academicJournals

Vol. 8(25), pp. 1166-1170, 4 July, 2013
DOI 10.5897/SRE12.653
ISSN 1992-2248 © 2013 Academic Journals
http://www.academicjournals.org/SRE

Scientific Research and Essays

Full Length Research Paper

Influence of sitting posture on tidal volume, respiratory rate, and upper trapezius activity during quiet breathing in patients with chronic obstructive pulmonary disease

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Accepted 3 June, 2013

This study was performed to determine the influence of sitting posture on tidal volume (TV), respiratory rate (RR), and muscle activity of the upper trapezius (UT) in patients with chronic obstructive pulmonary disease (COPD). Fifteen men with COPD based on the Global initiative for Chronic Obstructive Lung Disease (GOLD) criteria, participated in the study. Inductive respiratory plethysmography and surface electromyography were used to simultaneously measure TV, RR, and muscle activity of the UT during quiet natural breathing (QB) in three sitting postures: neutral position (NP), forward-leaning position with arm support (WAS), and forward-leaning position with arm and head support (WAHS). A video motion-analysis system was used to measure the distance between the tragus and acromion during each experimental sitting posture. TV and RR were not significantly different between the three sitting postures; however, muscle activity of the UT decreased significantly in the WAHS posture as compared with the NP posture. There was a significant difference in the distance between the tragus and the middle of the lateral aspect of the acromion between sitting postures. Based on the results of this study, the WAHS posture could be recommended to control the excessive recruitment of UT during inspiration for the patients with COPD.

Key words: Chronic obstructive pulmonary disease, muscle activity, respiratory rate, sitting posture, tidal volume.

INTRODUCTION

Patients with chronic obstructive pulmonary disease (COPD) report fatigue and dyspnea when performing activities associated with daily living (Panka et al., 2010). Dyspnea is a debilitating symptom (Yount et al., 2011) and a limiting factor during daily activities (Eisner et al., 2008) in patients with COPD. Neumann (2009) suggested that patients with COPD may assume a forward-leaning trunk position to reduce dyspnea, which involves stabilizing the body using the forearms.

A sitting posture with a forward-leaning trunk is recommended to relieve dyspnea in patients with COPD (O'Neill and McCarthy, 1983; Sharp et al., 1980). Kisner and Colby (2002) suggested that patients with COPD can assume a sitting posture with a forward-leaning truck to

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relieve shortness of breath. Another study indicated that in patients with COPD, active expiration while sitting with a forward-leaning trunk improved the length-tension relationship of the diaphragmatic fiber and its mechanical coupling with the thoracic cage better than by sitting and lying back (Willeput and Sergysels, 1991). O'Neill and McCarthy (1983) reported that sitting with a forward-leaning trunk was the optimum posture for patients with COPD to generate maximum inspiratory pressure and to obtain the greatest subjective relief of dyspnea.

Several studies have confirmed that various postures affect pulmonary function (Appel et al., 1986; Manning et al., 1999). The prone position in healthy subjects has been shown to cause compression of the anterior ribs, which limits the volume of air into the lungs and the ability to expel air from the lungs (Vilke et al., 2000). Another study reported that maximal inspiratory pressure (MIP), maximal expiratory pressure (MEP), and maximal voluntary ventilation (MVV) were higher in a standing position with arm bracing and a trunk anterior inclination of 30° as compared with a standing position without arm bracing in patients with COPD (Cavalheri et al., 2010).

However, few studies have evaluated the association between sitting positions and respiratory accessory muscles in patients with COPD. One previous study indicated significantly reduced scalene and sternocleidomastoid muscle activities in a forward-leaning position (Sharp et al., 1980). Another study reported that patients with COPD may stabilize the distal attachments of the arm muscles, such as the sternocostal head of the pectoralis major and latissimus dorsi, with a forward-leaning position to assist with inspiration by elevating the sternum and ribs (Neumann, 2009). The majority of the COPD patients complained severe neck and shoulder pain and, this pain may be related with COPD patients using their accessory muscles during inspiration to compensate the condition of dyspnea (Bentsen et al., 2011). These neck and shoulder pain are often related with over use of upper trapezius muscle in patients with chronic shoulder and neck pain (Turo et al., 2013). Previous research in this area has rarely examined the relationship between muscle activity of the inspiratory accessory muscles and pulmonary parameters, and there are no reported investigations on the upper trapezius as an inspiratory accessory muscle (Kendall et al., 2005) in tripod sitting position (Bhatt et al., 2008) or the other modified forward-learning position with arm support in patients with COPD.

