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Breathing parameters in healthy men and women in supine, sitting, and standing positions

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Abstract. The present study aimed to investigate the relationship between postural stability, external breathing, and sex, as this area of research is not yet well explored. The study included 19 healthy participants, both male and female, and compared their breathing parameters in three positions: sitting, standing, and supine. The objective was to collect data to develop a non-contact method for recording external respiration. The analysis included measurements of vital capacity and forced vital capacity pulmonary tests, as well as parameters of natural breathing. We confirmed that the lung volume component was higher in males than in females in the sitting position. Additionally, postural influence on breathing was observed only in male participants, with no significant impact on females. Men also exhibited an increased respiratory rate in both standing and supine positions, as well as increased minute ventilation when standing as compared to sitting. Furthermore, men demonstrated higher maximum inspiratory and expiratory vital capacities in all positions as compared to women. These results have important implications not only for the development of non-contact methods for recording respiration but also in the studies of vertical stance, in clinical investigations.

Keywords: external breathing, tidal volume, vital capacity, respiratory rate, sex differences, posture

Introduction

The human vertical pose is affected by the breathing parameters (Neiva et al. 2018), and vice versa, the parameters of external breathing depend on the human pose (Kocjan et al. 2017). The same complex relationship exists between sex and breathing, and between sex and posture. Morphological and functional differences exist between the male and female pulmonary systems (Dominelli, Molgat-Seon 2022). Moreover, the relationship between sex and postural stability is also complex (Dean et al. 2020).

There is a lack of comprehensive information on the mechanisms of maintaining an upright stance in humans, particularly with regards to sex-based differences in external respiration parameters. To investigate these mechanisms non-contact methods for recording external respiration parameters are needed. We studied the breathing parameters of healthy men and women in standing, sitting, and supine positions to create the non-contact method for recording external respiration.

Methods

Subjects

Twenty volunteers participated in the study (ten males) (Table 1). Four men are smokers, all women are non-smokers. The subjects, by signing an informed consent to participate in the study, confirmed that they were healthy. To check the normal state of the respiratory system, we determined the Tiffeneau-Pinelli index.

Protocol

Seven recordings of breathing parameters were performed in the following order:

1) sitting position: vital capacity and forced vital capacity pulmonary tests were conducted three times each;
2) sitting position; natural breathing; 1 min;
3) sitting position; vital capacity pulmonary tests, three times each;
4) standing position; natural breathing; 1 min;
5) standing position; vital capacity tests, three times each;
6) supine position; natural breathing; 1 min;
7) supine position; vital capacity tests, three times each.

All pulmonary tests were performed in accordance with the Guidelines of the Russian Respiratory Society (Aysanov et al. 2021).

Equipment

The Diamant KM-AP-01 clinical spirograph (Diamant LLC, Russia) was used for recording No. 1. The system combining PowerLab C, Octal Bio Amp and Spirometry Pod with a 1000 L respiratory flow head (ADInstruments Pty Ltd, Australia) was used for recordings No. 2–7.

Before each recording of the breathing, the equipment was calibrated using a one-liter calibration syringe.

Tested breathing parameters

The following breathing parameters were obtained in recording No. 1: tidal volume (TV) calculated from the forced vital capacity test, inspiratory vital capacity (IVC), expiratory vital capacity (EVC), forced vital capacity (FVC), forced expiratory volume in the first second during forced exhalation after maximal inspiration (FEV1), peak expiratory flow (PEF), and the FEV1/FVC ratio (Tiffeneau-Pinelli index).

In recordings No. 2–7, the following parameters were registered: TV from the entire recording, minute ventilation (MV), respiratory rate (RR), maximum inspiratory vital capacity (IVC_{max}), and maximum expiratory vital capacity (EVC_{max}). To register IVC_{max} and EVC_{max}, we asked participants to perform 3–5 series of maximum inspiration followed by maximum expiration.

