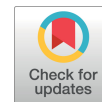


The immediate effect of incorporating short-term slow abdominal respiration into an exercise program on balance and the autonomic nervous system



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Objective: The purpose of this study was to examine the possible effects of incorporating short-term slow-abdominal respiration (SAR) into an exercise program, on balance and the cardiac-related autonomic nervous system (ANS).

Design: Cross-over repeated measures design.

Methods: Fifteen young and healthy adults were randomly assigned into two groups (7 in the C-R group, 8 in the R-C group), each of which carried out both control sequence (C) and respiration-experiment sequence (R) in the inverse order. In the C sequence, the subjects performed passive exercises and a general exercise program (P-GEP). In the R sequence, the subjects received a short-term SAR training session and then performed the respiration incorporated general exercises program (R-RGEP). Before and after both C and R sequences, the length and the area of the displacement of the center of pressure (COP) and heart rate variability parameters were measured.

Results: The total length of the COP displacement in the left single-leg-standing condition showed a significantly greater reduction after R-RGEP in the respiration-experiment sequence than after the P-GEP in the control sequence ($p < 0.05$). The mean heart rate was significantly reduced only after R-RGEP in the respiration-experiment sequence ($p < 0.05$).

Conclusions: The slow-abdominal-respiration, trained in a simple manner and integrated into the exercise program in a single session, showed partially positive immediate effects on balance stabilization. The decrease in heart rate indicated possible involvement of the parasympathetic ANS activation in the stability, although it is not enough to decide whether it is purely due to the controlled respiration.

Key Words: Autonomic nervous system, Postural balance, Respiration

Introduction

The effects of respiration exercise have been continuously studied, and the researchers have found various therapeutic benefits it can produce. Breathing exercises can induce many bio-psychological effects such as improvement of attention, and reduction of stress, depression, and anxiety [1-4]. It also brings a range of positive effects on the physical aspects of healing in various areas, including car-

diopulmonary, musculoskeletal, and pain management [5-8].

From the ancient times to the current history, many types of respiratory techniques have been practiced, and various methods of breathing have been presented in the previous studies. Slow breathing consists of longer inspiration and expiration, for example, 4 seconds of inspiration and 6 seconds of expiration [5]. In diaphragmatic breathing, a person puts the hands on the abdomen and inhales through the nose by expanding the abdomen, suspends the breath at the end of

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inhalation, and then exhales through the mouth as the abdomen expands [9]. Abdominal breathing had been commonly referred to be the same or a similar respiratory technique used as diaphragmatic breathing, but sometimes it had covered a more general or less specific type of breathing and did not necessarily include mouth-exhalation, breath-suspension, or hand- placement on the abdomen [10]. Mindful breathing focuses on gentle awareness of natural respiration [11]. The concepts and terminologies about these breathing methods were, however, often overlapped or mixed.

One of the widely accepted and used applications of respiratory exercises used in pulmonary rehabilitation is diaphragmatic breathing. Diaphragmatic breathing increases pulmonary functions such as forced vital capacity [12] and forced expiratory volume [13], activated respiratory muscles, and improved dyspnea [1,13]. In healthy subjects, ventilatory efficiency has improved through diaphragmatic breathing [14]. Another area where breathing exercise is actively applied is lumbar stabilization. Diaphragmatic breathing exercises have been known to facilitate activation of the core muscles including the transversus abdominis and pelvic floor muscles, which are key contributors to the stabilization of lumbar posture [15]. Abdominal-bracing, that is, co-activation of abdominal muscles and the diaphragm, increases intra-abdominal pressure, and this supports proper lumbar alignment [16].

Although breathing exercises have been proved to increase lumbar stability and contribute to posture by promoting alignment as described above, its effect on balance or postural stability has not been much investigated so far. Maintaining balance during normal or therapeutic activities is essential for a person to perform the movements effectively [17-19]. It is also critical to prevent falls and possible injuries from the fall [20], especially under clinical settings where patients are more vulnerable to falls. A modality that could improve balance instantly when incorporated into the activities, without additionally exerting much time or endeavor over the originally intended program, would provide more stability and safety to perform the activities. The purpose of this study was to preliminarily examine if breathing exercises can bring such an immediate effect on balance when incorporated into a general exercise program (GEP).

