reports have stated that DJ performance is affected by variables such as pre-activation, stretch reflex, and execution of force on the ankle, and that these components were related as per a time-series analysis (Taube, Leukel & Gollhofer, 2012). Furthermore, we have clarified that the state of the brain during the pre-set phase prior to jumping off the platform influences the performance of the DJ (Yoshida, Maruyama, Kariyama, Hayashi & Zushi, 2016a). The results showed the importance of selective disinhibition of the brain areas associated with the agonist muscles during the pre-set phase for higher DJ performance. In addition, it implies that disinhibition of the brain areas during the pre-set phase affects the facilitation of the stretch reflex during the take-off phase, which results in increased force development of the ankle joint during the take-off phase (Yoshida et al., 2016b). Therefore, the elements of the performance in each phase are possibly time-series related from the pre-set phase to performance acquisition. However, from these studies, it is not clear whether the brain condition is capable of being trained during the pre-set phase. Therefore, the effect on these physiological and biomechanical variables during the training process remains unclear. Thus, understanding these DJ characteristics may contribute to improving the explosive power output of the lower extremities. Moreover, by considering the trainability of the brain condition in the pre-set phase along with the biomechanical features, there is a possibility of contributing to the development of training method for improving explosive power. The purpose of this study was to investigate the change in DJ performance with a training process focusing on the state of the brain during the pre-set phase, on the stretch reflex, and the biomechanical characteristics of the lower leg during the take-off phase.

METHODS: We evaluated three male sprinters (Mean ± SD of; age, 20.00 ± 1.73 years; 1.80 ± 0.03 m; 71.20 ± 4.03 kg). This study has been approved by the Ethics Committee of the Institute of Health and Sport Sciences, University of Tsukuba, Japan.
The participants performed DJ from a drop height of 0.6 m. This drop height was reported to exhibit a remarkably disinhibition of the brain areas during the following pre-set phase (Yoshida et al., 2016a). Participants were orally instructed to shorten ground contact time as much as possible and to jump as high as possible. The measurement of variables for each phase (Figure 1) was performed during the subsequent procedure. The following variables

were measured twice (pre, post) during the winter training period.

Pre-set phase: Brain condition during the pre-set phase was evaluated using short-interval intracortical inhibition (SICI) established by Kujirai et al. (1993). Two transcranial magnetic stimulation (TMS) devices (Magstim 200, Magstim) and a stimulation coil (Double cone coil, Magstim) were used for measurement. The stimulation site was controlled by the gastrocnemius muscle. To unify the stimulation site in all the tests, the fixed position was recorded on the cranium with the subject's permission. In order to determine the stimulus intensity of the TMS with the maximum stimulator output set at 100%, we measured the resting exercise threshold (resting motor threshold [RMT]). Because motor evoked potential (MEP) measurement at the pre-set phase was performed in the standing position, MEP measurement at rest was performed in the same posture. The MEP amplitude value was determined by measuring the peak-to-peak amplitude. The test stimulus (TS) intensity was set to induce MEP of approximately 1 mV, and the conditioning stimulus (CS) intensity was set to 70% of the RMT. The relative value for paired pulse was obtained by dividing the MEP amplitude recorded by TMS by the TS and by the MEP amplitude was considered the %SICI. In this study, the value obrtaind by subtracting SICI measured at pre-set with SICI measured at rest was used as an index (⊿SICI).

Take-off phase: Stretch reflex was evaluated using the Hoffmann reflex (H-reflex). The H-reflex was measured from the left medial gastrocnemius muscle by stimulating the left tibial nerve using an induced electrical stimulation device (Neuropack S1, Nihon Kohden). The H-reflex was recorded with a photoelectric sensor (AO-YZ, Applied Officer) that was mounted on the floor side of the force platform. Next, as the foot region passed through the photoelectric beam, a signal from the TTL distribution box (AO-2TTL, Applied Office) was used as a trigger for stimulating the tibial nerve (rectangular pulse with a duration of 1 ms). Using a disposable electrode, the anode was placed on the rough surface of the tibia below the patella, and the cathode was placed on the medial gastrocnemius muscle. The amplitude of the H-reflex was measured as peak-to-peak amplitude. The stimulation intensity was set at 15%–35% of the maximum M-wave. In this study, we expressed the maximal H-reflex relative to M-wave (%H/M). Three-dimensional coordinates of the 12 retroreflective markers fixed on each subject’s body were obtained using a Vicon T20 system (Vicon Motion Systems Ltd.) with 10 cameras operating at 250 Hz. Ground reaction force was measured by a force platform at a rate of 1000 Hz. The DJ-index indicates that the mechanical power per body mass during take-off (Zushi, Takamatsu & Kotoh, 1993) was calculated by dividing the jump height by the contact time. The joint torque of the lower leg (take-off leg side) was calculated using inverse dynamics.

