EFFECTS OF STRETCH-SHORTENING CYCLE DURING TRUNK-TWIST EXERCISE USING DIFFERENT LOADS

Kazutaka Takahashi[1], Takuya Yoshida[1], Yasushi Kariyama[2], Ryohei Hayashi[1], and Koji Zushi[3]

Graduate School of Comprehensive Human Sciences, University of Tsukuba, Tsukuba, Japan[1]
Faculty of Sport Science, Yamanashi Gakuin University, Yamanashi, Japan[2]
Faculty of Health Sciences, University of Tsukuba, Tsukuba, Japan[3]

The purpose of this study was to investigate the effects of stretch-shortening cycle (SSC) movement during trunk-twist and whether the effects change on increasing the loads by using a special trunk-twist machine. Twenty-one male college students performed trunk-twist exercise with 3 loads. Participants performed this exercise for each load by using SSC and not using SSC (CON). Kinematic and kinetic data were recorded using Vicon system (250 Hz) and force platform (1,000 Hz). The following effects of SSC for this exercise were observed: (1) peak bar angular velocity was not potentiated by SSC, but SSC contributed to the acceleration of bar angular velocity and (2) for heavy loads, SSC did not affect mean angular velocity of the bar, upper trunk and pelvic rotation. Moreover, peak joint torque power of trunk-twist significantly decreased with heavy loads.

KEY WORDS: bar rotation, 3-dimentional motion analysis, joint torque power

INTRODUCTION: Improving ball release velocity and racket head velocity are important factors to win a game of baseball and tennis. In these movements, trunk-twist motion accompanying stretch-shortening cycle (SSC) movement contributes to excellent performance (Elliott, Takahashi, & Noffal, 1997). Thus, improving the ability of trunk-twist accompanying SSC movement is likely to assist in achieving excellent athletic performance. In the trunk-twist exercise, which is one of the training methods for improving trunk-twist ability, a trainee supports the barbell shaft on the shoulders in the standing positon and rotates it horizontally (Radcliffe & Farentinos, 1999). Although the effect of SSC on lower- or upper-body movements has been studied (Bosco, Viitasalo, Komi, & Luhtanen, 1982; Newton et al., 1997), to our knowledge, no studies have examined trunk-twist during maximal effort bar rotation. Moreover, no study has considered the load characteristics of trunk-twist exercise. The purpose of this study was to investigate the effects of SSC during trunk-twist and whether the effects change on increasing the loads during maximal effort bar rotation.

METHODS: Twenty-one healthy male college students participated in this study (mean ± S.D. age, 21.91 ± 3.18 years; height, 1.76 ± 0.05 m; weight, 78.67 ± 17.01 kg). This study was approved by the Ethics Committee of the Institute of Health and Sport Sciences, University of Tsukuba, Japan. All participants performed trunk-twist exercise using a special trunk-twist training machine. In this machine, bar rotation was limited on the horizontal plane. To investigate the effect of SSC on trunk-twist, participants performed the exercise by using SSC and not using SSC (CON) (Figure 1). In SSC, participants rotated the bar clockwise; when the right side of the bar passed the mark (located at bar angle −75°), participants immediately rotated the bar counterclockwise. In CON, the participants rotated the bar counterclockwise from the mark (not using SSC movement). Participants were required to rotate the bar with both legs planted, and keep the body steady when they stopped the bar in both SSC and CON. Three loads (0 kg, 10 kg, and 20 kg) were used in SSC and CON.
The three-dimensional coordinates of 49 retro-reflective markers fixed on the body (47 points, Suzuki, Ae, Takenaka & Fujii, 2014) and outer end of bar (2 points) were recorded by the Vicon system (Vicon Motion System, Ltd.), using twelve cameras operating at 250 Hz. The ground reaction force was measured with two force platforms at 1,000 Hz. The horizontal rotation angular velocity of the bar, upper trunk, pelvic, and trunk-twist were calculated (Figure 2). The time to peak bar angular velocity was defined from the moment in the

