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Original Article

The effect of aging on respiratory synergy

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Abstract. [Purpose] The purpose of this study was to investigate the effect of aging on respiratory synergy, through the comparison of an elderly group and a young group, to help further understanding of postural control in the elderly. [Subjects and Methods] Ten community-dwelling elderly subjects and ten young subjects performed standing under two different respiratory conditions: quiet breathing and apnea. Center of foot pressure displacement and joint angular movements of the head, trunk, pelvis, hips, knees and ankles were measured. [Results] The results of this study showed that the elderly group had a respiratory synergy different from that of the young group. The elderly group in quiet stance used significantly more hip and pelvis movements when compensating for respiratory disturbance than standing with apnea, while the young group used significantly more whole body segments. There were no differences in angular displacements in the quiet stance between the elderly and the young groups. [Conclusion] The elderly group demonstrated a respiratory synergy pattern different from that of the young group. The findings indicate that aging changes the respiratory synergy pattern and this change is not due to decreased functioning of the ankle joint alone.
Key words: Respiratory synergy, Aging, Kinematic analysis

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INTRODUCTION

Respiratory synergy is defined as compensatory movement of the body segments, in particular, those of the hip joint in reaction to respiration-induced trunk movement[1)]. Many studies have concluded that respiration has disturbing effects on postural control. However, these effects differ among subjects. For example, they are greater in subjects with low back pain[2)], elderly subjects and subjects with stroke[3)]. Also, respiratory disturbing effects on postural control differ according to position[4)] and breathing patterns[5)]. Other follow up studies have demonstrated that respiratory synergy includes multi- joint movements not just being single joint movement[6–9)]. It is also known that the respiratory synergy pattern is not fixed[6, 8)], there being variations of synergy patterns among subjects. Limitations of previous studies are that most studies were performed only with young subjects and/or kinetic data was measured. The elderly are well-known to have decreased sensory inputs, muscle strength, and joint flexibility compared to the young[10, 11)]. Therefore, the elderly compensate for respiratory disturbance with decreased sensory inputs, muscle strength, and joint flexibility. However, due to the limitations noted above, it is not clear whether the elderly use respiratory synergy patterns similar to the young.

Accordingly, this study was designed to investigate whether there are differences in respiratory synergy between the elderly and the young, to help further understanding of postural control in the elderly.

SUBJETCS AND METHODS

Ten elderly subjects were recruited, who met the following inclusion criteria: older than sixty-five years old, no previous lower extremity trauma, no history of respiratory disease, and no history of neurological, musculoskeletal disease or impairment. Ten young subjects were also recruited, and the inclusion criteria were the same as for the elderly group except for the age condition. Prior to participation, all participants were required to read and sign an informed consent, in accordance with the ethical principles of the Declaration of Helsinki. The protocol for this study was approved by the local ethics committee of Yeungnam University College.

To measure movements of body segments, the 12-camera Vicon T40 motion analysis system (Oxford Metrics, Oxford, UK) with 35 reflective markers was used. Reflective markers were placed on the landmarks of body surface to measure motion of the head, trunk, pelvis, thigh, lower leg and foot following the manual of the manufacturer. Data from the cameras were sampled at 120 Hz, and converted automatically into three-dimensional coordinates. Calibration was done using a fixed frame with five markers and a bar. Angu-

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Table 1. Angular displacements and CoP displacements of the young and elderly groups

Body segment	Young group breathing pattern (n=10)		Elderly group breathing pattern (n=5)	
	Quiet breathing	Apnea	Quiet breathing	Apnea
Head (°)	14.01 ± 8.91	8.95 ± 4.69*	9.42 ± 9.43	6.58 ± 3.89
Hip (°)	6.34 ± 4.33	3.60 ± 2.04*	5.13 ± 2.55	3.04 ± 1.00*
Knee (°)	6.06 ± 3.28	4.24 ± 2.07*	4.60 ± 1.74	4.24 ± 2.05
Ankle (°)	3.91 ± 2.41	2.90 ± 1.45*	2.97 ± 1.11	2.57 ± 0.81
Thorax (°)	8.86 ± 4.02	5.49 ± 2.16*	5.87 ± 1.74	4.80 ± 2.52
Pelvis (°)	7.22 ± 2.70	4.95 ± 1.81*	7.88 ± 2.42	5.87 ± 1.74*
CoP (mm)	1,555.82 ± 454.37	1,593.13 ± 496.71	1,359.82 ± 240.10	1,321.45 ± 297.35

*p< 0.05 significant difference between quiet breathing and apnea
(Mean ± SD)

