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Original Article

Effects of core strength training on core stability

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Abstract. [Purpose] To investigate the effects of core strength training on core stability with and without the Valsalva maneuver. [Participants and Methods] Twenty-four students were randomly assigned to the training and control groups. Students in the training group undertook a 4-week training program that included exercises for the transverse abdominis, multifidus, diaphragm, and pelvic floor muscles, whereas students in the control group performed their usual activities. Participants were required to perform four types of task with and without the Valsalva maneuver. Seated stabilometry was assessed according to the center of pressure (COP). [Results] In the training group, the rectus area in the quiet sitting position with the Valsalva maneuver was enlarged and the length of trajectory during a sudden perturbation task was decreased. No significant changes to the COP were seen in the control group. [Conclusion] Some parameters of core stability improved after participants completed a 4-week core strength training program.

Key words: Core strength training, Core stability, Effect

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INTRODUCTION

Stability of the trunk play roles in the elderly and individuals with disabilities, not only in maintaining an upright body posture, but also in helping to change positions when sitting, standing, and walking. In sports performances, core strength is also very important to improve body balance and postural control in movements such as landing and contact.

Core muscles including the transverse abdominis, multifidus, diaphragm, and pelvic floor muscles are thought to contribute stability of the spine[1)]. Reports have shown that transverse abdominis contracts first to contribute to stiffness as a feedforward function during upper limb activities[2)] and standing tasks involving sudden perturbation[3)]. The other core muscles (i.e., multifidus, diaphragm, and pelvic floor muscles) are supposed to perform the similar functions to transverse abdominis. These four core muscles contract first to increase stability of the trunk during extremity exercises and have been considered to help prevent injuries from sports[4)].

Strength exercises for the abdominal muscles among student participants in experiments have been reported to increase stability of the lumbar spine[5)]. Core training excluding the diaphragm for elderly individuals can also improve balance ability[6)]. Strength exercises for these four muscles are therefore hypothesized to help improve balance ability during sitting without support.

Contraction of trunk core muscles increases intra-abdominal pressure, providing stability and stiffness of the body[1, 4, 7)]. Reports have also shown higher, stable intra-abdominal pressure is related to both postural reaction and stability of the spine in a situation when the base of support of a stance changed due to external forces[8)]. In addition, co-contraction of the trunk core muscles while performing the Valsalva maneuver increases stability of the body more than that without the Valsalva maneuver. The Valsalva maneuver might thus also influence posture control.

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This study aimed to investigate the effects of core strength training on core stability with and without performance of the Valsalva maneuver.

PARTICIPANTS AND METHODS

Twenty-four normal students were randomly assigned to either a training group (8 men, 4 women) undertaking a 4-week training program or a control group (7 men, 5 women) without any training program. All participants received explanations of the purpose and methods of this study, and provided signed consent to participate. This study was reviewed and approved by the Ethics Committee of the Akita University Graduate School of Health Sciences (approval no: 1930).

For all participants, stabilometry before and after the training program were assessed by sitting on a force plate (GS-3000; Anima Corp, Tokyo, Japan) without foot support. To assess stabilometry, total length (LNG) of the center of pressure (COP), rectus area (REC AREA), and root mean square area (RMS AREA) were used as parameters. During assessments, 4 types of task were performed. Tasks were as follows: 1) quiet sitting; 2) dumbbell lifting; 3) functional reach; and 4) sudden perturbation. Quiet sitting was a task involving crossing the arms on the chest and moving as little as possible. Dumbbell lifting was a task involving lifting a 5-kg dumbbell overhead with elbow extension and holding during the sampling time. Functional reach was a task achieving maximal forward reach and holding. Sudden perturbation was a task crossing the arms on the chest and trying to move as little as possible. A 3-kg bag was suspended by a rope from a pivot on an overhead frame right behind the participant's back. The bag was also set up at the height of the participant's scapula. During the task, the bag was used as an external force and was released as a pendulum from an angle of 45° to hit between the participant's scapulae (Fig. 1). Each task was performed with and without Valsalva maneuver for 10 s.

