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Original Article

Lower trunk muscle activity-induced alignment and cop position during single-leg standing

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Abstract. [Purpose] The purpose of this study was to clarify fundamental changes induced by lower trunk muscle contraction during single-leg standing. [Subjects and Methods] Ten healthy normal males participated in this study. All subjects could accurately perform lower trunk muscle contraction-type Abdominal Expansion (AE), Abdominal Bracing (AB), and Abdominal Cave-in (AC). The alignment and position of the center of foot pressure (COP) during single-leg standing with SLR and step position after rotating the body from single-leg standing with maximum SLR were measured in each lower trunk muscle contraction type. [Results] When AC was performed during single-leg standing with SLR, the SLR angle increased, COP shifted backward, and the posterior tilt angle of the trunk and cross step distance decreased. [Conclusion] It was assumed that AC during wind-up increases the angle of lower limb elevation and decreases the posterior tilt angle of the trunk and cross step distance.

Key words: Abdominal Cave-in, Cross step, Posterior tilt angle of the trunk

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INTRODUCTION

To safely and effectively perform body movement, such as throwing, induction of an appropriate kinetic chain by utilizing gravity and ground reaction force is essential to improve performance and prevent damage[1)]. Pitching motion in baseball starts with shifting the center of gravity of the body from the base of support in wind-up, which is standstill single-leg standing, toward pitching direction by abductor and external rotator muscle forces of the hip joint of the supporting leg. The speed of movement increases with an increase in the force of these muscles in wind-up. This increase in the speed augments the ground reaction force upon grounding the stepping foot in the late-cocking phase[2–4)]. This ground reaction force doesn't produce ascending kinetic chain unless the force is effectively linked to pelvic rotation.

It is difficult to directly change problematic phenomena in various motions. To improve the problematic phenomena, it is necessary to approach factors causing the problems.

Unconscious cross stepping in the late-cocking phase has to be corrected, but correction in the early-cocking phase during step motion is difficult. Since the cause of cross step may be present in wind-up, setting a proper alignment in wind-up is necessary. It is important to move the trunk from the back inclination to the upright direction and the foot pressure from the front inside to the center during windup[5)]. Lower trunk muscle contraction changes alignment of single-leg standing[6)], but there has been no report on the relation between lower trunk muscle contraction and pitching motion during wind-up.

The objective of this study was to clarify lower trunk muscle contraction-induced fundamental changes during SLR

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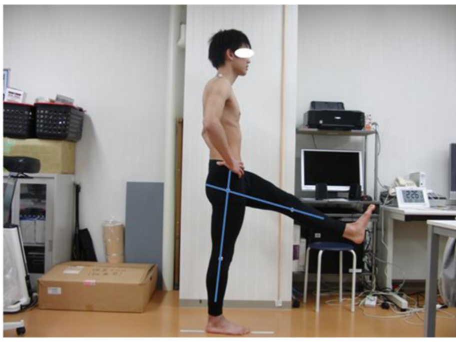

Fig. 1. SLR angle on single-leg standing
The subject stood in the upright posture with both hands placed on the hip and contracted the lower trunk muscles. The subject stood so as to align the acromion, greater trochanter, and lateral epicondyle in a vertical straight line and then raised one leg to the maximum level while retaining knee extension.

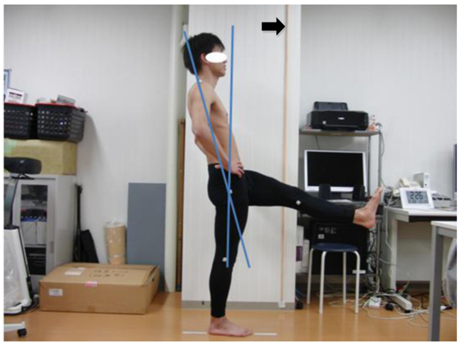

Fig. 2. Maximum posterior tilt angle of the trunk after SLR on single-leg standing
Keen extension on the support side was maintained. The posterior tilt angle was measured regarding a vertical line drawn from the greater trochanter as a baseline axis and a line connecting the greater trochanter and acromion as a moving axis. Vertical line (➡) was drew on the wall.

on single-leg standing, focusing on its posture control at the time of lower limb lifting with knee extension caused from wind-up to early-cocking. So, SLR alignment and COP position during single-leg standing and step position after SLR on single-leg standing were measured in different lower trunk muscle contraction types. Lower trunk muscle contraction types were Abdominal Expansion (AE), Abdominal Bracing (AB), and Abdominal Cave-in (AC)[7].

SUBJECTS AND METHODS

Ten healthy normal males participated in this study (age: 20.9 ± 1.6 years old, height: 174.5 ± 3.6 cm, body weight: 68.6 ± 8.5 kg). All subjects could accurately perform lower trunk muscle contraction types AE, AB, and AC.