lar placement of the head, trunk, pelvis, hip, knee and ankle were calculated using the plug-in gait version 1.7 of the Vicon Nexus software program. To measure center of pressure (CoP) displacement as an output of respiratory synergy, a single AMTI-OR6 force platform (AMTI, Watertown, MA, USA) with a sampling rate of 960 Hz was used. CoP displacement was also calculated using the plug-in gait version 1.7 of the Vicon Nexus software program. After attachment of the reflective markers, the subjects were asked to stand as quiet as possible, without shoes, on the force plate with their feet shoulder-width apart and their arms by the sides of the body. Subjects wore shorts and a T-shirt during measurement. Data were recorded in 3 trials under each of the following conditions: quiet breathing (QB), the breathing pattern normally observed during resting; and apnea (AP), standing with the breath held. The participants were asked to breathe naturally or hold their breath for up to 40 seconds. A rest was allowed whenever requested by the subjects, and for as long as needed. At both the start and end of each task, 5 seconds of data were discarded, leaving 30 seconds of data for analysis. After the initial data collection, 5 subjects in the elderly group were excluded from the data analysis because they could not hold their breath for 40 seconds. Therefore, the data of 10 young subjects (6 males, 4 females, 20.50 ± 2.46 years old, height 1.69 ± 0.11 m, weight 60.10 ± 8.77 kg, BMI 20.90 ± 1.75 kg/m^2) and 5 elderly subjects (2 males, 3 females, 72.40 ± 3.58 years old, height 1.56 ± 0.05 m, weight 57.80 ± 3.83 kg, BMI 23.90 ± 2.26 kg/m^2) were used in the analysis of this study. There were no differences in the general characteristics of the two groups, except for height (p=0.04) and age. For data analysis, CoP displacements were resampled at 120 Hz to enable comparison with the other data. CoP displacement was defined as the total distance CoP moved in the sagittal plane during the task[12]. CoP displacements of each trial were calculated using MATLAB version 7.12.0.635 (R2011a). Joint angular displacements of the body segments were the total angular distance each joint moved in the sagittal plane during the tasks. Similar to CoP displacement, angular distances were calculated using MATLAB version 7.12.0.635 (R2011a).

All statistical analyses were performed using SPSS version 18.0. Based on the results of the Kolmogorov-Smirnov test, the paired t-test or Wilcoxon's test were used for within group comparisons. Statistical significance was accepted for values of p<0.05.

RESULTS

To evaluate the effect of breathing pattern on angular displacements, within group comparisons were performed (Table 1). For the young group, joint angular displacements of the head, hip, knee, ankle, thorax, and pelvis during quiet breathing were significantly more than during apnea (p=0.017, p=0.002, p=0.002, p=0.017, p<0.001, p<0.001, respectively). Although CoP displacement was slightly smaller during quiet breathing, it was not significantly different between quiet breathing and apnea (p=0.481). Different from the young group, the elderly group demonstrated increased angular movements in fewer body segments than the young group during quiet breathing compared to apnea. During quiet breathing, the elderly group showed increased hip and pelvis movements only (p=0.016, p=0.011 respectively). CoP displacement was slightly larger during quiet breathing compared to apnea, but not significantly different (p=0.140).

There was no difference between the elderly group and the young group in angular displacements of the body segments during quiet breathing, except those of the head and thorax (p=0.010, p=0.011, respectively). CoP displacement was not significantly different between the two groups (p>0.05).

DISCUSSION

In addition to decreased sensory inputs, muscle strength, and joint flexibility, many studies have reported decreased respiratory functions in the elderly, especially peak expiratory flow (PEF)[10, 11], which is used to measure expiratory muscle strength. Expiratory muscles include the transversus abdominis, internal oblique abdominis, external oblique and rectus abdominis muscles which are also involved in postural control during quiet stance[13–16]. With decreased respiratory muscles strength, we expected that the elderly group would have decreased postural control in the quiet stance. However, the elderly group of this study showed no significant difference in CoP displacement from the young group. There are two possible explanations for this: 1) the elderly group had decreased expiratory muscle strength, but the strength was enough to compensate respiratory disturbance; or 2) the elderly group might have developed a different compensatory strategy, which successfully compensates the respiratory disturbance even though they have decreased respiratory muscle strength. The results of this study provide evidence for the latter possibility, as the elderly group demonstrated a different respiratory synergy pattern from that of the young group.

The elderly group showed a preference for hip and pelvis movement when compensating for respiratory disturbance. The young group did not show any preference among the body segments when compensating for respiratory disturbance. Compared to during apnea, the elderly group showed significantly increased angular displacements of the hip and pelvis during quiet breathing, while the young group demonstrated significantly increased angular displacements of whole body segments. Increased reliance on the proximal joints for postural control has been reported for healthy elderly with a decreased base of support[17] and subjects with lower-limb amputation[18]. Also, regardless of age, subjects with unilateral transtibial amputation showed reliance on the hip strategy for initial postural control[18]. We consider that either insufficient torque production at the ankle joint or insufficient proprioceptive contribution of the ankle joint was the reason for the increased reliance on the proximal joints for postural control in the elderly group. Other possible explanations are that the elderly use increased co-contraction of the muscles at the ankle joint[19–21], or rely on the hip joint to complete postural control[17, 22, 23]. Interestingly, however, subjects with unilateral transtibial amputation showed decreased reliance on the hip joint after rehabilitation[18]. In addition, the elderly group of this study showed no difference in ankle angular displacement from that of the young group. Therefore, increased reliance on the proximal joints was not simply an alternative to decreased ankle joint function.

A limitation of this study was that only 5 out of the 10 elderly subjects were included in the data analysis because the other 5 elderly subjects could not hold their breath for 40 seconds. Further studies are necessary to investigate whether apnea for shorter than 30 seconds generates a similar respiratory synergy in the elderly, and to study respiratory synergy with bigger numbers of elderly subjects.

In conclusion, this study showed that aging has a significant influence on respiratory synergy. The elderly group demonstrated increased reliance on hip and pelvis angular movements for successful respiration. The results of this study also suggest the possibility that the different respiratory synergy pattern is not simply a preprogrammed alternative to an ankle joint strategy, but a new and self-organized motor control method utilizing available physiological attributes, such as range of motion, strength or sensation.

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