In addition, breathing exercises have found to influence the autonomic nervous system (ANS) reaction by increasing parasympathetic or sympathetic modulation [21]. In turn, the ANS modulation was indicated to be possibly involved in postural stability from a recent study where the different

levels of a certain hormone-marker of the sympathetic nervous system were shown to accompany with different types of exercise performance and different levels of balance [22]. We postulated that the effect of respiration exercise on the ANS could possibly play a role in balance, and investigated a possible change in the ANS reaction as well.

As a breathing method to be used in this study, rather than taking a single specific method among the previously known ones, we tailored some of them into an adapted method reflecting the key features (slow, using abdomen, cognitive or mindful) and called it ‘slow abdominal respiration (SAR)’.

Methods

Subject

The subjects were recruited among healthy young adults. A total of 15 subjects (2 man, 13 woman) voluntarily participated in the study after informed consent was obtained (Table 1). Anyone who had cardiac diseases or musculoskeletal disorders in their ankles or feet were excluded. This study followed the ethical standards of the Declaration of Helsinki (1975. Revised 1983) and was performed under approval by the Institutional Review Board of Konyang University (IRB No. 2017-078).

Exercise sessions

The slow-abdominal respiration

The key features of multiple breathing methods, such as slow breathing, diaphragmatic breathing, abdominal breathing, and mindful breathing [5,9-11] were selected to compose the SAR and were modified in order to fit for the subjects and the environment in this study so that the subjects could learn and apply the respiration techniques easily in a short period of time.

The instructions given to a subject in the procedures of the SAR training were as below.

1. “Sit up straight in a comfort posture.” (or “Lie down on

Table 1. General characteristics of the subjects (N=15)

Item	Subject
Age (y)	19.73 (0.92)
Gender (man/woman)	2/13
Height (cm)	163.00 (7.56)
Weight (kg)	55.28 (7.23)
Body mass index (kg/m ²)	20.76 (2.17)

Values are presented as mean (SD) or number only.

- your back in a comfort posture.”)
2. “Put your hands on the abdomen.”
 3. “Breathe in with your nose, slowly pushing the abdomen forward, and breathe out with the nose, pushing the abdomen inward.”
 4. “Breathe in for 3 seconds, and breathe out for 4 seconds.” (approximately 8-9 breaths for 1 minutes)
 5. “While breathing, gently put your attention on the abdomen under the hands, and then feel the movements of the abdomen.”
 6. “One, two, three” (while breathing in), “One, two, three, four” (while breathing out) (The instructor counts one, two, three, ..., verbally with sound to pace the subject’s respiration to be slow.)

Passive exercises and a series of general exercises

The control sequence (C) was composed of passive exercises and a series of general exercises (P-GEP). That is, the subject performed passive exercises first for 6 minutes (3 minutes in sitting and 3 minutes at supine) moved by a researcher, in order to set the length of a session as same as The SAR-incorporated general exercises (R-RGEP). Then, the subject performed the GEP.

The GEP was composed of generally and frequently utilized exercise movements in many rehabilitative clinical settings. The exercises started with bridging exercises in supine for 2 sets of 10 times and hip flexion with resistive band performed in supine with each leg 10 times. In sitting, knee extension with a weight on the ankle was performed for each leg for 2 sets of 10 times. In standing, shoulder abduction with resistive band as well as shoulder internal/external rotation with resistive band was performed for 2 sets of 10 times, right/left single-leg standing for 30 seconds, and 3 minutes of walking in place were performed in order. During the GEP, the subjects were instructed to breathe naturally.

The SAR-incorporated general exercises

In the experiment sequence (R), R-RGEP was carried out. First, respiration training with the SAR method was carried out for 6 minutes (3 minutes in sitting and 3 minutes in supine). As the respiration training session ended, the subject executed RGEP (the respiration [SAR]-incorporated GEP), which consisted of the same exercise components as GEP but it was performed together with the SAR without hand placement on the abdomen. Before the RGEP began, subjects were instructed to breathe with the just trained SAR method while they perform the exercises until the end of the

session.

Procedure

The study adopted a cross-over design. The 15 subjects were divided into two groups of 7 and 8 people and were randomly assigned to either the C-R or R-C groups using computer-generated numbers. The two groups went through both control sequence (C) and respiration-experiment sequence (R), but the order of performing the sequences was opposite. As described above, the C sequence was made of P-GEP in which a subject performed the passive exercises, making a session length as same as in the R sequence, and the GEP and the R sequence was composed of R-RGEP in which the SAR training was performed first and then was incorporated into the GEP to perform the RGEP.

