International Journal of Occupational Safety and Ergonomics

ISSN: 1080-3548 (Print) 2376-9130 (Online) Journal homepage: https://www.tandfonline.com/loi/tose20

Respiratory chest movement measurement as a chair quality indicator – preliminary observations

Elżbieta Szczygieł, Katarzyna Zielonka, Tadeusz Mazur, Sylwia Mętel & Joanna Golec

To cite this article: Elżbieta Szczygieł, Katarzyna Zielonka, Tadeusz Mazur, Sylwia Mętel & Joanna Golec (2015) Respiratory chest movement measurement as a chair quality indicator – preliminary observations, International Journal of Occupational Safety and Ergonomics, 21:2, 207-212, DOI: 10.1080/10803548.2015.1028224

To link to this article: https://doi.org/10.1080/10803548.2015.1028224

International Journal of Occupational Safety and Ergonomics (JOSE), 2015
Vol. 21, No. 2, 207–212, http://dx.doi.org/10.1080/10803548.2015.1028224

Respiratory chest movement measurement as a chair quality indicator – preliminary observations

Elżbieta Szczygieł[a,c*], Katarzyna Zielonka[a], Tadeusz Mazur[b], Sylwia Mętel[c] and Joanna Golec[c]

[a]Jagiellonian University Medical College, Poland; [b]"Zdrowie" Rehabilitation Centre, Poland; [c]The University School of Physical Education in Cracow, Poland

Regardless of the constantly increasing time man is spending in a sitting position, there is still a lack of objective chair quality assessment criteria. The aim of this paper is to find the answer to whether respiratory chest movement measurements can be a chair quality indicator. The study included 34 participants (mean 34.7 years ± 5.2). Their chest movements were assessed using respiratory inductive plethysmography while sitting on two subsequent chairs. Significant differences in chest movements depending on chair type were observed concerning the breathing duct (upper and lower) and breathing movement amplitude. The amplitude of the upper respiratory track in the first chair was higher (239.4 mV) compared with the second seat (207.3 mV) ($p = .018$). The analyzed parameters of respiratory chest movement may become a helpful indicator for design and selection of chairs which enable people to both work and relax in the most ergonomic conditions.

Keywords: chair; breath; chest breathing movements; sitting posture

1. Introduction

Sitting is the main everyday 'activity' of contemporary people. People sit when driving a car, waiting for an appointment with a physician and, most frequently, working at a desk and a computer. In most cases, typical sitting postures observed today are incorrect and produce several pain syndromes of the motor system, especially among people who spend many hours behind their computers.[1] According to the National Statistical Office, the number of computer owners is constantly growing, and the extensive range of the Internet network has caused a dramatic increase in the time people spend in a sitting position. In 1997, the number of hours spent weekly behind a screen was 5.9, whereas in 2003 it reached 14.6 per week.[2] In view of this trend, it is obvious that the type of chair is a factor of major impact on people's health and work comfort. According to Donkin, a chair shapes a body posture and represents a physical support allowing for efficient performance and implementation of tasks.[3] Incorrect sitting posture impairs both the static and the dynamic balance of the pelvis and the spine.[4,5] However, sitting comfort perception is subjective and may not necessarily be related to an ergonomic chair.[6]

Our choice of a seat is driven by our individual feelings, commercials, appearance and competitive price. Despite an awareness of the impacts of a sitting posture on health, as well as the role of a chair, no objective assessment criteria exist.

A well-functioning respiratory system is the basis of well-being of the whole body. Any deterioration of the respiratory function decreases oxygen saturation of human cells, affecting not only the physical, but also the mental condition. A number of research studies have confirmed the impact of body posture on the respiratory system, chest and diaphragm mobility, as well as on the number and quality of inhalations and exhalations.[7–9] This is triggered by muscle tension disturbances, stretching or shortening of capsulo-ligamentous structures, as well as overloading of the skeletal system, particularly in the spinal discs. Excessive posterior pelvis tilt affects the elimination of lumbar lordosis, and excessive arterial pelvis tilt increases thoracic kyphosis and cervical lordosis, consequently multiplying the spinal burden. Moreover, such a posture affects the performance of the diaphragm as the main human respiratory muscle. Under physiological conditions, the diaphragm falls during inhalation and rises during exhalation. An inclined position prevents proper functioning of this muscle, resulting in increased activity of the upper respiratory duct.[5,10]

The most suitable chair should provide adequate biomechanical conditions for the human motor system, consequently securing appropriate respiration. The aim

---

*Corresponding author. Email: elzbietasz@gmail.com

of the study was to confirm whether chest respiratory movements may be perceived as an indicator of chair quality.