Therefore, this study was performed to compare the tidal volume (TV), respiratory rate (RR), and muscle activity of the upper trapezius (UT), collected during quiet natural breathing (QB), in three different sitting postures: a neutral position (NP), forward-leaning position with arm support (WAS), and forward-leaning position with arm and head support (WAHS) in patients with COPD. We hypothesized that pulmonary parameters and muscle activity of the UT would differ between the three sitting postures.

MATERIALS AND METHODS

Subjects

Fifteen COPD patients were recruited from the Division of Pulmonary Medicine, Department of Internal Medicine, Gangnam Severance Hospital, Yonsei University Health System, Seoul, Korea. All subjects were classified as stage 2 (7 male) or 3 COPD (8 male) by the Global initiative for chronic Obstructive Lung Disease (GOLD) criteria (Rabe et al., 2007). Exclusion criteria were as follows: 1) subjects who complained of pain or discomfort during breathing training, 2) subjects who were diagnosed with musculoskeletal diseases or other cardiorespiratory disorders without COPD, and 3) subjects who had undergone recent operations or were taking any medications that may affect breathing patterns. Demographic characteristics and pulmonary functions of the subjects are presented in Table 1.

Measurement tools

Functional analyses of lung volume and capacity were performed using a portable spirometer (Vitalograph 2120; Vitalograph, Buckingham, UK) to assess normal lung function. Criteria of acceptability and reproducibility were met (Pereira et al., 2002). Inductive respiratory plethysmography and surface electromyography were performed using an Embla N7000 (Embla Systems, Broomfield, CO) to enable the acquisition and recording of simultaneous respiratory parameters and surface electromyographic measurements (Droitcour et al., 2009).

Data collection

TV and RR were measured by inductive respiratory plethysmography (Embla N7000; Embla Systems). Respiratory data were also obtained from the Signals Lab's calibrated nasal cannula (Micro Switch AWM200 Microbridge Mass Airflow sensor; Honeywell, Morristown, NJ), which displayed the direction, level, and duration of airflow (Gross et al., 2009).

For surface electromyography, the Ag/AgCl electrode and reference electrode pair were affixed on the patient's UT muscle and forehead, respectively. The EMG unit of the Embla N7000 (Embla Systems) was used to measure the surface muscle activity of the UT muscle (Gregory, 2007). EMG activity and pulmonary function were recorded in the neutral position (baseline). A 5-min baseline period was first recorded and then, the EMG was collected for each position for at least 30 s. Only the data recorded during the inspiration phase were used and converted to root mean square (RMS) values. The inspiration phase was determined from the nasal pressure curve measured by a nasal cannula using the respiratory analysis software for inductive respiratory plethysmography.

For normalization, the reference voluntary contraction (RVC) was determined for the UT. Data are expressed as percentages of the reference voluntary contraction (%RVC). The average of the three trials was calculated. A 1-min rest period was provided to minimize any potential effects of fatigue. Data acquisition was performed using a biological signal acquisition system (EMG System of the Embla N7000; Embla Systems) consisting of a signal conditioner with a notch filter gain of 60 Hz and band-pass filter of 100–250 Hz (Cram et al., 1998). Muscle activity was measured during the inspiration phase.

A video camera was used to record the positions of passive

Table 1. Demographic characteristics and pulmonary function of study subjects.

Parameter	Mean ± SD		*p*-value
	GOLD 2 (N=7)	GOLD 3 (N=8)	(Mann-Whitney U)
Age (y)	62.3 ± 8.2	71.3 ± 6.9	0.07
Height (cm)	167.4 ± 5.5	166.9 ± 5.8	0.96
Weight (kg)	61.4 ± 8.1	57.6 ± 5.3	0.28
BMI (kg/m^2)	21.9 ± 2.6	20.7 ± 2.3	0.28
FVC (L)	3.3 ± 0.6	3.2 ± 0.8	0.96
FEV1(L)	1.5 ± 0.2	1.2 ± 0.3	0.03
FEV1/FVC (%)	47.6 ± 8.5	37.5 ± 2.8	0.01
Predicted FEV1 (%)	54.3 ± 8.0	47.9 ± 7.7	0.09
PEF(L/s)	4.9 ± 1.1	3.1 ± 0.7	0.01
Predicted PEF (%)	64.6 ± 14.9	43.4 ± 9.0	0.02
MVV(L/min)	63.1 ± 13.3	43.9 ± 8.6	0.03
Predicted MVV (%)	52.1 ± 8.9	40.1 ± 6.1	0.02

BMI, body mass index; FVC, forced vital capacity; FEV_1, forced expiratory volume in 1 s; PEF, peak expiratory flow; MVV, minute ventilation volume.

reflective markers placed on the tragus and the middle of the lateral aspect of the acromion, and a video motion-analysis system was used to measure the distance between the tragus and acromion during each experimental sitting posture using SIMI (Simi Reality Motion System; SIMI Unterschleissheim, Germany) (Lamoth et al., 2008). Two markers were attached to the tragus and the middle of the lateral aspect of the acromion in the dominant upper limb with a thin neoprene strip. One video camera was placed approximately 1 m from the dominant lateral aspect of the subject to record movement of the shoulder and head during the tests.