The subjects in the C-R group executed the C sequence first, then after 10-11 days of the wash-out period has passed to remove the transfer effect, they executed the R sequence. The R-C group performed the R sequence first, then had 10-11 days of the wash-out period [23,24], and went through the C sequence (Figure 1).

Before and immediately after C or R sequence, the degree of balance was measured by the Pedoscan, and the heart rate variability (HRV) as an indicator of the ANS’s reaction was

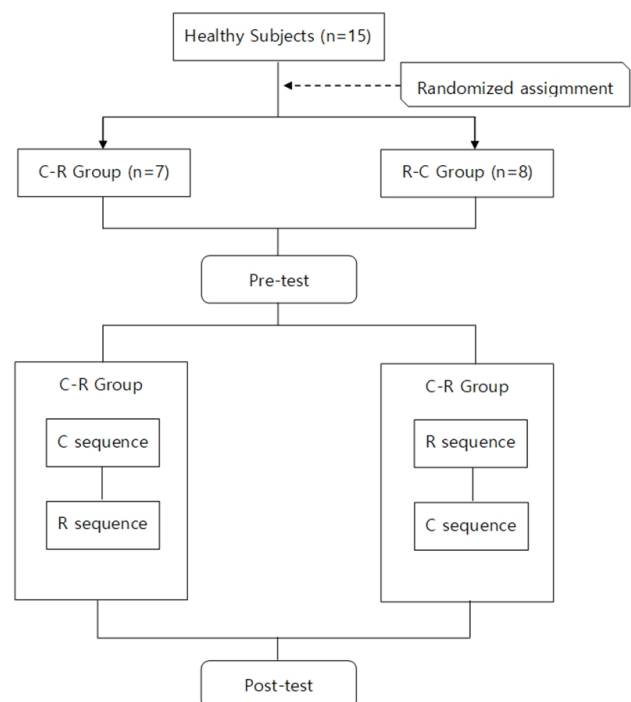


Figure 1. Flowchart of the study design and procedure. C: control, R: respiration.



Figure 2. Measurement of the center of pressure displacement using Pedoscan.



Figure 3. Measurement of heart rate variability.

measured by QECG-3 (LXC3203, LAXTHA Inc., Daejeon, Korea).

Instruments and measurements

Center of pressure displacement

The Pedoscan (RSscan, Diers, Germany) can locate the center of pressure (COP) of the foot while standing and records the trace or displacement of the COP as the COP moves with the sway of the foot. The Pedoscan then calculates the length of the trace of the COP and the area of the ellipse that the shape of the whole COP trace makes with its short and long axes. The sampling rate was set as 100 Hz.

The force plate (1.0 m×4.0 m) measuring the COP was placed on a level surface. The subject stood in a natural standing posture with feet at shoulder-width apart (Figure 2). The subjects were instructed to look at the wall with their eyes horizontally forward.

The parameters were measured in two modes: bilateral stance and unilateral stance. First, the subject remained in standing position for 1 minute on both feet. The measurements were performed three times with a one minute-rest period in between. Next, the subject remained in single-leg standing for 10 seconds. Three measurements were made for each foot with a thirty-second rest period in between.

Heart rate variability

To record changes in the ANS, HRV was measured by analyzing the electrocardiogram with the QECG-3. The four electrodes were attached on both wrists and ankles. Activities such as eating, drinking, and smoking that could affect the heart rate (HR) were prohibited 2 hours before the measurement. The subject was in a comfortable supine position on the table during the measurement, which was 5 minutes in duration (Figure 3).

The TeleScan software (LAXTHA Inc.) analyzed the electrocardiogram data into mean HR, standard deviation of normal-beat to normal-beat interval (SDNN), low frequency (LF: 0.04-0.15 Hz), high frequency (HF: 0.15-0.4 Hz), and the LF/HF ratio.

Statistical analysis

The data was statistically analyzed using PASW Statistics for Windows, Version 18.0 (SPSS Inc., Chicago, IL, USA). The paired-t test was used to compare the pre-post effects, and to compare between the control and the experiment sequences (to compare the pre-measurements with the post-measurements of each C or R sequences, and to compare the differences between the pre- and the post-measurements of C sequence with those of R sequence) [23]. Statistical significance was set as 0.05.