The training group performed a 4-week training program that included exercises for the transverse abdominis, multifidus, diaphragm, and pelvic floor muscles. For training the transverse abdominis and multifidus, a hand-knee bird dog exercise with draw-in[9] was performed for 30 s ×10 sets. For the diaphragm, abdominal inspiratory exercises with a 3-kg weight resting on the abdomen was performed for 10 min. For pelvic floor muscles, an exercise requiring maximal contraction of the perineal muscles in a sitting position against a towel between the thighs[10] was performed 15 times × 2 sets. These three kinds of training were performed 5 days a week (Fig. 2). The training program was fully explained to participants before the first assessment. Participants in the training group were required to report the training process everyday through a social

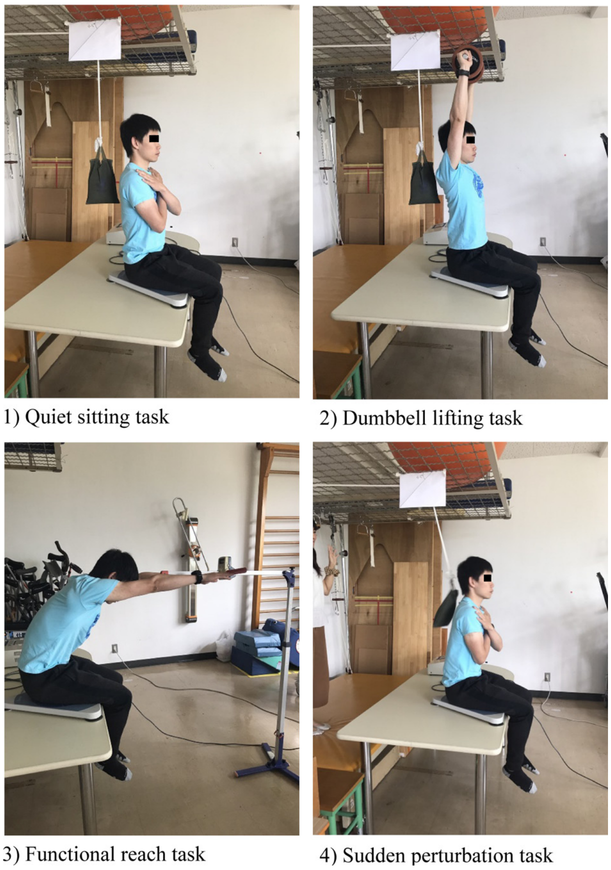

Fig. 1. Assessments in sitting stabilometry.

Fig. 2. Training method.

networking service. Participants in the control group were asked to live a usual life.

SPSS for Windows version 22 software (IBM Japan, Tokyo, Japan) was used for data analysis. The independent samples t-test was used for intergroup statistical analyses, while the paired samples t-test was used for intragroup and pre- and post-training program analyses. Values of $p<0.05$ were considered significant.

RESULTS

Mean (± standard deviation) ages were 19.4 ± 0.7 years and 18.6 ± 0.7 years, mean heights were 169.0 ± 9.7 cm and 164.4 ± 7.1 cm, mean weights were 61.4 ± 12.0 kg and 56.0 ± 6.1 kg, and mean BMIs were 21.4 ± 2.6 kg/m^2 and 20.7 ± 2.3 kg/m^2 in the training and control groups. No significant difference in background characteristics was seen between groups.

Results of the four tasks with or without Valsalva maneuver condition and inter- or intra-group data are shown in Tables 1–4.

Under the Valsalva maneuver condition, the REC AREA of quiet sitting from pre- and post-training increased significantly. Parameters of dumbbell lifting and functional reach showed no significant differences between with Valsalva and without Valsalva maneuver. The LNG of sudden perturbation after training showed significant intergroup differences both with and without Valsalva maneuver. LNG decreased in the training group compared to the control group.

DISCUSSION

Because core strength training is supposed to improve stability of the trunk, stabilometry was hypothesized to be decreased under all kinds of task and condition.

During the quiet sitting task in the training group, REC AREA under Valsalva maneuver condition increased and differed significantly between pre- and post-training. REC AREA was calculated by the maximum anterior-posterior COP variation multiplied by the maximum lateral COP variation, which might be reflected by instantaneous and occasional stabilometry, since stabilometry showed no significant difference between pre- and post-training RMS AREA. However, the possibility of type II statistical error cannot be excluded, given the small sample size.