2. Material and methods

The research material comprised 34 subjects, including 18 women and 16 men, aged from 20 to 40 (mean 34.7 years ± 5.2) with body weight ranging from 52 to 87 kg (mean 69.5 kg ± 9.1).

The participants were completely healthy, recruited from the general population, without any respiratory disorders, chest deformations, pain complaints or postural defects.

The study covered respiratory chest movement assessment of the subjects sitting in two different chairs. Both upper (URD) and lower (LRD) respiratory duct function was assessed. The first chair (F1) was typical and commonly available, with adjustable seat and backrest, with no possibility to adjust the seat angle against the ground surface. The seat and the back were connected, which implies that no adjustment of the backrest to the length of the upper part of the body was possible. The backrest had an option to be set at an angle in the range of 95°–100°. The second chair (F2) also had an adjustable seat and backrest. It was possible to set the angle at 105°–110°. Both, the seat and the backrest were movable, which provided a small movement range (~ 15°) both in the sagittal and the frontal planes. The backrest consisted of three separate head, chest and pelvis rests adjustable to the individual body segments. Supporting individual spine sections with a possibility of small movements while sitting, enabled dynamic trunk stabilization. Other features were similar in both types of chair, including the shape of the armrest.

Studies were conducted between 9.00 am and 10.00 am in order to eliminate the impact of fatigue on body posture of the subjects. The task of each subject was to take a seat in the consecutive chairs, adjust the screen, take a comfortable position and start silent reading of the text appearing on the screen. Sitting on each chair took 5–10 min. This time was needed to acclimatize to the chair, take a comfortable position and regulate breathing. Throughout this time breath was registered. When breathing became regular, the subjects were asked to read the text on the screen. For the purpose of the analysis a one-minute record of regular, calm breathing while reading was chosen.

The respiratory chest movements were assessed with the respiratory inductive plethysmography (Embletta Gold, Mediserv International, Warsaw, Poland). This system enables the measurement of the frequency and amplitude of chest respiratory movements. Owing to the RIP (Respiratory Inductive Plethysmograph) technology, all chest (upper respiratory duct) and abdomen (lower respiratory duct) respiratory movement measurements were acquired using the XactTrace inductive method. The XactTrace sensors were located on two belts fixed according to the manual, below the arms and on the navel level. The recording of the chest respiratory movements started from the moment the subjects began reading the text from the screen. A one minute period following a few minutes of free sitting was measured. A fragment of the one-minute record reproduced in RemLogic was selected to assess respiratory movements. The test enabled one to get separate charts reflecting the respiratory movements of the upper and lower chest. The calculation programme allowed for assessment of the respiratory movements on the basis of the following variables: amplitudes of the upper (URD) lower (LRD) respiratory duct, depending on the measured chair, respiratory movement frequency depending on chair type.

The statistical analysis methods: since the data was not distributed according to the standard procedures, it was analysed using the Mann–Whitney *U* test and the Wilcoxon signed rank test. The Spearman rank correlation coefficient was used in order to estimate the analysed variable covariance character. The level of significance was set at 0.05.

3. Results

3.1. *Comparison of respiratory movements of the upper and lower respiratory duct when sitting in the first and the second chair*

Table 1 illustrates average breath amplitudes measured for abdominal (LRD) and chest respiratory ducts (URD) according to the chair used. The analysis of the data comparisons shows that the average abdominal respiratory amplitude for the first chair (245.5 mV) is slightly lower than for the second one (271.2 mV). The noticeable difference is not statistically significant (Wilcoxon signed rank test, $p = .155$). For the chest respiratory duct, noticeable differences also occurred between the respiratory amplitude for the first chair (239.4 mV), and for the second chair (207.3 mV). In that case, the measurements for the first chair reached a higher average level than for the the second one. The difference noted may be considered statistically significant (Wilcoxon signed rank test, $p = .018$). It can be confirmed that for the first chair measurement, a higher amplitude of chest breathing occurs. Examples of records of the chest respiratory movements when sitting in the first chair and in the second chair are given in Figures 1 and 2, respectively.