Results

The post-measurement of the COP trace length during left single-leg-standing was significantly decreased than the pre-measurement (Table 2, $p < 0.05$). There was significant difference between the C and the R sequences in the length of the COP displacement during left single-leg-standing; It

Table 2. Comparison between pre- and post- measurements for COP change during static standing (N=15)

Standing leg(s)	COP variable	Pre	Post	t(p)
Bilateral	Area (mm ²) ^a			
	Control	189.98 (138.04)	190.65 (125.25)	-0.047 (0.963)
	Respiration	150.20 (49.82)	188.03 (115.64)	-1.600 (0.132)
	Length (mm) ^b			
Right	Control	1619.66 (180.84)	1576.62 (139.11)	1.414 (0.179)
	Respiration	1563.87 (206.32)	1553.68 (219.38)	0.617 (0.547)
	Area (mm ²)			
	Control	341.74 (141.90)	372.37 (105.82)	-0.857 (0.406)
Left	Respiration	328.39 (84.03)	354.18 (112.79)	-0.914 (0.376)
	Length (mm)			
	Control	317.97 (59.24)	309.88 (63.91)	0.752 (0.464)
	Respiration	316.40 (66.45)	300.60 (54.72)	1.402 (0.183)
Left	Area (mm ²)			
	Control	309.33 (104.74)	342.37 (82.35)	-1.562 (0.141)
	Respiration	334.73 (125.30)	330.18 (108.31)	0.173 (0.865)
	Length (mm)			
Left	Control	290.73 (57.10)	297.80 (52.63)	-0.835 (0.418)
	Respiration	297.31 (49.46)	279.00 (46.79)	2.167 (0.048)*

Values are presented as mean (SD).

COP: center of pressure.

^aArea of the eclipse drawn with the short and long axes of the shape of the COP trace. ^bLength of the COP trace on both-feet-standing.

* $p < 0.05$.

Table 3. Comparison between control- and respiration- sequences for the pre-post difference of the COP change during static standing (N=15)

Standing leg(s)/COP variable	d (pre-post) in control dC	d (pre-post) in respiration dR	Change	t(p)	
Bilateral					
	Area (mm ²) ^a	-0.66 (55.35)	-37.83 (91.60)	37.17	1.483 (0.160)
Right	Length (mm) ^b	43.04 (117.86)	10.18 (63.91)	32.86	0.966 (0.350)
	Area (mm ²)	-30.63 (138.39)	-25.79 (109.32)	-4.84	-0.099 (0.923)
Left	Length (mm)	8.08 (41.64)	15.79 (43.63)	-7.71	-0.389 (0.703)
	Area (mm ²)	-33.04 (81.93)	4.54 (102.12)	-37.59	-1.044 (0.314)
Left	Length (mm)	-7.06 (32.79)	18.30 (34.29)	-25.38	-2.156 (0.049)*

Values are presented as mean (SD).

COP: center of pressure, dC: difference between pre- and post-measurements [d (pre-post)] in the control sequence (C), dR: difference between pre- and post-measurements [d (pre-post)] in the respiration sequence (R).

^aArea of the eclipse drawn with the short and long axes of the shape of the COP trace. ^bLength of the COP trace on both-feet-standing.

* $p < 0.05$.

showed a greater decrease in the length of the COP after the R sequence compared to the C (Table 3, $p < 0.05$). Below the level of statistical significance, the area tended to show no decrease or slight decrease in R but showed increases in C during left single-leg standing. There were minor trends showing that COP length and area decreased or increased less after the R sequence with right single-leg-standing,

while those after the C sequence showed a less decrease or a more increase in COP length and area.

From the HRV measurement, significant pre-post effects in the mean HR was observed only from the experiment sequence; the mean HR was significantly lowered after the R-RGEP (Table 4, $p < 0.05$). Otherwise, statistically significant differences between the C sequence and the R se-

Table 4. Comparison between pre- and post- measurements of the HRV variable (N=15)

HRV variable	Pre	Post	t(p)
LF (msec ²)			
Control	6.19 (0.84)	6.31 (0.60)	-1.134 (0.276)
Respiration	6.11 (0.80)	6.33 (0.77)	-0.990 (0.339)
HF (msec ²)			
Control	6.30 (1.06)	6.42 (1.08)	-0.925 (0.370)
Respiration	6.47 (0.80)	6.44 (0.90)	0.122 (0.905)
LF/HF			
Control	1.13 (0.92)	1.11 (0.71)	0.137 (0.893)
Respiration	0.85 (0.45)	1.18 (0.86)	-1.583 (0.136)
MEAN HR (beats per minute)			
Control	67.84 (6.83)	66.24 (7.25)	1.198 (0.251)
Respiration	68.17 (7.13)	63.84 (7.01)	2.680 (0.018)*
SDNN (msec ²)			
Control	53.10 (15.88)	57.18 (15.79)	-1.735 (0.105)
Respiration	52.95 (14.10)	53.42 (16.43)	-0.158 (0.877)

Values are presented as mean (SD).