Statistical analysis

Data were presented as median ± standard deviation and extremum range. Comparisons between sexes for anthropometric variables were performed using the Mann-Whitney test. Paired comparisons within sex subgroups were performed using the Wilcoxon signed-rank test for dependent variables. Spearman's correlation analysis was used.

Results

One of the twenty participants, a 36 years old male had an FEV1/FVC ratio of 63% which indicated airway obstruction (Swanney et al. 2008), therefore we excluded his data from further analysis. The remaining participants had an FEV1/FVC ratio of over 75% (94.6 ± 4.6%) which demonstrates

Table 1. Anthropometric parameters

	Men (N = 9)	**Women (N = 10)**	**p-value[1]**
Age (years)	31.5 ± 12.7 [18–55]	27.2 ± 9.4 [24–48]	$p > 0.05$
Weight (kg)	78.1 ± 27.5 [67–160]	60.1 ± 8.2 [60–78]	$p < 0.01$
Height (cm)	179.5 ± 5.7 [172–191]	169 ± 5.7 [158–175]	$p < 0.01$

Note: [1]—comparison between men and women.

the absence of obstructive and restrictive lung disease (Forced Expiration 1995).

The anthropometric characteristics of the entire group were divided based on sex (Table 1). The two sex subgroups were homogeneous in age but differed in weight and height ($p < 0.01$).

The results of the study showed significant differences in TV, IVC, EVC, FVC, and PEF between men and women obtained from recording No. 1 (Table 2). FEV1 and FEV1/FVC ratio did not differ significantly. Men have higher TV, IVC, EVC, FVC, and PEF compared to women. These results are consistent with the global reference values for static lung volumes in individuals of European ancestry for men and women (Hall et al. 2021). However, there are currently no reference values for standing and supine positions.

The Spearman's correlation analysis showed that breathing parameters obtained in the sitting position were highly influenced by sex (Fig. 1). There were significant negative ($p < 0.01$) correlations between sex and breathing parameters which indicates differences between female and male breathing patterns. Women had lower TV, IVC, EVC, FVC and PEF (correlation coefficients were –0.70, –0.73, –0.60, –0.51 and –0.61, respectively). The lung volume components also correlated with weight and height (Dominelli, Molgat-Seon 2022), which were higher in the men in our study group. There were also expected significant correlations between FVC and EVC (0.85, $p < 0.001$), PEF and all volume characteristics regardless of sex. At the same time correlation between these volume breathing parameters in the subgroups was not similar in all cases. Coefficients in pairs EVC/FVC and EVC/PEF were over 0.7 ($p < 0.01$) in the female subgroup, and these ones were ~0.5 (non-significant) in the male subgroup.

To analyse the impact of posture, we used the sitting position as a control measurement and

Table 2. Respiratory parameters of males and females differed significantly in the sitting position ($p < 0.05$)

Sex	TV (l)	IVC (l)	EVC (l)	FVC (l)	PEF (l/s)
Male	1.06 ± 0.29	4.19 ± 1.04	5.07 ± 0.96	4.67 ± 1.08	9.96 ± 2.50
Female	0.63 ± 0.68	2.61 ± 0.55	3.62 ± 0.74	3.39 ± 0.82	6.96 ± 1.74