Table 1. Mean respiratory movement amplitudes of [mV] upper (URD) lower (LRD) respiratory duct, dependent on measured chair.

Type of chair and respiratory duct	Mean	Minimum	Maximum	*SD*
Chair 1 - LRD	245.5	57.6	571.8	137.5
Chair 2 - LRD	271.2	80.2	614.5	151.2
Chair 1- URD	239.4	84.1	534.5	116.7
Chair 2 - URD	207.3	62.2	646.5	134.4

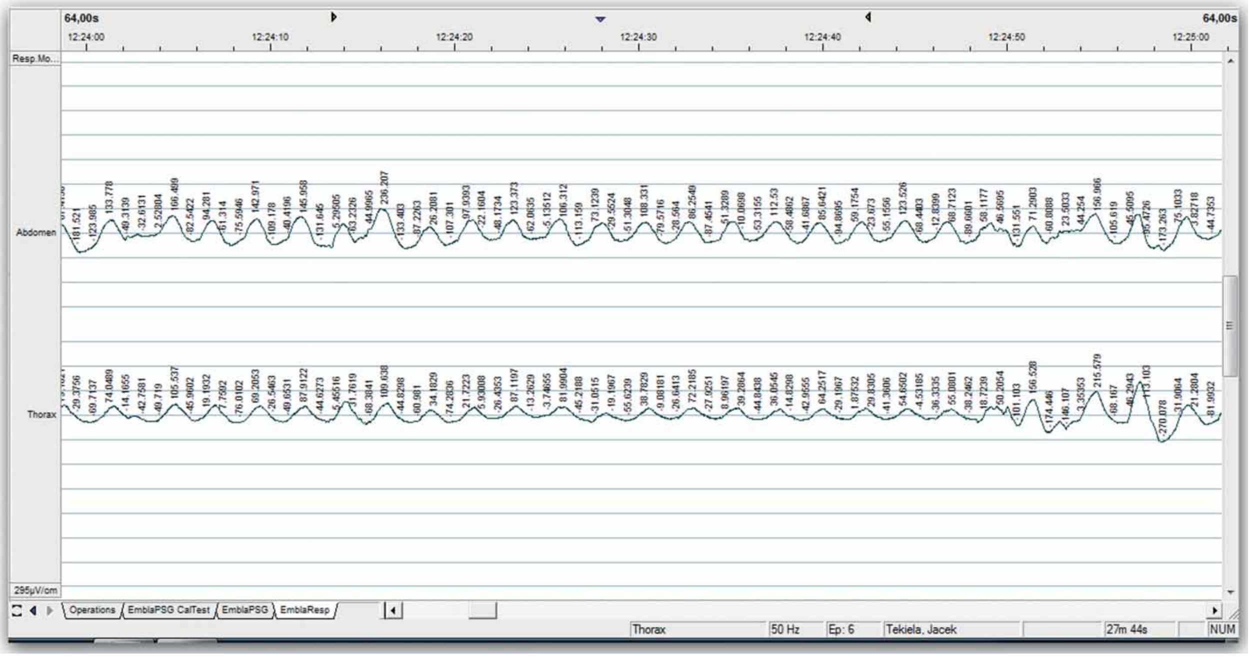

Figure 1. Examples of records of the chest respiratory movements while sitting on the first chair (with adjustable seat and backrest, with no possibility to adjust seat angle relative to the ground surface. The seat and back were connected, which implies that the backrest could not be adjusted to the length of the upper part of the body. The backrest was able to set at an angle in the range of 95°–100°).