counterclockwise rotation during which the bar angular velocity exceeded 10°/s till the moment at which the peak angular velocity was achieved. Smoothing of the coordinates was achieved by using a Butterworth digital filter with optimal cut-off frequencies of 2.5–15 Hz, which were determined using the residual method. The global coordinate system was defined as follows: The X-axis represented the mediolateral direction, Y-axis represented the anterior-posterior direction, and Z-axis represented the vertical direction (Figure 1). The location of the center of mass and inertia of each segment was estimated based on the body segment parameters for Japanese athletes, as described by Ae (1996). Joint torque of the trunk joint that modeled the middle point of the lower end of the right and left ribs was calculated using the bottom-up approach of inverse dynamics. Joint torque power was determined as a dot product of joint torque and the angular velocity of the trunk joint.
A two-way analysis of variance with Bonferroni post hoc contrasts was used to detect differences in the means. P value < 0.05 was considered statistically significant.

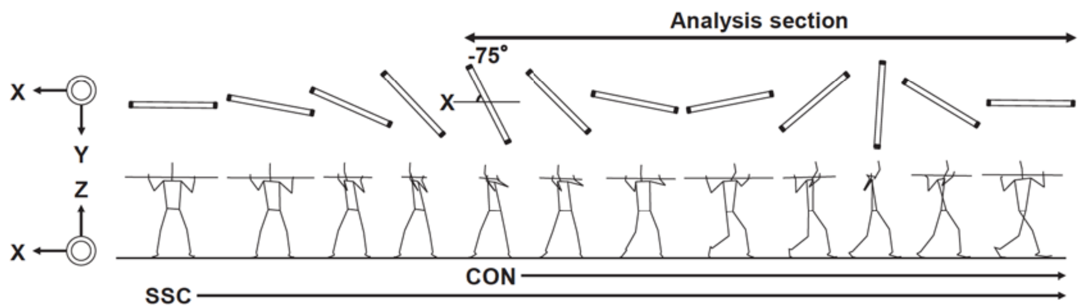
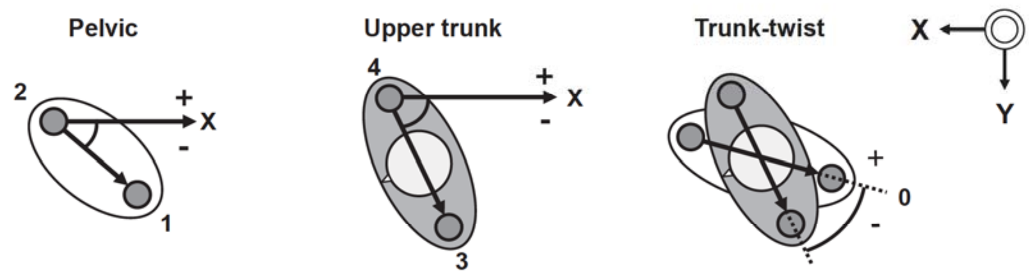


Figure 1: Method of trunk-twist exercise.



1: Left ilium-anterior superior iliac spine (2: right) 3: Left scapula-acromion (4: right)

Figure 2: Angle definition of pelvic rotation, upper trunk rotation, and trunk-twist.

RESULTS: Table 1 shows the kinematics parameters of trunk-twist exercise for each load. There were significant main effects of peak angular velocity of the bar, upper trunk, pelvic, and trunk-twist among the loads. However, there were no main effects between SSC and CON, and interaction effects between the tasks (SSC-CON and loads). For the mean angular velocity of the bar, upper trunk, and pelvic, significant main effects were observed between SSC and CON, and among the loads, as well as for the interaction effect between the task. Peak and mean bar angular velocity in SSC and CON decreased significantly with increasing loads. In terms of the the peak angular velocity, there were no significant differences between SSC and CON for each load. However, mean angular velocity with 0 kg load was higher for SSC than for CON. Similar results were obtained for peak and mean angular velocity of the upper trunk and pelvic. The time to peak bar angular velocity in SSC was significantly earlier than in CON for each load. Furthermore, the time was delayed with increasing load in both SSC and CON. Figure 3 shows peak and mean joint torque and joint torque power of trunk-twist for each load. In terms of joint torque, there were neither main effect between SSC and CON nor interaction effects between the tasks. In terms of joint torque power, there were significant main effects among the loads, but no significant main effects between SSC and CON, nor interaction effects between the tasks. Peak joint torque showed no significant differences between SSC and CON and among the loads. Similar results were obtained for the mean peak joint torque. Peak joint torque power was also not significantly different between SSC and CON. Peak joint torque power for 20 kg load was significantly lower than that for 0 kg. Mean joint torque power for CON with 20 kg load was also significantly lower than that for CON with 0 kg.

