Respiratory Physiology & Neurobiology 172 (2010) 184–191

Contents lists available at ScienceDirect

Respiratory Physiology & Neurobiology

journal homepage: www.elsevier.com/locate/resphysiol

Effects of gender and posture on thoraco-abdominal kinematics during quiet breathing in healthy adults

M. Romei [a,*], A. Lo Mauro [b], M.G. D'Angelo [a], A.C. Turconi [a], N. Bresolin [a,c], A. Pedotti [b], A. Aliverti [b]

[a] IRCCS E.Medea, Bosisio Parini (Lc), Italy
[b] TBM Lab, Dipartimento di Bioingegneria, Politecnico di Milano, Milano, Italy
[c] Fondazione Policlinico – Mangiagalli – Regina Elena, IRCCS Ospedale Maggiore, Università degli Studi di Milano, Istituto di Clinica Neurologica, Milano, Italy

ARTICLE INFO

Article history:
Accepted 19 May 2010

Keywords:
Chest wall
Posture
Abdomen
Opto-electronic plethysmography
Gender
Thorax

ABSTRACT

To investigate the effects of posture and gender on thoraco-abdominal motion and breathing pattern, 34 healthy men and women were studied by Opto-Electronic Plethysmography during quiet breathing in five different postures from seated (with and without back support) to supine position.

Chest wall kinematics and breathing pattern were significantly influenced by position and gender. The progressively increased inclination of the trunk determined a progressive reduction of rib cage displacement, tidal volume, and minute ventilation and a progressive increase of abdominal contribution to tidal volume. Female subjects were characterized by smaller dimensions of the rib cage compartment and during quiet breathing by lower tidal volume, minute ventilation and abdominal contribution to tidal volume than males. The effect of posture on abdominal kinematics was significant only in women. The presence of a back support in seated position determined differences in breathing pattern. In conclusion, posture and gender have a strong influence on breathing and on chest wall kinematics.

1. Introduction

It is well known that posture influences thoraco-abdominal kinematics during spontaneous quiet breathing. Previous studies (Wade, 1954; Fugl-Meyer, 1974; Sharp et al., 1975; Verschakelen and Demedts, 1995; Lee et al., 2010) have investigated both erect (sitting or standing) and supine positions in healthy subjects, and have shown that quiet breathing is predominantly abdominal in the former and thoracic in the latter position.

On the other hand, the effect of gender on chest wall kinematics is still controversial. While some authors (Fugl-Meyer, 1974; Gilbert et al., 1981) reported a relatively greater rib cage motion in women, others (Sharp et al., 1975; Verschakelen and Demedts, 1995) did not. There is evidence in the literature, however, that the differences in pulmonary function (namely, lung volumes, maximal expiratory flow rates, diffusion surfaces and maximal pulmonary ventilation) between females and males are mostly due to the smaller height and trunk size in women (McClaran et al., 1998). These controversies remain when considering possible interactions between posture and gender on thoraco-abdominal motion during quiet breathing.

In the previous studies, different measurement techniques such as mercury-in-rubber strain gauges (Wade, 1954), linear differential transducers (Konno and Mead, 1967), magnetometers (Fugl-Meyer, 1974; Sharp et al., 1975; Gilbert et al., 1981), and respiratory inductive plethysmography (Verschakelen and Demedts, 1995) were used. The differences in experimental methods, particularly in the kind of measurement they provide (changes of diameters, perimeters, transversal sections), could contribute to the different findings regarding the effects of gender and possible interactions between posture and gender on chest wall kinematics.

Opto-Electronic Plethysmography (OEP, Cala et al., 1996) has been proposed as a new method that, starting from the three-dimensional coordinates of markers positioned on a subject's trunk and acquired by an opto-electronic system for motion analysis, allows the accurate measurement of the kinematics and the volume variations of the chest wall and its compartments (rib cage and abdomen) in different positions: standing, seated, supine (Aliverti et al., 2000), and prone (Aliverti et al., 2001).

The present study was conducted in order to prove the hypothesis that posture, gender and their interaction all have significant effects on rib cage and abdominal kinematics during quiet breathing and to clarify which are the limits of validity of chest wall kinematics measurements when considering different geometrical parameters. For these purposes, we used the novel OEP technique to study a group of healthy female and male subjects in different postures, i.e., different inclinations of the trunk from seated

* Corresponding author at: IRCCS "E. Medea", Via Don Luigi Monza, 20, 23842 Bosisio Parini (Lc), Italy. Tel.: +39 031 877351; fax: +39 031 877499.
E-mail address: marianna.romei@bp.lnf.it (M. Romei).

1569-9048/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.resp.2010.05.018

Table 1
Subjects' characteristics (data are expressed as mean ± SD). M: males; F: females; M + F: overall group. In the last column on the right, the *p*-value of the comparison between males and females are shown.