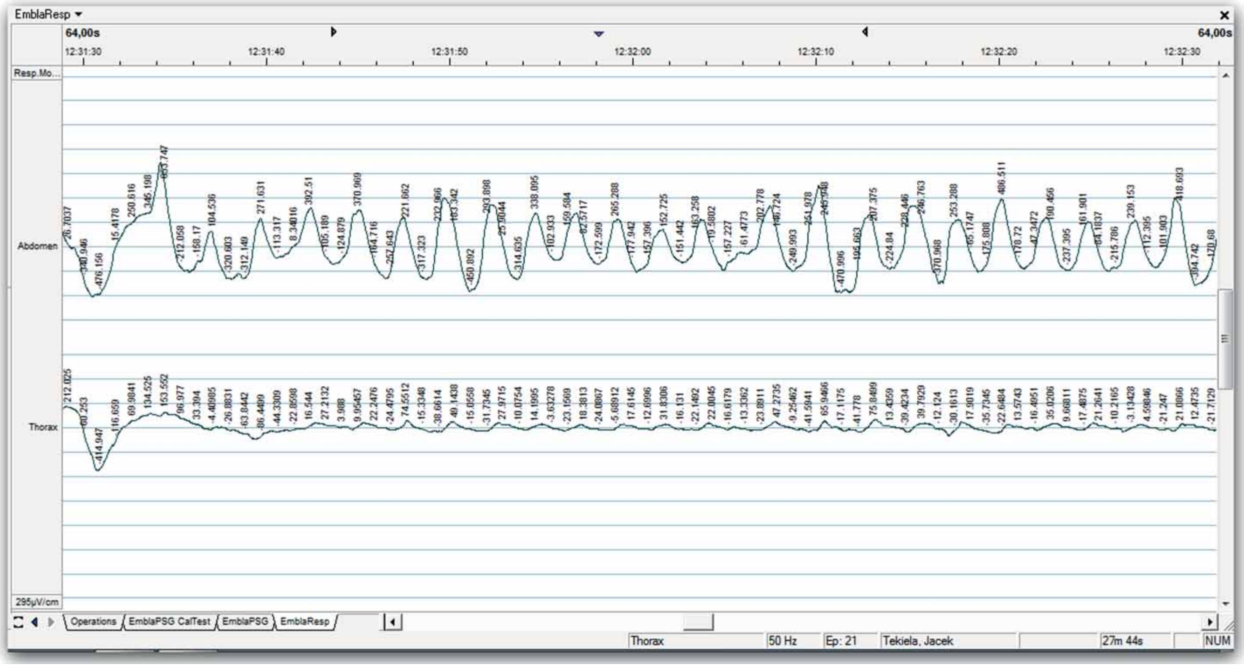

Figure 2. Examples of records of the chest respiratory movements while sitting on the second chair (with adjustable seat and backrest, both, seat and backrest were movable, which provided a small movement range (∼ 15°) both in the sagittal and the frontal planes. The backrest consisted of three separate head, chest and pelvis rests adjustable to the individual body segments. The backrest had the opportunity to be set in the range 105°–110°).

3.2. Comparison of respiration amplitudes depending on the body weight of the subjects and the chair type

Table 2 shows the r Spearman correlations between the body weight and the upper (URD) and lower (LRD) respiratory duct in a sitting position in different chairs. The first chair measurement demonstrated a statistically significant correlation between the body weight and both respiratory ducts. A negative correlation, $R = –0.35$ for the abdominal duct and $R = –0.45$ for the thoracic duct, was observed. This result confirms that the respiratory amplitude measured in the first chair decreases parallel to the increase in body weight. The second chair measurements confirmed correlations between the body weight and the thoracic duct only. A moderate negative correlation is noticeable ($R = -0.35$), indicating that the increase in the body weight decreased the upper duct respiratory amplitude. The result observed reached the threshold significance level (0.05) which makes it difficult to define its statistical significance. Nevertheless, it can be unquestionably stated that the body weight is not relevant to the upper duct respiratory amplitude for the second chair, since a very slight correlation occurs in this case: $R = -0.11$, moreover, the correlation is clearly not statistically significant.