Table 1 Kinematic parameters of trunk-twist exercise (Mean ± S.D.)

	0 kg	10 kg	20 kg	Difference between SSC and CON	Difference among loads
Peak angular velocity ($deg \cdot s^{-1}$)					
Bar - SSC	403.23 ± 42.92	316.42 ± 39.47	270.38 ± 34.96	n.s.	0 kg > 10 kg > 20 kg
Bar - CON	390.60 ± 48.36	306.51 ± 38.29	255.44 ± 28.96		0 kg > 10 kg > 20 kg
Upper trunk - SSC	355.42 ± 44.12	285.44 ± 37.11	248.63 ± 35.69	n.s.	0 kg > 10 kg > 20 kg
Upper trunk - CON	349.76 ± 50.00	276.39 ± 46.31	233.81 ± 28.81		0 kg > 10 kg > 20 kg
Pelvic - SSC	245.51 ± 40.52	194.03 ± 34.75	166.44 ± 34.41	n.s.	0 kg > 10 kg > 20 kg
Pelvic - CON	230.75 ± 37.11	178.92 ± 38.95	151.03 ± 31.17		0 kg > 10 kg > 20 kg
Trunk-twist - SSC	280.83 ± 56.13	224.52 ± 47.89	191.26 ± 44.94	n.s.	0 kg > 10 kg, 20 kg
Trunk-twist - CON	270.60 ± 66.42	203.22 ± 42.00	177.39 ± 25.78		0 kg > 10 kg, 20 kg
Time to peak bar angular velocity (s)					
SSC	0.71 ± 0.07	0.90 ± 0.08	1.09 ± 0.12	All loads; SSC < CON	0 kg < 10 kg < 20 kg
CON	0.80 ± 0.09	1.02 ± 0.11	1.20 ± 0.12		0 kg < 10 kg < 20 kg
Mean angular velocity ($deg \cdot s^{-1}$)					
Bar - SSC	278.18 ± 34.47	216.06 ± 32.22	184.54 ± 26.57	0 kg; SSC > CON	0 kg > 10 kg > 20 kg
Bar - CON	252.39 ± 38.50	198.83 ± 26.33	166.37 ± 20.93		0 kg > 10 kg > 20 kg
Upper trunk - SSC	264.10 ± 32.94	203.66 ± 29.11	174.83 ± 24.08	0 kg; SSC > CON	0 kg > 10 kg > 20 kg
Upper trunk - CON	241.99 ± 37.38	189.28 ± 24.84	159.16 ± 19.05		0 kg > 10 kg > 20 kg
Pelvic - SSC	171.54 ± 25.38	127.93 ± 25.01	110.22 ± 21.29	0 kg; SSC > CON	0 kg > 10 kg > 20 kg
Pelvic - CON	158.57 ± 21.16	121.93 ± 20.33	99.70 ± 18.43		0 kg > 10 kg > 20 kg
Trunk-twist - SSC	101.64 ± 21.15	81.94 ± 20.09	70.18 ± 17.29	n.s.	0 kg > 10 kg, 20 kg
Trunk-twist - CON	91.65 ± 23.85	73.94 ± 15.44	64.97 ± 12.83		0 kg > 10 kg, 20 kg