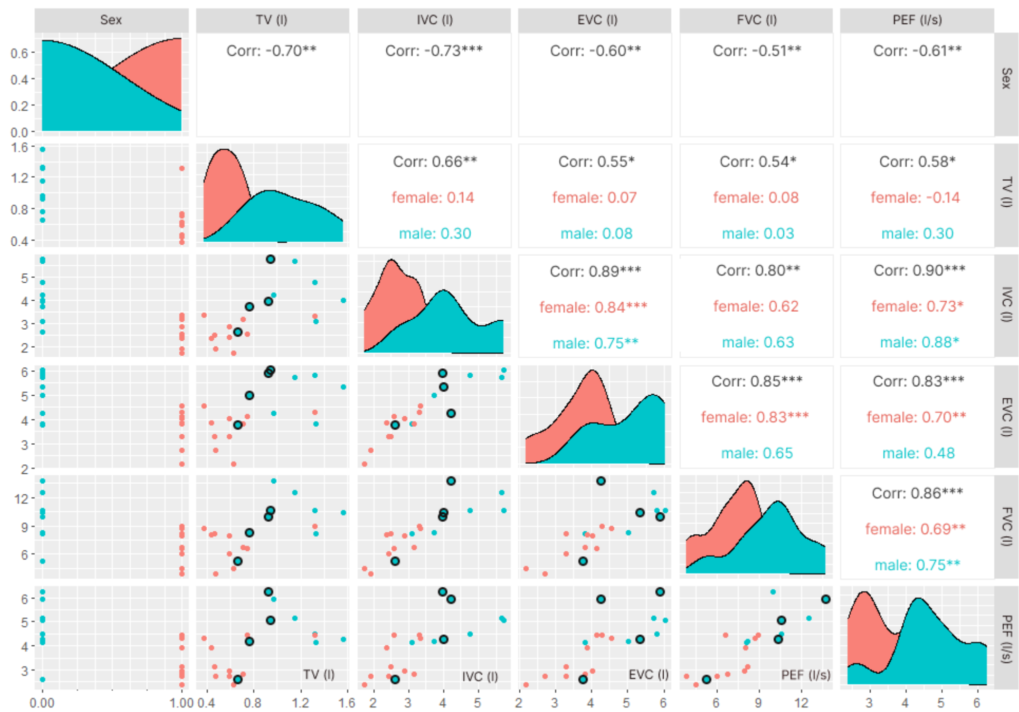

Fig. 1. Spearman's correlations between breathing parameters in sitting position grouped by sex. Correlations between breathing parameters and sex are shown in black font at the first row. Correlations between breathing parameters ungrouped by sex are shown in black font in all other rows. Correlations grouped by sex are shown in red (female) and blue (male) fonts. *—$p < 0.05$, **—$p < 0.01$, ***—$p < 0.001$. Density plots are arranged diagonally, scatter plots are presented under the diagonal. The breathing data of smokers are circled in black

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compared natural breathing data in the standing and supine positions separately in each subgroup (Table 3). The results showed that RR significantly increased in the supine and standing positions in men, while MV increased only in the standing position, whereas there were no changes in TV. The position did not affect breathing parameters in women. There were also statistically different TV values in the supine position between the two subgroups.

We calculated IVC_{max} and EVC_{max} from recordings No. 3, No. 5 and, No. 7 (Table 4). The data corresponds with the results obtained from natural breathing. Two subgroups showed statistically different IVC_{max} and EVC_{max} in all the registered positions (Table 4; Fig. 2).

Influence of smoking on breathing parameters

We checked whether the obtained difference in the parameters of male and female breathing is associated with the presence of smokers in the male group. The analysis was repeated after excluding the data of four smokers and it showed the same correlations as demonstrated in Fig. 1 (–0.70, –0.72, –0.64, –0.62 and –0.62 for TV, IVC, EVC, FVC and PEF, respectively, without smokers). The breathing data of four smokers was plotted in Fig. 1 and their TV, EVC, IVC and PEF were evenly distributed among the data of non-smokers.