Similarly, the possibility of type II error contributing to the lower LNG in the training group than in the non-training group with the sudden perturbation task after 4 weeks cannot be ruled out. However, the statistical results seemed quite definitive,

Table 1. Comparison of quiet sitting task with or without Valsalva maneuver

	Training group	Control group
Without Valsalva		
LNG (cm)		
Pre	5.19 ± 1.51	4.48 ± 0.83
Post	5.46 ± 1.77	4.94 ± 1.12
REC AREA (cm^2)		
Pre	0.07 ± 0.05	0.06 ± 0.03
Post	0.14 ± 0.15	0.10 ± 0.07
RMS AREA (cm^2)		
Pre	0.02 ± 0.01	0.02 ± 0.01
Post	0.04 ± 0.03	0.03 ± 0.02
With Valsalva		
LNG (cm)		
Pre	6.03 ± 1.77	5.86 ± 0.98
Post	6.40 ± 2.05	6.18 ± 1.57
REC AREA (cm^2)		
Pre	0.10 ± 0.05	0.12 ± 0.07
Post	0.18 ± 0.11*	0.13 ± 0.05
RMS AREA (cm^2)		
Pre	0.03 ± 0.02	0.04 ± 0.02
Post	0.05 ± 0.03	0.04 ± 0.03

Values are presented as mean ± SD.
LNG: length; REC AREA: rectus area; RMS AREA: root mean square area.
*$p<0.05$, difference compared to pre-training value.

Table 2. Comparison of dumbbell lifting task with or without Valsalva maneuver

	Training group	Control group
Without Valsalva		
LNG (cm)		
Pre	12.35 ± 3.76	12.18 ± 3.11
Post	13.39 ± 4.23	14.18 ± 3.43
REC AREA (cm^2)		
Pre	0.84 ± 0.53	1.01 ± 0.60
Post	1.50 ± 1.58	1.22 ± 0.58
RMS AREA (cm^2)		
Pre	0.27 ± 0.20	0.36 ± 0.21
Post	0.61 ± 0.87	0.38 ± 0.21
With Valsalva		
LNG (cm)		
Pre	13.04 ± 3.76	14.00 ± 3.76
Post	12.90 ± 2.92	13.76 ± 3.22
REC AREA (cm^2)		
Pre	0.92 ± 0.68	1.35 ± 0.68
Post	0.91 ± 0.36	1.29 ± 0.81
RMS AREA (cm^2)		
Pre	0.26 ± 0.14	0.51 ± 0.40
Post	0.33 ± 0.13	0.41 ± 0.26

Values are presented as mean ± SD.
LNG: length; REC AREA: rectus area; RMS AREA: root mean square area.

because the training effect indicated under the condition without Valsalva maneuver was identical to that in the condition with Valsalva maneuver, which was assumed to greatly improve stability of posture. No significant inter- or intragroup differences were identified in REC AREA or RMS AREA during the sudden perturbation task. A significant difference between groups was only seen for LNG, both with and without Valsalva maneuver after 4 weeks. This result may be explained by the peculiarity of the task. The quiet sitting task is a postural control task which keeps the COP at the center of the base of support in a stationary state. The dumbbell lift while sitting is a task that adds heavy lifting to this task. The functional reach task requires maintenance of a posture in forward of the base of support. While all these tasks involve stillness in a sitting position, the sudden perturbation task requires holding forward displacement of the COP to a minimum in opposition to a heavy load striking against the back. We initially thought COP movement to the front would be restrained by core stability and would improve with training. However, the difference between groups was not in REC AREA after training, and LNG was low in the training group. We inferred that COP movement to the front was not influenced by impact to the back, but the training group could return to the original state more rapidly after COP movement to the front, and LNG was thus low. In terms of the effect of the Valsalva maneuver, a desirable effect on the sudden perturbation task under the condition with Valsalva maneuver was also confirmed under the condition without Valsalva maneuver in the training group. The Valsalva maneuver does not bring about any change in the function maintaining core stability in opposition to sudden perturbation. Only improvement of the function of quickly returning the displaced COP irrespective of the Valsalva effect was identified with training.