Procedures

Prior to enrollment in the study, all subjects received a training session for quiet natural breathing (QB); patients were instructed to breathe in a comfortable manner in accordance with their normal habitual comfortable breathing (Bianchi et al., 2007) without specific training. A two-band inductive respiratory plethysmography system consisting of surface electromyographic electrodes and two small light-reflective markers were attached to the patient to measure pulmonary function, muscle activity, and the distance between the acromion and tragus. Velcro was used to fasten the surface EMG cable and sensors of the Signals Lab's calibrated nasal cannula to avoid motion artifacts. Sitting postures were applied in a random order.

In the neutral position (NP) sitting posture, the subject assumed a sitting posture while maintaining bilateral hip, knee, and ankle joint angles of 90°. In the sitting posture with arm support (WAS), the subject assumed a sitting posture while maintaining bilateral hip, knee, and ankle joint angles of 90°. Both elbows and forearms rested on the anterior thighs by leaning the trunk forward. An imaginary line connecting the tragus and hip joint formed a 45° angle relative to the vertical position. The head and cervical spine were aligned comfortably with the trunk. The subject was asked to stabilize their gaze by looking at a predetermined dot located at a position level with the eyes and 1 m in front of the subject. In the sitting posture with arm and head support (WAHS), the WAHS position was identical to the WAS position except that the chin was held with both cupped hands. This standardized experimental position was practiced with verbal and tactile cues. All subjects felt relaxed and comfortable after a familiarization period of 5 min.

Statistical analyses

The SPSS software (ver. 12.0; SPSS Inc., Chicago, IL) was used. Data were analyzed using the Shapiro-Wilk test to assess normality. Since the data were not normally distributed, the Friedman test (non-parametric analysis of variance) was used to assess differences in TV, RR, %RVC, and the distance between the tragus and acromion in the three sitting postures. The Wilcoxon signed ranks test was used to compare between WAS, WAHS, and NP data. Since multiple analyses were performed, a Bonferroni correction was used. P values of less than 0.017 (0.05/3) were considered to indicate statistical significance.

RESULTS

The means and standard deviations of TV and RR in each sitting posture are presented in Table 2. For both TV and RR there were no significant differences between the positions ($P = 0.109$ and $P = 0.247$, respectively).

The means and standard deviations of %RVC for each sitting posture are presented in Table 2. When comparing the three different positions, muscle activity was decreased significantly in the order of NP, WAS, WAHS ($P < 0.001$). Bonferroni's *post hoc* test, muscle activity of the upper trapezius muscle in WAHS was decreased significantly as compared with that in NP ($P = 0.015$). However, there was no significant difference between WAS and NP ($P = 0.053$) or WAS and WAHS ($P = 0.048$).

The means and standard deviations of the distance between the tragus and acromion for each sitting posture are presented in Table 2. In comparing the three different positions, the distance was decreased significantly in the order NP, WAS, WAHS ($P < 0.001$). There were significant differences between the three positions (NP and WAS, $P = 0.001$; NP and WAHS, $P = 0.001$; WAS and WAHS, $P = 0.005$).

Table 2. Tidal volume, respiratory rate, muscle activity, and distance between the tragus and acromion in each sitting posture.

Parameter	QB		
	NP	**WAS**	**WAHS**
TV (ℓ)	0.6 ± 0.2	0.7 ± 0.2	0.7 ± 0.2
RR (f/min)	18.3 ± 2.9	16.5 ± 3.1	16.5 ± 2.0
UT (%RVC)	100.0 ± 0.0	94.1 ± 16.0	88.0 ± 13.7
Distance (cm)	15.4 ± 0.7	13.5 ± 0.5	13.4 ± 0.6

QB, quiet breathing; NP, neutral position; WAS, breathing training with arm support; WAHS, breathing training with arm and head support; TV, tidal volume; RR, respiratory rate; UT, upper trapezius; %RVC, percentage of reference voluntary contraction.