3.3. *Respiratory movements frequency depending on a chair type*

Table 3 illustrates the comparison between the average number of breaths for the two types of chairs. The statistically significant difference (0.7 breaths) occurs between the mean number of breaths for the first (19.1) and the second chair (18.4) (Wilcoxon signed rank test $p = .02$). It should be noticed that the difference of 0.7 breaths observed seems to be minor. It may be, however, attributed to a relatively short observation time (1 min). For longer measurements this difference may be much more significant.

3.4. *Respiratory movements frequency, depending on gender*

The results obtained clearly indicate that no important differences occur between the number of breaths for men and women. None of the four comparisons presented in Table 4 exceeded one breath in terms of mean number of breaths difference between the genders. It can be expected that all differences between the genders presented in Table 4 are statistically insignificant, which is confirmed by the *p* value coefficient for the Mann–Whitney *U* test.

Table 2. R Spearman correlation between weight and upper (URD) and lower (LRD) respiratory duct.

Weight, type of chair, respiratory duct	*R*	*p*
weight & chair 1 - LRD	**–0.35**	**.04**
weight & chair 1 - URD	**–0.45**	**.01**
weight & chair 2 - LRD	–0.11	.53
weight & chair 2 - URD	**–0.35**	**.05**

Note: Bold typeface means statistically significant.

Table 3. Average breaths number for chair types.

The number of breaths, type of chair	Average	Minimum	Maximum	*SD*
breath chair 1	19.1	16	28	2.9
breath chair 2	18.4	13	26	3.0

Table 4. Breath frequency dependent on chair type and gender of the research participants.

Gender	Breaths number Chair 1	*SD*	Breaths number Chair 2	*SD*
Women	19.1	3.24	18.3	3.54
Men	19.2	2.43	18.4	2.13
p Mann–Whitney *U* test	.512	—	.479	—

Table 5. Average respiratory movements amplitudes of [mV] upper (URD) and lower (LRD) respiratory duct dependent on chair type and gender.

Type of chair, respiratory duct, gender		Average amplitude	*SD*	Difference*
Chair 1- URD	Women	295.75	122.19	129.02
	Men	166.73	64.5	
Chair 2-URD	Women	253.52	162.52	106.12
	Men	147.33	56.86	
Chair 1-LRD	Women	232.87	118.29	−14.49
	Men	247.37	163.94	
Chair 2- LRD	Women	218.67	99.78	−107.34
	Men	326.01	176.89	

Note: *Average respiratory amplitude of women minus average respiratory amplitude of men.

3.5. *Amplitude of respiratory movements in relation to the gender and the chair used*

A higher mean thoracic respiratory amplitude and a lower abdominal respiratory amplitude were recorded for women, as compared to men. The differences in thoracic respiration were statistically significant. For the first chair the Mann–Whitney *U* test reached 44.00, $p = .001$, and for the second chair, the Mann–Whitney *U* test reached 71.00, $p = .012$. Table 5

4. Discussion

The sitting posture is an integral part of our life. It has been changing over the centuries, as have the items used for sitting – from simple wooden stools to sophisticated thrones and complex and comfortable chair designs. The chair as an innovation appeared in the 18th century in Scandinavia. Many rational reasons for creating new solutions for sitting posture can be identified. Incorrect sitting posture maintained for a longer period of time may be a cause of many motor disturbances.[11] The latest research confirms the significant impact of the sitting posture on the respiratory system function.[6,8] The study results stress the considerable changeability of the upper and lower chest segment respiratory movements, depending on the orientations of joints and muscle activation.[12] It was confirmed that our different postures are shaped by our trunk muscles' activity, which affects the changeable activity of the upper ribs and lower abdomen ducts.[13,14] A 'stooped' posture results in a lack of proper diaphragm working space, which stimulates the upper respiratory duct, overloading the auxiliary inhale muscles. Such a person would raise their shoulders during the inhalation, which may cause future pain syndrome in the cervical-thoracic segment.[10] A head, with its several kilogram weight, located outside the body axis generates squeezing forces, which eventually leads to upper spinal disc destruction and joint overloading. The upper rib dysfunction develops, blocking the upper duct respiration. At a lower section, it causes lower back segment overload, resulting in pain and weakening of the abdominal and pelvic muscles.