No significant differences were apparent from measurement parameters other than those mentioned above in intergroup (training vs. control group) and intragroup (pre- vs. post-training) comparisons. In a clinical trial by Kang[6)], elderly individuals performed co-contractions of the transverse abdominis, multifidus, and pelvic floor muscles, with training for 30 min/day, 5 times/week for 8 weeks. Weight distribution index and stability index were employed as outcome measures, and training was reportedly effective. In our trial, participants were relatively active students compared to elderly and disabled persons, and training effects could not be indicated by REC AREA and RMS AREA, or LNG of a task besides sudden perturbation. Training for a little less than 30 min/day was performed 5 days/week for 4 weeks to strengthen 4 core muscles. This regimen may not have been sufficiently intense, frequent, or long to achieve improvements in static balance function.

The key limitations of this study were the small sample size, the unclear adequacy of the intensity, frequency and period of training, the fact that participants were relatively active students and training effects may not have been achieved, and the use of an outcome measurement that was a parameter of static balance relatively with little examination of dynamic balance.

Table 3. Comparison of functional reach task with or without Valsalva maneuver

	Training group	Control group
Without Valsalva		
LNG (cm)		
Pre	9.12 ± 2.44	7.10 ± 2.08
Post	8.96 ± 2.89	7.44 ± 1.66
REC AREA (cm^2)		
Pre	0.31 ± 0.39	0.25 ± 0.17
Post	0.30 ± 0.18	0.25 ± 0.11
RMS AREA (cm^2)		
Pre	0.11 ± 0.15	0.08 ± 0.07
Post	0.11 ± 0.08	0.08 ± 0.05
With Valsalva		
LNG (cm)		
Pre	8.93 ± 2.60	7.35 ± 2.57
Post	8.85 ± 2.89	7.29 ± 1.76
REC AREA (cm^2)		
Pre	0.32 ± 0.49	0.21 ± 0.16
Post	0.27 ± 0.32	0.25 ± 0.11
RMS AREA (cm^2)		
Pre	0.09 ± 0.13	0.07 ± 0.07
Post	0.11 ± 0.21	0.09 ± 0.05

Values are presented as mean ± SD.
LNG: length; REC AREA: rectus area; RMS AREA: root mean square area.

Table 4. Comparison of sudden perturbation task with or without Valsalva maneuver

	Training group	Control group
Without Valsalva		
LNG (cm)		
Pre	18.78 ± 11.10	18.94 ± 4.35
Post	16.07 ± 2.89[#]	19.58 ± 4.69
REC AREA (cm^2)		
Pre	16.55 ± 40.63	8.08 ± 4.56
Post	5.68 ± 3.10	6.85 ± 2.70
RMS AREA (cm^2)		
Pre	3.59 ± 5.55	3.50 ± 2.74
Post	3.39 ± 2.22	3.81 ± 2.24
With Valsalva		
LNG (cm)		
Pre	17.52 ± 5.08	17.24 ± 3.35
Post	16.09 ± 3.16[#]	18.04 ± 3.05
REC AREA (cm^2)		
Pre	5.23 ± 3.44	5.94 ± 3.49
Post	4.59 ± 2.08	6.36 ± 3.67
RMS AREA (cm^2)		
Pre	1.61 ± 0.76	2.36 ± 1.04
Post	1.83 ± 0.66	2.51 ± 0.95

Values are presented as mean ± SD.
LNG: length; REC AREA: rectus area; RMS AREA: root mean square area.
[#]$p<0.05$, difference compared to control group.

Nevertheless, core strength training influenced core stability, and had a desirable effect in the sudden perturbation task. When a person with disabilities or a senior citizen loses balance in an upright position, or before and after landing or post-contact during a sporting activity, the ability to more rapidly reaction with posture control is important. Partial improvement of core stability was suggested after implementing core muscle training for 4 weeks in this study. Further research with a larger number of participants, trials in elderly or disabled individuals, use of training with sufficient stimulation of body function, and investigation of more outcome measures is required in the future.

Conflict of interest

None.

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