<, >; $P < 0.05$
n.s.; No Significance

DISCUSSION: Although the peak angular velocity of bar rotation was not significantly different between SSC and CON, the time to peak angular velocity in SSC was significantly earlier than that in CON. Newton et al. (1997) investigated the effect of SSC on the upper body during maximal effort bench throws. The peak throwing velocity was not potentiated by performing the pre-stretch, but mean velocity was higher for the SSC throw than for the concentric only throw. The effect of SSC in drop jump has been shown that both elastic energy and reflex potentiation may operate effectively during SSC (Bosco, Viitasalo, Komi, & Luhtanen, 1982). According to those studies, the effect of SSC on the trunk-twist performance is similar to that on the upper and lower extremity. In trunk-twist, SSC movements in the rotational muscles, such as the external oblique and internal oblique, contribute toward inducing the acceleration of the rotating bar (Radcliffe & Farentinos, 1999). In contrast, peak joint torque of trunk-twist was not significantly different between SSC and CON (Figure 3). In addition, similar results were observed for peak joint torque power. Thus, SSC movements did not result in changes of force and power output of trunk-twist.
Considering the difference among the loads, mean angular velocity of bar rotation in SSC was significantly larger than that in CON for only 0 kg load (Table1). Moreover, peak joint torque power for 20 kg load was sigificantly lower than that for 0 kg load (Figure 3). Cronin et al. (2001) investigated the difference in SSC according to the load intensity during bench press. Heavier loads during a bench press resulted in lower peak concentric power than that resulting with light loads, because the contraction velocity of the muscles slows down. According to the current study,a 20 kg load in bar rotation might be too heavy for participants to rotate the bar. It was therefore suggested that the decreasing contraction velocity of trunk-

twist muscles affected joint torque power, acceleration of bar angular velocity, and did not potentiate mean bar angular velocity in heavy loads. Thus, SSC did not affect bar rotation with heavy loads.

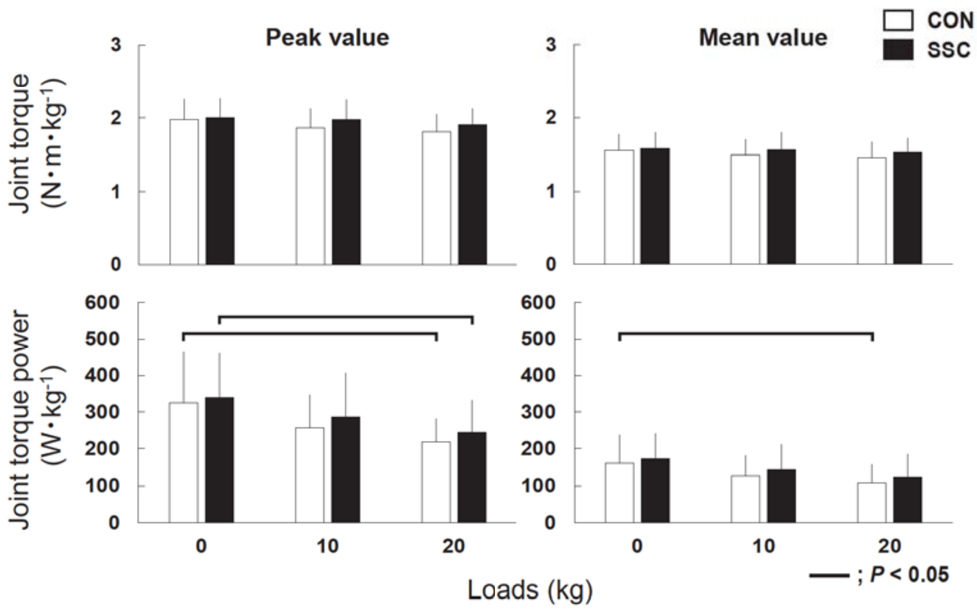


Figure 3: Peak and mean joint torque and joint torque power of trunk-twist.

CONCLUSION: The purpose of this study was to investigate the effects of SSC during trunk-twist and whether the effects change with increasing loads during maximal effort bar rotation. The results revealed the following effects of SSC during trunk-twist exercises: (1) SSC did not potentiate the peak bar angular velocity, but contributed to the acceleration of bar rotation with each load. (2) For heavy loads, SSC did not affect mean angular velocity of the bar, upper trunk and pelvic rotation, but decreased power output of the trunk muscles. Therefore, when athletes perform trunk-twist training, using SSC with light loads may be effective to improve trunk-twist ability.

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