Conclusion

The significant differences in lung volume component between male and female subgroups observed in the sitting position were not revealed in the standing and supine positions. The position did not affect breathing parameters in women. The postural influence was observed in the male subgroup with a significant increase in RR in standing and supine positions and increased MV in the standing

Table 3. Spirometry data by sex in supine, sitting and standing positions during natural breathing

Sex	Position	TV (l)	MV (l)	RR (bpm)
Male	Supine	$0.78 \pm 0.20^{\alpha}$	11.10 ± 5.20	$14.05 \pm 4.10^{\beta, \gamma}$
	Sitting	0.80 ± 0.13	10.65 ± 2.85	13.25 ± 3.10
	Standing	0.73 ± 0.16	$13.00 \pm 4.73^{\beta}$	$15.95 \pm 4.01^{\beta}$
Female	Supine	0.56 ± 0.08	9.64 ± 2.93	18.60 ± 3.06
	Sitting	0.52 ± 0.25	9.25 ± 4.12	15.90 ± 2.70
	Standing	0.55 ± 0.21	9.40 ± 3.96	17.10 ± 2.38

Note: $^{\alpha}$—$p < 0.05$ with female supine, $^{\beta}$—$p < 0.01$with male sitting, $^{\gamma}$—$p < 0.01$ with male standing.

Table 4. IVC_{max} and EVC_{max} of males and females

Sex	Position	$IVC_{max (l)}$	$EVC_{max (l)}$
Male	Supine	$9.7 \pm 3.3^{\alpha}$	$9.8 \pm 3.2^{\alpha}$
	Sitting	$11.8 \pm 3.5^{\beta}$	$12.2 \pm 3.5^{\beta}$
	Standing	$9.8 \pm 4.7^{\gamma}$	$11.4 \pm 4.5^{\gamma}$
Female	Supine	7.35 ± 1.8	7.4 ± 1.9
	Sitting	7.5 ± 1.7	7.9 ± 1.8
	Standing	7.9 ± 1.8	7.8 ± 1.9

Note: $^{\alpha}$—$p < 0.01$ with female supine, $^{\beta}$—$p < 0.01$with female sitting, $^{\gamma}$—$p < 0.05$ with female standing.

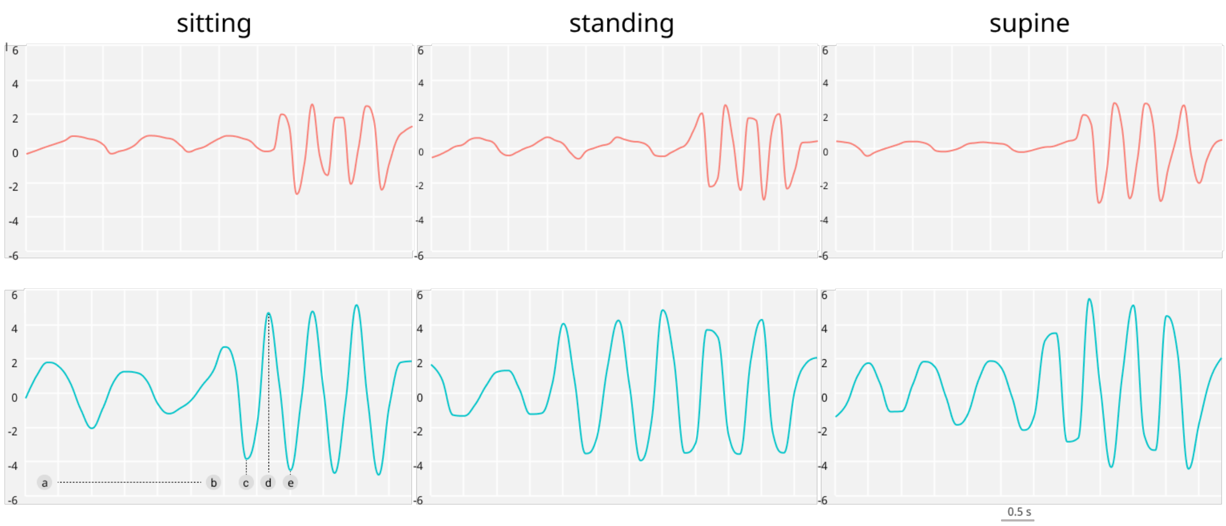

Fig. 2. Individual IVC_{max} and EVC_{max} in all registered positions in female EA, 42 y.o. at the upper part and male OV, 30 y.o. From a to b—natural breathing, from c to d—IVC_{max}, from d to e—EVC_{max}.

compared to the sitting position. Men also had statistically higher IVC_{max} and EVC_{max} in all positions compared to women.