Many trunk muscles fulfil respiratory, postural as well as motor functions, related to joint functioning. The example provided by Whitelaw and Rimmer describes the trunk rotations and breathing as the activation stimulating intercostal, abdominal and spinal muscles. Such competition between the respiratory and postural function differs regarding the sitting posture quality (stooping, twisted) and probably affects respiratory patterns.[15–18] Our research confirms that the chair type used for our work has an impact on chest movements. The research confirmed the differences in the mean respiratory chest amplitude measured for both chairs. The subjects sitting in the 'standard computer chair' typically adopted a stooped posture with a protracted head, forward shoulders and eliminated pelvic lordosis. Our results are confirmed in papers published by Morl. The author states that an individual sitting in a chair is prone to a slump position, flattening of lumbar lordosis and posterior pelvic tilt.[19] The second chair ensured postural alignment of individual segments, additionally securing support for each of them. These conditions decreased thoracic duct activity in the second chair, as compared to the first one. In addition, this chair enabled increased abdominal activity. A decrease in the number of breaths was noticeable. It probably resulted from an increased amplitude of abdominal respiration. Moreover, it seems that a seat angle was important. Lengsfeld showed that the curvature of the lumbar segments of the L1-L2 to L4-L5, remained unchanged when the chair had a reclining backrest with the ability to adjust the seat angle. In chairs without seat adjustment, lumbar lordosis decreased despite support.[20] It seems that the protection of curvatures during sitting is a condition not only for ergonomics [21–23] but also for better breathing. It appears that chairs having supporting elements for the head, chest and lumbar spine enable people to maintain better posture providing better conditions for breathing. Based on this, it seems that the correct chair should offer the option of individual adjustment to the person sitting in it.

Russos and Koutsoukou proved that obese individuals need more energy to perform respiratory activity, with decreased system efficiency. Additionally, their breathing pattern consists of quicker and shallower breaths in order to minimize the shortness of breath caused by obesity.[24] Our research results confirmed the relationship between the subjects' body weight and their respiratory system function, as well as the chair they use. The correlation between body weight increase and respiratory amplitude was recorded for the first chair only. The lack of such correlation for the second chair suggests the need for proper positioning and support of key body segments, such as pelvis, spine and head, in order to facilitate the respiration process for people with obesity.

Fugl-Meyer and Gilbert's research demonstrated a relationship between gender and the respiratory duct. It confirmed that women had lower abdominal duct activity and related respiratory volume as compared to men, in th epeaceful free breathing phase.[25,26] Binazzi documented that women more commonly used the thoracic duct when sitting in a comfortable chair, as compared to men.[27] Our research confirms the tendency of female subjects to use the thoracic duct for breathing. However, the second chair helped them to use the abdominal duct to a much higher extent.

5. Conclusions

The tests carried out showed differences in chest mobility depending on the type of chair on which the individuals under examination were seated. These differences regarded the changes in respiratory path (upper and lower) and the size of respiratory movement amplitude.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

[1] Groszek M, Babula G, Nagraba Ł, Stolarczyk A, Mitek T. Risk connected with a wrong sitting position. Arthrosc Jt Surg. 2011;7(3–4):50–61.

[2] Kang JH, Park RY, Lee SJ, Kim JY, Yoon SR, Jung KI. The effect of the forward head posture on postural balance in long time computer based worker. Ann Rehabil Med. 2012;36(1):98–104.

[3] Leavitt SB, Steward B. Sitting smarter. Health Facil. Manag. 1995;8(6):22.

[4] Cybart G. Bóle dolnego odcinka kręgosłupa i miednicy w aspekcie łącznotkankowego mechanizmu przenoszenia bólu. [Pain in lower back and pelvis in terms of connective mechanism for the transmission of pain]. Akupunkt Pol. 2000;17/18:564–567.

[5] Janda V. Evaluation of muscular imbalance. In: Liebenson C, editor. Rehabilitation of the spine. Baltimore (MD): Williams and Wilkins; 1996. p. 319–328.