HRV: heart rate variability, LF: low frequency, HF: high frequency, LF/HF: ratio between low frequency and high frequency, MEAN HR: mean heart rate, SDNN: standard deviation of n-n interval.

* $p < 0.05$.

Table 5. Comparison between control- and respiration- sequences for the pre-post difference of the HRV variables (N=15)

HRV variable	d (pre-post) in control dC	d (pre-post) in respiration dR	Change	t(p)
LF (msec ²)	-0.12 (0.42)	-0.21 (0.85)	0.09 (1.82)	0.380 (0.710)
HF (msec ²)	-0.12 (0.50)	0.02 (0.67)	-0.14 (0.75)	-0.729 (0.478)
LF/HF	0.03 (0.79)	-0.33 (0.81)	0.36 (1.01)	1.377 (0.190)
MEAN HR (beats per minute)	1.60 (5.18)	4.32 (6.25)	-2.73 (7.73)	-1.367 (0.193)
SDNN (msec ²)	-4.08 (9.10)	-0.47 (11.59)	-3.61 (13.75)	-1.016 (0.327)

Values are presented as mean (SD).

HRV: heart rate variability, dC: difference between pre- and post-measurements [d (pre-post)] in the control sequence (C), dR: difference between pre- and post-measurements [d (pre-post)] in the respiration sequence (R), LF: low frequency, HF: high frequency, LF/HF: ratio between low frequency and high frequency, MEAN HR: mean heart rate, SDNN: standard deviation of n-n interval.

quence were not found (Table 5). The trends for the pre-post change were different between the C and the R, which will be also addressed in the discussion.

Discussion

This study aimed to find if short-term training in breathing and incorporation of such breathing into an exercise session would lead to an instant gain in stability and balance benefits, and also to see if any observable effect in the ANS would be accompanied in such possible change in balance.

As the length of COP increased or the area of the COP ellipse became larger, it indicated that the sway of the body had increased, and it could be interpreted as a decrease in the

ability to maintain balance [24-26]. The results showed that the slow abdominal breathing involved session can more or less beneficial to improving balance, as the significantly positive effect of a decrease in sway length of the COP compared to the control was observed from the single-leg-standing on the non-dominant (left) side (Tables 2, 3). The area of the sway on the left-leg-standing, although it was not to the level of significance as shown in the length of the sway, also showed a tendency to decrease (increase in balance) a small degree in the SAR involved sequence [R-RGEP] while it appeared to increase (decrease in balance) in the control sequence [P-GEP] (Tables 2, 3). Not as prominent as in the left leg standing, such balance-stabilizing effect can be traceable in the case of the right single-leg-standing. With the SAR in-

volved program [R-RGEP], the ellipse length of the COP displacement had decreased more and the area had increased less than the control program [P-GEP]. The bilateral standing examination did not show any additional balance-improving effect (Tables 2, 3).

The strength of the hip abductors of the non-dominant side was found to be relatively weaker than that of the dominant side in the healthy subjects [27]. For this reason, standing on the non-dominant side may have been more challenging and required more attention to maintain balance. The result of this study showed that SAR brought significant stabilizing effect under the left-side-standing condition and may indicate that breathing exercises can be more helpful in maintaining balance in a more challenging situation. This could be possibly due to the attention-improving effect of breathing exercise [28] since postural control involves significant attention requirement as well as reflex or autonomic control [29]. By the same token, the right single-leg-standing would need a higher level of attention relatively than the easier bilateral standing condition (although the level may be less when compared with left-standing because it is usually the dominant side and has more abductor strength) and it may be the reason that the stabilizing effect after the SAR program was more noticeable in the right single-leg-standing than with bilateral standing.

Considering that the SAR was incorporated to the exercises only after 6 minutes of training and that this short and easy introduction of the SAR still had some supportive effect on balance, it can be indicated that it is worth trying when the time for therapeutic or health-promoting sessions are limited but it is still desirable to obtain additional stabilization or balance improvement. Further studies are required to see if the more distinct effect can be expectable from the longer, repetitive trials. Stephens et al. [30] examined the effect of including 8 weeks extensive breathing exercises on balance in multiple modes of supine, prone, sitting, and with a stretchable belt on, but with no exercise combination or integration. The balance turned out to be improved both in single-leg-standing and in tandem standing after the completion of the programs. On the other hand, Roh [31] examined the effect of the abdominal breathing combined with strengthening exercises for a 6-week period on balance, but the results did not show an improvement in balance compared with the strengthening-only program.