All analyses were done on the take-off leg side. In this study, since there were only three participants, for the comparison of measured values, the average values before and after the training process were compared with relative values.

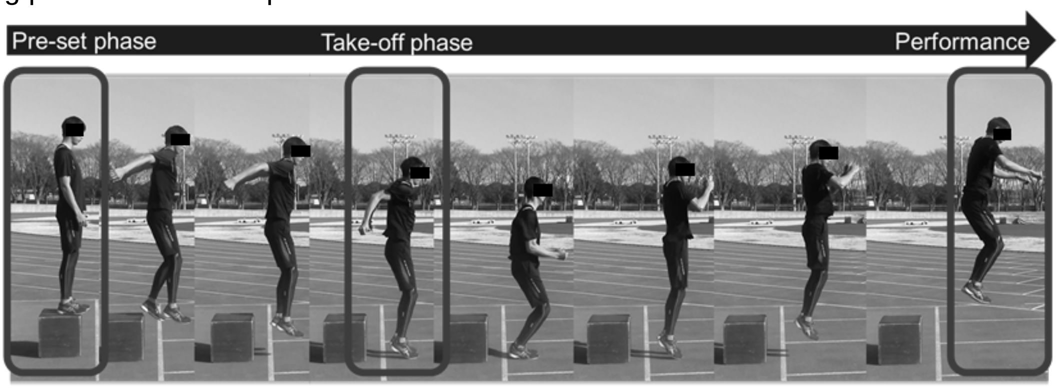

Figure 1: Analysis phase of the present study.

RESULTS: The results of DJ performance and kinetic variables are shown in Table 1. DJ performance showed an increased tendency (15.31%) on the DJ-index and jump height (14.78%) in post compared with pre. In addition, the contact time was reduced tendency

(0.69%) in post compared pre. Among the 3 lower leg joints, the peak joint torque with the highest increase was the ankle (41.70%), followed by the hip (9.85%) and the knee joint (0.89%) in post compared with pre. Figure 2 shows the brain conditions during the pre-set phase (a), the stretch reflex during the take-off phase (b), the ankle joint torque of the same phase (c), and the DJ performance (d) in time-series. In the brain condition during the pre-set phase, ΔSICI showed an increase tendency (90.44%) in post compare with pre. In the stretch reflex during take-off, %H/M showed an increase tendency in post compare with pre (99.31%). The peak ankle torque (c) and DJ-index (d) are as shown in the above (Table 1).

Table 1: Comparison of DJ performance and kinetic variables.

	Sub.	DJ-index (m/sec)	Contact time (sec)	Jump height (cm)	Peak hip joint torque (Nm/kg)	Peak knee joint torque (Nm/kg)	Peak ankle joint torque (Nm/kg)
Pre	A	2.10	0.19	40.22	4.86	4.80	3.68
	B	1.43	0.18	25.75	5.27	4.79	3.44
	C	1.36	0.21	28.33	9.98	4.77	2.75
	Mean	**1.63**	**0.19**	**31.43**	**6.71**	**4.78**	**3.29**
	SD	0.41	0.01	7.72	2.85	0.01	0.48
Post	A	2.30	0.19	43.10	6.23	4.97	5.52
	B	1.64	0.19	30.92	7.60	4.25	5.28
	C	1.71	0.20	34.23	8.26	5.26	3.19
	Mean	**1.88**	**0.19**	**36.08**	**7.37**	**4.83**	**4.66**
	SD	0.37	0.01	6.30	1.04	0.52	1.28
Pre/Post (%)		**115.31**	**99.31**	**114.78**	**109.85**	**100.89**	**141.70**