The lower trunk muscle contraction types were classified into three types, because of importance to synchronize the timing of exercise and respiration[7]. In AE, the abdominal circumference increases from that in resting expiration due to inhalation of air, and abdominal lateral muscle activity is observed. In AB, abdominal lateral muscle activity is observed without a change in the abdominal circumference from that in resting expiration. In AC, the abdominal circumference is decreased from the resting expiratory position by exhalation and physiological lumbar lordosis, and muscle thickness increases due to concentric contraction of the abdominal lateral muscles[8–11].

The breathing types were confirmed using a respiration wave sensor (DL-230, S&M Co., Ltd.), and the abdominal circumference was measured using a measure. The muscle contraction types and muscle thickness were determined using a diagnostic ultrasound imaging system (LOGIQ e, GE Healthcare Japan) and electromyogram analysis system (Biolog DL-3100, S&M Co., Ltd.)[12, 13].

The maximum SLR angle and COP position during single-leg standing with SLR were measured. The subjects stood on both legs placing their hands on the bilateral hips in order to fix their scapulars and contracted the lower trunk muscles. They stood so as to align the acromion, greater trochanter, and lateral malleolus in a vertical line. Then, they raised one leg to the maximum level while retaining knee extension. The COP position (shift of the mean center of anteroposterior sway) at the maximum level of SLR on single-leg standing was measured using a lower limb gravimeter (G-620, Anima Corp.). The measurement time and sampling frequency were set at 10 seconds and 20 Hz, respectively. The SLR angle was measured using an image analysis system (Dartfish software 5.5, DARTFISH) (Fig. 1). Measurement was initiated with SLR from standing on both legs with AE, followed by SLR from standing on both legs with AB and then SLR from standing on both legs with AC.

The maximum posterior tilt angle and COP position were measured after maximum SLR on single-leg standing. The trunk was tilted backward from the standing SLR posture while contracting the lower trunk muscles, and the posterior tilt angle of the trunk and COP position were measured during posterior tilting. The knee of the supporting leg was kept extended. The posterior tilt angle was measured regarding a vertical line drawn from the right greater trochanter as a baseline axis and a line connecting the right greater trochanter and right acromion as a moving axis. The measurement devices and order of measurement were the same as described above (Fig. 2).

The position of the left heel grounded after leftward rotation of the body from SLR on single-leg standing was measured using a carpenter's square ruler. The baseline was set to a vertical line drawn from a line drawn along the lateral side of the right foot. The distance between the grounded left heel and baseline was measured as the cross step distance. A distance of the step position on the right side of the baseline was judged as cross step+. The order of measurement was the same as described above (Fig. 3).

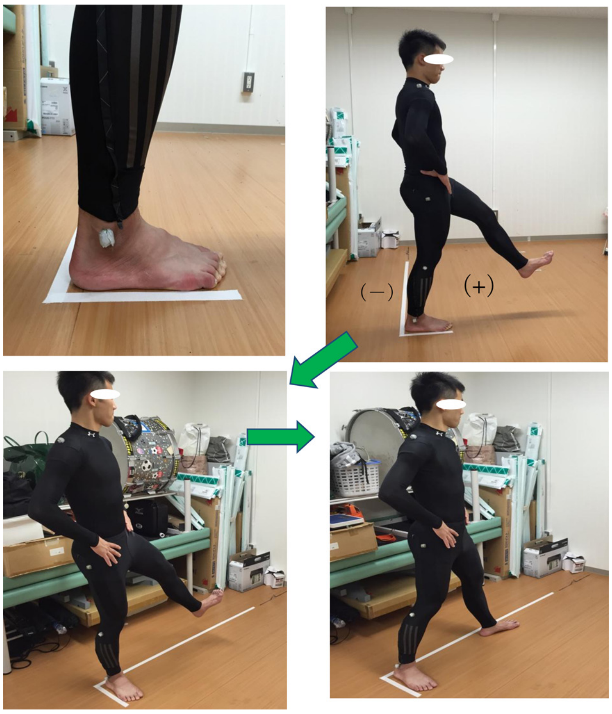

Fig. 3. Step position after rotating the body from SLR on single-leg standing
The step position was measured at the front heel grounded site after forward rotation of the body from SLR on single-leg standing using a carpenter's square ruler. The baseline was set to a vertical line drawn from a line drawn along the lateral side of the rear foot. The distance between the grounded front heel and baseline was measured. The distance of the step position on the right side of the baseline was regarded as cross step+.