DISCUSSION

The study was performed to compare changes in TV, RR, and the activity of the upper trapezius (UT) in three different sitting postures (NP, WAS, WAHS) in patients with COPD.

TV and RR did not differ significantly regardless of sitting posture. These findings are consistent with a recent study by Bhatt et al. (2009) who found no significant difference in forced expiratory volume in 1 s, the ratio of forced expiratory volume in 1 s to forced vital capacity, maximal inspiratory pressure, maximal expiratory pressure, diaphragmatic movements during tidal breathing, and forced breathing while sitting, supine, and sitting while leaning forward with the hands supported on the knees (tripod position) in patients with COPD. A recent study (Kera and Maruyama, 2005) reported that TV did not change significantly according to sitting posture (sitting with elbows on knees [SEK], supine, standing, and sitting) in 15 young adult men.

The lack of significant findings in TV and RR with respect to position in the present study may have been due to COPD-related pulmonary hyperinflation, which is caused by air trapped within the lungs and a loss of elastic recoil pressure (Gosselink, 2004). This results in flattening of the diaphragm in patients with COPD, putting it at a mechanical disadvantage (Kealy et al., 2003). In addition to increasing the work load involved in breathing, diaphragmatic fibers are shortened, with hyperinflation of the thorax. This alters the length–tension relationship and limits diaphragmatic capacity for force generation (Roussos and Macklem, 1982). The diaphragm also has a propensity for fatigue in COPD (Bellemare and Grassino, 1982). Thus, it is possible that COPD-related structural variation was advanced in subjects in this study such that the pulmonary function parameters used, that is, TV and RR, were not influenced by the position changes.

Muscle activity of the UT in WAHS was significantly less than that in NP. This decreased UT muscle activity in the forward-leaning position may be explained by the length–tension relationship. As the trunk leaned forward, the distance between the tragus and the acromion decreased significantly; therefore, the shortened muscle could not produce sufficient tension as compared with the relatively upright NP. The results of our pilot study were similar, indicating that UT muscle activity in WAHS was significantly less than that in NP. Based on the results of the pilot study, a passive marker-movement registration system was used to record the distance between the tragus and acromion using SIMI to enable comparison of UT muscle activity between each posture. The distance between the acromion and tragus decreased significantly in the order NP, WAS, WAHS. The significantly decreased activity of the UT in WAHS as compared with that in NP is thought to be due to the decreased length of the UT in WAHS as compared with that in NP.

The association between muscle activity and muscle pain has been a topic of clinical interest for several decades (Wakefield et al., 2011). The majority of the COPD patients reported moderate-to-severe pain, located primarily in the chest, shoulder, and neck, and this pain may be related to the fact that patients with COPD use their primary and accessory muscles during respiration to overcome the sensation of dyspnea (Bentsen et al., 2011). Because of its recurrent involvement in shoulder and neck pain, the trapezius muscle has received much attention in studies examining the relationship between habitual trapezius muscle activity during periods with low biomechanical loading and shoulder and neck pain (Wakefield et al., 2011; Larsson et al., 2007). This is the first randomized controlled trial to indicate that muscle activity of the UT decreases with a forward-leaning position.

Based on the findings of this study, while UT activity appears to be decreased during inspiration in WAS and WAHS positions, it does not seem valid to recommend the WAHS over WAS position. Furthermore it seems incorrect from this study's findings to suggest that decreasing activity of UT in isolation would be enough to reduce musculoskeletal pain. This issue seems complex with presumably multiple muscles, including postural stability muscles, involved and the participant's included in this study had no musculoskeletal pain.

This study has several limitations. First, because muscle activities of primary and other accessory muscles were not measured, the effects of changes in muscle activity of the UT in different sitting postures on primary and accessory muscles activities could not be determined. Second, because the activity of the UT muscle during periods of deep inspiration (that is, similar conditions to ventilatory insufficiency) were not considered in the experimental procedures, the effects of changes in the muscle activity of the UT, TV, and RR rate cannot be used as fundamental data to resolve the role of sitting posture in ventilatory insufficiency in patients with COPD. Third, dyspnea is discussed as a reason for forward leaning trunk position, however, the degree of dyspnea was not evaluated in the study. Further studies are required to measure major muscles of respiration, including examination of the primary and accessory muscles, and conditions of ventilatory insufficiency with a larger sample size.

Conclusions

The WAHS posture decreases the muscle activity of the UT during inspiration compared to NP. Hence, the WAHS posture could be recommended to control the excessive recruitment of UT during inspiration for the patients with COPD.

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