The results obtained can be used in studies of the participation of respiration in maintaining vertical balance, in clinical studies. The authoritative clinical guidelines for spirometry (Graham et al. 2019) say that posture affects respiratory performance and there is no information that posture effects are different in the male and female subgroups. These data will be used for the development of non-contact methods for recording respiration.

Conflict of Interest

The authors declare that there is no conflict of interest, either existing or potential.

Ethics Approval

The procedures and investigations were approved by the Ethics Committee of Pavlov Institute of Physiology RAS (minutes No. 22–06, date of approval 3 November 2022) and were performed in accordance with the Declaration of Helsinki.

Author Contributions

a. Natalia D. Shandybina—methodology, writing an article;

b. Sergey S. Ananev—investigation;

c. Tatiana A. Klishkovskaia—data processing;

d. Andrey Yu. Aksenov—data processing;

e. Tatiana R. Moshonkina—methodology, writing an article, supervision.

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References

Aysanov, Z. R., Kameneva, M. Yu., Chernyak, A. V. et al. (2021) *Spirometriya. Rukovodstvo Rossijskogo respiratirnogo obschestva [Spirometry. Guidelines of Russian Respiratory Society]*. [Online]. Available at: https://spulmo.ru/upload/spirometriya_16_12_2021_extEd.pdf?t=1 (accessed 05.02.2023). (In Russian)

Dean, C. J., Sell, T. C., Robertson, A. M. (2020) Sex-based differences in postural stability: A systematic review. *Duke Orthopedic Journal*, vol. 10, no. 1, pp. 1–9. (In English)

Dominelli, P. B., Molgat-Seon, Y. (2022) Sex, gender and the pulmonary physiology of exercise. *European Respiratory Review*, vol. 31, no. 163, article 210074. https://doi.org/10.1183/16000617.0074-2021 (In English)

Forced Expiration. (1995) *Johns Hopkins University*. [Online]. Available at: https://oac.med.jhmi.edu/res_phys/encyclopedia/forcedexpiration/forcedexpiration.html (accessed 28.01.2023). (In English)

Graham, B. L., Steenbruggen, I., Miller, M. R. et al. (2019). Standardization of spirometry 2019 update. An official American thoracic society and European respiratory society technical statement. *American Journal of Respiratory and Critical Care Medicine*, vol. 200, no. 8, pp. e70–e88. https://doi.org/10.1164/rccm.201908-1590ST (In English)

Hall, G., Filipow, N., Ruppel, G. et al. (2021) Official ERS technical standard: Global Lung Function Initiative reference values for static lung volumes in individuals of European ancestry. *European Respiratory Journal*, vol. 57, no. 3, article 2000289. https://doi.org/10.1183/13993003.00289-2020 (In English)

Kocjan, J., Adamek, M., Gzik-Zroska, B. et al. (2017) Network of breathing. Multifunctional role of the diaphragm: A review. *Advances in Respiratory Medicine*, vol. 85, no. 4, pp. 224–232. https://doi.org/10.5603/ARM.2017.0037 (In English)

Neiva, P. D., Kirkwood, R. N., Mendes, P. L. et al. (2018) Postural disorders in mouth breathing children: A systematic review. *Brazilian Journal of Physical Therapy*, vol. 22, no. 1, pp. 7–19. https://doi.org/10.1016/j.bjpt.2017.06.011 (In English)

Swanney, M. P., Ruppel, G., Enright, P. L. et al. (2008) Using the lower limit of normal for the FEV1/FVC ratio reduces the misclassification of airway obstruction. *Thorax*, vol. 63, no. 12, pp. 1046–1051. https://doi.org/10.1136/thx.2008.098483 (In English)