The HRV is defined as beat-to-beat variation in heart rate, and the measurement the HRV parameters can be used to assess autonomic control [32,33]. The heart rate is controlled

by ANS, and parasympathetic nervous system decreases heart rate. The SDNN means overall variability, and larger variability means higher adaptability to changing stimuli from the environments and higher physical and psychological anti-stress capacity [33,34]. The HF is generally considered as representing parasympathetic activity and vagal activation, and is associated with more relaxed state. The LF is reflective of both sympathetic and parasympathetic activities to be associated with baroreflex sensitivity [32,35].

In the study where the relationship between sleep-deprivation and balance in healthy adults, the subjects with deteriorated sleep presented with changes in the HRV parameters (lowered LF, significantly lowered HF, and larger LF/HF) and decreases in balance [36]. This suggests a possibility that the lowered ability in balance may have a relationship with the change in their ANS reactions (toward more sympathetic activation) measured through the HRV. Mikołajec's study [22], as mentioned before, also observed a change in concentration of the sympathetic neurotransmitter of the ANS together with the change in postural stability when the different types of lower extremity strengthening exercise were tried.

The result of our study also showed that the heart rate decreased significantly after the controlled-breathing involved SAR sequence, and, although not to the level of significance, it decreased in the control too. This may indicate that more parasympathetic activation has occurred in both and especially in the SAR involved program and that this ANS modulation could have had an influence on balance. Although more future studies are needed, there is a possibility that the ANS may be involved in balance control in some way or another.

Both breathing and exercises are known to affect the HRV, the cardiovascular ANS marker, in somewhat of a different and varied way [32,35,37]. After our SAR combined and integrated exercise session, the directions of the change of the other HRV parameters were increase in LF, almost no change in HF, increase in LF/HF, and a mild increase in SDNN. According to the previous studies, slow breathing or meditation was related to an increase in LF [35,37], which is in line with the same direction of this study. The enhancement of LF of the cardiovascular system was reported to improve baroreflex sensitivity and lower blood pressure in patients with hypertension [37] In the control, which was basically active and resistive exercises with addition of passive exercises, the tendencies of the changes were an increase in LF, increase in HF, almost no change in LF/HF ratio, and an

increase in SDNN. Somewhat different from the results of our study, active exercises were reported to affect the HRV in the directions of showing a decrease in LF, increase in HF, decrease in LF/HF, and increase in SDNN [32,35,38]. However, there are certain types of movement or exercises presented with the varied HRV reaction: for example, eurhythmic movements, moving slowly with meditative imagery, and decreased LF [35]. The inclusion of passive exercises in the control of this study, even though it was included in the intention to make the overall session length the same between the control and the experiment without causing any other additional effect, may actually have affected the HRV in a different direction than active exercises, as seen in the eurhythmic exercise, and this possible influence may have added to the overall change in the HRV.

The new learning and application process for the SAR, can require more alertness and attention, and such process can cause a load of stress, as it can happen in the new learning process [39]. This study involved only a one-time trial of the respiration incorporated intervention. If the trial is repeated over several times, then the initial learning stress will reduce. Further studies are needed to see whether it would bring a more noticeable and clearer effect of balance stabilization or any activation/deactivation of the ANS if controlled respiration intervention is repeated over multiple sessions.

The limitations of this study include having a small number of subjects, although a cross-over design requires a relatively smaller number in terms of statistical analysis. Due to this limitation that renders difficulty in having a clear statistical analysis, the interpretations and considerations about the result of this study should be taken cautiously. Another limitation is the transfer effect, which is intrinsic to a cross-over research design, although it was minimized by wash-out periods.

In conclusion, the slow-abdominal-respiration integrated into an exercise program showed partially positive immediate effect on balance stabilization after a one-time session. The decrease in heart rate after the program indicated possible involvement of the parasympathetic ANS activation, although the extent of the effect was not enough to decide that it was genuinely due to the respiration. Due to the small number of the subjects, the result of this study is suggested to be taken as preliminary, and future research with larger number of subjects and with varied time or repetitions of the respiration training will be needed.

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the authorship and/or publication of this article.

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