Table 1. Body alignment of single leg standing

	AE	AB	AC	AE–AB	AE–AC	AB–AC
Single leg standing SLR						
F-B position of COP (cm)	1.61 ± 1.02	0.69 ± 1.23	−0.41 ± 1.36	*	*	*
Angle of SLR (°)	58.4 ± 9.3	61.6 ± 9.9	69.6 ± 9.5	*	*	*
From single leg stanging SLR						
F-B position of COP (cm)	−0.03 ± 1.25	−0.9 ± 1.51	−2.02 ± 1.33	*	*	*
Angle of trunk posterior tilt (°)	19.4 ± 4.4	17.5 ± 3.4	14.4 ± 3.6	*	*	*
Instep distance	12.5 ± 8.7	7.3 ± 8.7	−8.1 ± 14.5	*	*	*

Values are mean ± standard deviation (SD).
*Significant differences (p<0.05)
F-B position of COP: The forward and backward position shift of the foot presure
The COP (−) means backward position from line of navicular and cuboid.

Normality was confirmed in all measurement data using Shapiro-Wilk (analysis software, IBM SPSS Statistics 19), but homogeneity could not be confirmed. Thus, the significance of differences among groups was confirmed using Friedman's nonparametric test, and between-group comparison was performed using Wilcoxon signed-rank test after confirming the significance of difference ($p<0.05$).

This study was approved by Kansai University of Health Sciences Ethics Committee, and informed consent was obtained from the subjects after explaining risks and safety.

RESULTS

The SLR angle significantly decreased on single-leg standing with AE (58.4 ± 9.3°) compared with those with AB (61.6 ± 9.9°) and AC (69.6 ± 9.5°), and it significantly decreased on single-leg standing with AB compared with that with AC ($p<0.05$) (Table 1).

The COP position significantly shifted forward on single-leg standing with AE (1.61 ± 1.02 cm) compared with those with AB (0.69 ± 1.23 cm) and AC (−0.41 ± 1.36 cm), and it was significantly shifted forward on single-leg standing with AB compared with that with AC ($p<0.05$) (Table 1).

The posterior tilt angle of the trunk significantly increased on single-leg standing with AE (19.4 ± 4.4°) compared with those with AB (17.5 ± 3.4°) and AC (14.4 ± 3.6°), and it significantly increased on single-leg standing with AB compared with that with AC ($p<0.05$) (Table 1).

The COP position in posterior tilt of the trunk with AE (−0.03 ± 1.25 cm) significantly shifted forward compared with those with AB (−0.9 ± 1.51 cm) and AC (−2.02 ± 1.33 cm), and it significantly shifted forward in posterior tilt of the trunk with AB compared with that with AC ($p<0.05$) (Table 1).

The cross step distance significantly increased after rotation with AE (12.5 ± 8.7 cm) compared with those with AB (7.3 ± 8.7 cm) and AC (−8.1 ± 14.5 cm), and it significantly increased after rotation with AB than that with AC ($p<0.05$) (Table 1).

DISCUSSION

When the lower trunk muscles are contracted to perform AE and AB, the abdominal organs are lowered while increasing the abdominal circumference and the external sphincter of the anus is relaxed similarly to that in defecation[14]. In AB and AE not using pelvic floor muscle contraction, stabilization of the lumbosacral region by pelvic floor muscle action may be lacking[15–18]. In AC, since the thoracolumbar fascia is tensed by concentric contraction of the transverse abdominal and pelvic floor muscles, it becomes the lower trunk muscle contraction type stabilizing the lumbosacral region[15–18].

It has been clarified that muscle forces of the four limbs and trunk significantly decrease in AB compared with those in AC[7], suggesting that securing stability of the lumbosacral region was difficult in AB, which may have resulted in the reduction of the SLR angle on single-leg standing with AE and AB compared with that with AC. It was assumed that since the COP position was already shifted forward by AE or AB, the center of gravity of the raised leg could not be shifted forward and increasing the SLR angle was difficult. When AC was performed during SLR on single-leg standing, the COP position shifted backward, and the SLR angle on single-leg standing with AC was larger than those with AE and AB, suggesting that posterior tilting of the trunk and augmentation of lower limb elevation after SLR on single-leg standing were difficult.

It has been clarified that performing AE and AB on single-leg standing shifts COP anteromedially and makes the pelvis face the elevation side[6], trunk tilts backward when loading anteromedially of the foot induced cross step[5]. Also, it was clarified that the posterior tilt angle of the trunk was increased during SLR on single-leg standing with AE and AB compared with that with AC in this study. So that increasing of posterior tilt angle during SLR on single leg standing may have extended the anterior soft tissue of the hip joint and increased the cross step distance. When the pelvis was rotated toward the elevated side from this state, the anterior surface soft tissue of the hip joint may have tensed from the early phase and limited the pelvic rotatory movement, increasing the cross step distance. Accordingly, it is assumed that performing AC in wind-up increases the left leg elevation angle, decreases the posterior tilt angle of the trunk, and decreases the cross step distance. We are planning to clarify the relationship between lower trunk muscle contraction in wind-up and the cross step distance in the late-cocking phase in pitching motion.

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