	M + F	M	F	*p*-Value (M vs F)
Size group	34	17	17	
Age (years)	32.1 ± 8 (range: 22–52)	31.5 ± 9.4 (range: 22–52)	32.8 ± 6.6 (range: 22–50)	0.65
Weight (kg)	64.6 ± 11.4 (range: 46–83)	72.1 ± 6.5 (range: 60–83)	56.3 ± 8.4 (range 46–76)	<0.01
Height (cm)	172.9 ± 8.2 (range: 157–187)	177 ± 5.4 (range: 165–187)	164.9 ± 5.4 (range: 157–180)	<0.01

(with and without back support) to supine position. By using the same set of three-dimensional coordinates measured by the same opto-electronic system for motion analysis, we calculated simultaneous variations in diameters, perimeters, transversal sections and volumes at the levels of the rib cage and the abdomen as different descriptors of chest wall kinematics. In this way we aimed to exclude all the possible differences between these parameters due to measurement errors introduced by the different sensors and/or devices, which in part may explain the controversial results reported in the literature.

2. Materials

2.1. Subjects

34 healthy adults (17 females, 17 males) were recruited for the present study. The inclusion criteria were: absence of cardiac and pulmonary disease, no smokers, no endurance-trained athletes, and age higher than 18 years. Subjects' characteristics are shown in Table 1.

The study was approved by the local Ethical committee of IRCCS "E. Medea" Institute where all the data acquisitions were performed and all subjects gave informed consent.

2.2. Protocol

For each subject, the data acquisition protocol consisted of five trials performed in a single session.

Each session took about 45 min in total, including both the time for the subject's adaptation on the different positions and data acquisition. All subjects were asked to maintain a spontaneous breathing pattern for the whole duration of the experimental session. Five different positions were considered (Fig. 1) and measurements were repeated five times (one for each position) in which data were acquired during at least 3 min of quite breathing. In the first position (position A in Fig. 1), the subject was seated on a rigid bed without back support. In the three other positions (positions B–D in Fig. 1), the subject was seated on a wheelchair, with the back support position adjusted to one of three different inclinations (B: ~80°, C: ~65°, D: ~40° with respect to the floor). Finally, the subject lay supine on a rigid bed.

2.3. Opto-Electronic Plethysmography analysis

Opto-Electronic Plethysmography (OEPSystem BTS, Italy) was based on an eight-infrared cameras system working at 60 Hz. For positions A–C, four cameras were positioned in front of the subject, and four were behind. For position D and supine, four cameras were positioned to the right of the subject, and four to the left.

For position A, 89 passive markers were placed on the anterior and posterior side of the trunk, according to the protocol described by Cala et al. (1996). For positions B–D and supine, the markers on the posterior trunk surface were removed, and 52 markers were left on the anterior and lateral trunk surface. In these cases, 45 markers were positioned according to the protocol described by Aliverti et al. (2001), adding a row of 7 markers at the nipple level, in order to have the same anterior surface arrangement in all the 5 positions.

The same operator identified the anatomical positions, and placed the passive retro-reflective markers on the chest wall surface.

2.4. Data analysis

2.4.1. Total chest wall volume

As previously described, total chest wall volume was calculated from the 3D coordinates of the markers, surface triangulation, and Gauss' theorem (Cala et al., 1996; Aliverti et al., 2001). In the case of the seated position without back support (A) the whole trunk was visible, whereas for the positions with back support (B–D and supine), the posterior part of the trunk was defined by a virtual plane. This was obtained by calculating a reference plane defined by the co-ordinates of the markers positioned laterally on the trunk (Aliverti et al., 2001).

2.4.2. Compartmental volumes

As in previous studies, the total chest wall was divided into three compartments (Ward et al., 1992), namely Pulmonary Rib Cage, Abdominal Rib Cage and Abdomen (Kenyon et al., 1997). For the purposes of the present study, the Pulmonary and Abdominal Rib Cage compartments were considered as a single compartment (Rib Cage), given by their sum (Grimby et al., 1976) (Fig. 2a).

2.4.3. Chest dimensions and displacement

From 3D marker coordinates measured by OEP, the medio-lateral (ML) diameters, the antero-posterior (AP) diameters, the

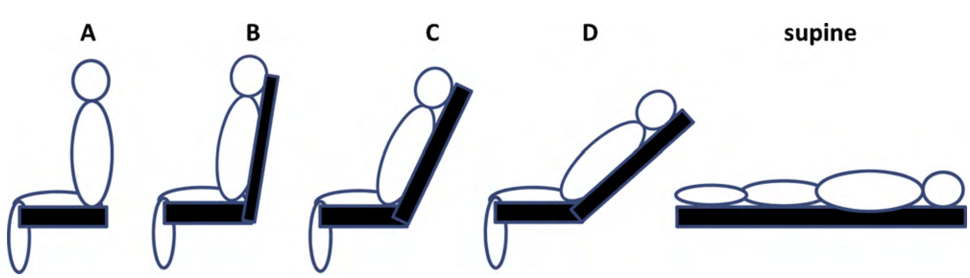

Fig. 1. Schematic representation of the five postures adopted by the subjects. From left to right: seated on a rigid bed without back support (position A); seated with three different back support inclinations (position B: ~80°, position C: ~65°, position D: ~40° with respect to the floor) and supine on a rigid flat bed.