[6] Mueller G, Hassenzahl M. Sitting comfort of ergonomic office chairs - developed versus intuitive evaluation. Int J Occup Saf Ergon. 2010;16(3):369–374. DOI:10.1080/10803548.2010.11076853

[7] Crosibie WJ, Myles S. An investigation into effect of postural modification on some aspects of normal pulmonary function. Physiotherapy. 1985;71:311–314.

[8] Butler JE, McKenzie DK, Gandevia SC. Discharge frequencies of single motor units in human diaphragm and parasternal muscles in lying and standing. J Appl Physiol. 2001;90:147–154.

[9] Chang AT, Boots RJ, Brown MG, Paratz JD, Hodges PW. Ventilatory changes following head-up tilt and standing in healthy subjects. Eur J Appl Physiol. 2005;95:409–417.

[10] Hodges P, Heinjnen I, Gandevia S. Postural activity of the diaphragm in reduced in humans when respiratory demand increases. J Physiol. 2001;537(3):999–1008.

[11] Sauter SL, Schleifer LM, Knutson SJ. Work posture, workstation design and musculoskeletal discomfort in a VDT data entry task. Hum Factors. 1991;33(2):151–167.

[12] Lee LJ, Chang AT, Coppieters MW, Hodges PW. Changes in sitting posture induce multiplanar changes in chest wall shape and motion breathing. Respir Physiol Neurobiol. 2010;170(3):236–245.

[13] Floyd WF, Silver PH. The function of the erectores spinae muscles in certain movements and postures in man. J Physiol (Lond). 1955;129:184–203.

[14] Callaghan JP, Dunk NM. Examination of the flexion relaxation phenomenon in erector spinae muscles during short duration slumped sitting. Clin Biomech. 2002;17: 353–360.

[15] Rimmer KP, Ford GT, Whitelaw WA. Interaction between postural and respiratory control of human intercostal muscles. J Appl Physiol. 1995;79:1556–1561.

[16] Whitelaw WA, Ford GT, Rimmer KP, De Troyer A. Intercostal muscles are used during rotation of the thorax in humans. J Appl Physiol. 1992;72:1940–1944.

[17] Andersson EA, Grundstrom H, Thorstensson A. Diverging intramuscular activity paterns in back and abdominal muscles during trunk rotation. Spine. 2002;27: E152–160.

[18] Lee LJ, Coppieters MW, Hodges PW. Differential activation of the thoracic multifidus and longissimus thoracis during trunk rotation. Spine. 2005;30:870–876.

[19] Morl F, Bradl I. Lumbar posture and muscular activity while sitting during office work. J Electromyogr Kinesiol. 2012;23(2):1–6.

[20] Lengsfeld M, Frank A, van Deursen L, Griss P. Lumbar spine curvature during office chair sitting. Med Eng Phys. 2000;22:665–669.

[21] O'Sullivan K, O'Sullivan P, O'Sullivan L, Dankaerts W. What do physiotherapists consider to be the best sitting spinal posture? Man Ther. 2012;17(5):432–437.

[22] O'Sullivan K, O'Keeffe M, O'Sullivan L, O'Sullivan P, Dankaerts W. Perceptions of sitting posture among members of the community, both with and without nonspecific chronic low back pain. Man Ther. 2013;18(6): 551–556.

[23] Claus AP, Hides JA, Morseley GL, Hodges PW. Is 'ideal' sitting posture real? Measurement of spinal curves in four sitting postures. Man Ther. 2009;14(4):404–408.

[24] Roussos C, Koutsoukou A. Respiratory failure. Eur Respir J Suppl. 2003;47:3–14.

[25] Fugl-Meyer AR. Relative respiratory contribution of the rib cage and the abdomen in males and females with special regard to posture. Respiration. 1974;31:240–251.

[26] Gilbert R, Auchincloss JH, Peppi D. Relationship of rib cage and abdomen motion to diaphragm function during quiet breathing. Chest. 1981;80:607–612.

[27] Binazzi B, Lanini B, Bianchi R, Romagnoli I, Nerini M, Gigliotti F, Duranti R, Milic-Emili J, Scano G. Breathing pattern and kinematics in normal subjects during speech, singing and loud whispering. Acta Physiol. 2006;186: 233–246.