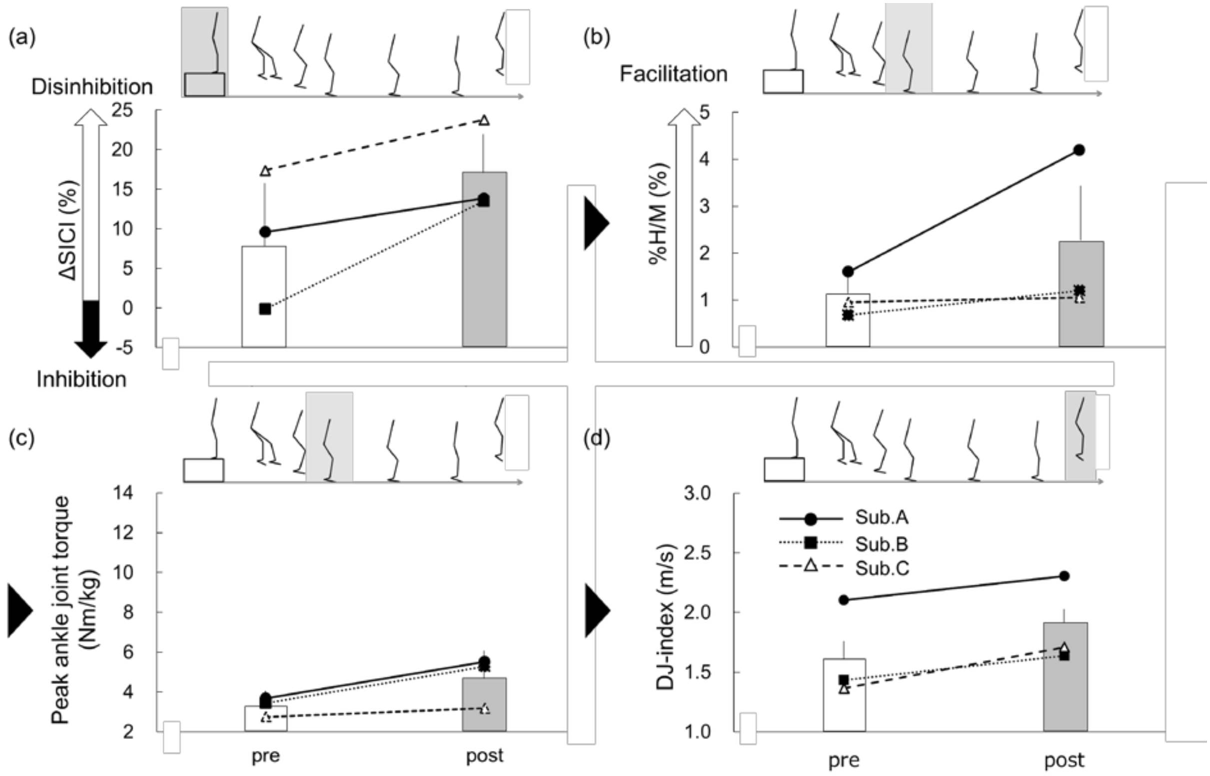

Figure 2: Comnparison of variables in each phase. Brain condition (a), stretch reflex (b), force development of the ankle joint (c), and DJ performance (d) in time-series.

DISCUSSION: DJ performance showed an increase tendency on the DJ-index and jump height, and a reduced tendency on the contact time. In addition, among the three lower leg joints, the joint torque with the highest increase was the ankle joint (Table 1). These results suggest that the participants' ability to acquire higher jump height in a short time period improved with progressive training, and that the increase in force exertion of the ankle was largely responsible. Previous studies have reported a significant correlation between ankle joint torque, jump height, and ground contact time during the take-off phase in a DJ or 5 continuous rebound jumps (Yoon, Tauchi & Takamatsu, 2007). Therefore, the results of the current study are in agreement with those of previous studies.

In the brain condition during the pre-set phase, ΔSICI showed an increase tendency (Figure 2a). In ΔSICI indicates higher the value the decreased excitability of the intracortical inhibitory circuit, the so-called disinhibition state. This infers that the disinhibition state of the brain in the pre-set phase improves with progressive training, and may demonstrate trainability. Previous studies have reported that the disinhibited state due to training is promoted with increasing muscle strength specific to movement (Weier, Pearce & Kidgell, 2012). The pre-set phase in the DJ is the phase before it catches the large stretching load that occurs in the landing after jumping off the platform. In this reason, the preparatory state for explosive power such DJ infer that it formed by the brain region controlling the agonist muscle in advance on the pre-set phase. Furthermore, in the stretch reflex during take-off, %H/M increase tendency (Figure 2b), and peak ankle joint torque during take-off and DJ-index increase tendency (Table 1, Figures 2c, d) were shown. Our previous studies have suggested that the neural factors (the disinhibition of brain areas during the pre-set phase affects facilitation of the stretch reflex during the take-off phase, and facilitation of the stretch reflex results from the development of explosive force in the ankle joint during the take-off phase) controlling the ankle affects force development of the ankle joint (Yoshida et al., 2016b). These results suggest that mutual enhancement of physiological and biomechanical measures due to the performance in each phase may be effective for improving DJ performance in a training course.

CONCLUSION: The purpose of this study was to investigate the change in DJ performance with a training process that focused on the state of the brain during the pre-set phase, and the stretch reflex, and the biomechanical characteristics of lower extremity during the take-off phase. As a result, DJ-index and jump height showed an increase tendency, contact time showed an reduce tendency in post compared with pre. The joint torque with the highest increase was the ankle, followed by the hip and the knee joint in post compared with pre. There, looking at the results of neural factors controlling the ankle joint, ΔSICI evaluating the brain condition during the pre-set phase showed an increase tendency in post compare with pre. Also, %H/M evaluating the stretch reflex during the take-off phase showed an increase tendency in post compare with pre. Therefore, mutual enhancement of physiological and biomechanical measures due to the performance in each phase may be effective for improving DJ performance in a training course.

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