DOI: 10.1590/1809-2950/18010326032019

ORIGINAL RESEARCH

Change in biomechanics of sitting posture affects the pulmonary function

Mudança na biomecânica da postura sentada afeta a função pulmonar

Alteración en la biomecánica de la postura sentada afecta la función pulmonar

Adriana Maria Contesini[1], Thiago Henrique da Silva[2], Francis Meire Favero[3], Silvana Maria Blascovi-Assis[4], Mariana Callil Voos[5], Fátima Aparecida Caromano[6]

ABSTRACT | The objective of this study was to characterize the postures induced by two different chair-desk systems and analyze their effects on lung function. This was a cross-sectional, descriptive study of single subject with intra-series type analysis (A-B, B-A) during consecutive days of data collection. Fifteen volunteers participated using two chair-desk systems: conventional (A) and experimental (B). Postural evaluation was performed in both systems using photogrammetry. These images were analyzed using AutoCAD 2010, estimating the average position of the joint angles of individuals in each system. These values were analyzed verifying the averages in each posture. Postural and respiratory data were compared by checking whether the different positions adopted by the participants resulted in changes in the spirometry values. Conventional chair-desk system promoted two different postural patterns, considering that one presented joint angles similar to experimental system, with similar spirometry results and the other presented body angles according to the reference of standards and spirometry results significantly lower in FEV_1, FEV_1/FVC and FEF_{max}. Experimental system differed from values of literature in standing posture only in FEF_{max}, suggesting similarity of postural situation. It was concluded that the experimental furniture proved a tool capable of benefiting respiratory function in sitting posture and may be an option to benefit people in special conditions such as pregnant women, obese individuals and people with chronic pulmonary diseases.

Keywords | Posture; Respiratory Mechanics; Spirometry; Ergonomics.

RESUMO | Este trabalho teve como objetivo caracterizar as posturas induzidas por dois sistemas diferentes de cadeira-mesa e analisar seus efeitos na função pulmonar. Trata-se de estudo transversal, descritivo, do tipo sujeito único e intrasséries (A-B, B-A), com coleta em dias consecutivos. Participaram da pesquisa 15 voluntárias e foram utilizados dois sistemas cadeira-mesa: convencional (A) e experimental (B). A postura foi avaliada por meio de fotogrametria em cada um dos sistemas, com imagens analisadas por meio do programa AutoCAD 2010. Posteriormente, foram calculados os ângulos articulares da postura média das participantes em cada sistema. Os dados posturais e respiratórios foram comparados considerando as diferentes posições adotadas. O sistema cadeira-mesa convencional promoveu dois diferentes padrões posturais: um deles apresentou ângulos articulares similares aos do sistema experimental, com resultados de espirometria semelhantes, e o outro padrão apresentou ângulos corporais de acordo com os padrões esperados com valores de espirometria significativamente inferiores em VEF_1, VEF_1/CVF e $FEF_{máx}$. O sistema experimental diferiu de valores de espirometria da postura ortostática relatados na literatura somente em $FEF_{máx}$, sugerindo similaridade de condição postural. Conclui-se que o mobiliário experimental melhorou a função respiratória na postura sentada em comparação com o mobiliário tradicional, podendo beneficiar pessoas em condições especiais, como gestantes, obesos e pessoas com doenças pulmonares crônicas.

Descritores | Postura; Mecânica Respiratória; Espirometria; Ergonomia.

[1]Universidade de São Paulo (USP) – São Paulo (SP), Brazil. E-mail: dricontesini@hotmail.com. Orcid: 0000-0002-2535-0942
[2]Universidade de São Paulo (USP) – São Paulo (SP), Brazil. E-mail: thiagohenrique@usp.br. Orcid: 0000-0002-3502-6687
[3]Universidade Federal de São Paulo (Unifesp) – São Paulo (SP), Brazil. E-mail: ffave.nexp@latoneuro.com.br. Orcid: 0000-0001-8063-8167
[4]Universidade Presbiteriana Mackenzie – São Paulo (SP), Brazil. E-mail: silvanablascovi@mackenzie.br. Orcid: 0000-0002-5437-891X
[5]Universidade de São Paulo (USP) – São Paulo (SP), Brazil. E-mail: marivoos@usp.br. Orcid: 0000-0001-6252-7287
[6]Universidade de São Paulo (USP) – São Paulo (SP), Brazil. E-mail: caromano@usp.br. Orcid: 0000-0001-5258-2960

Corresponding address: Fátima Aparecida Caromano – Rua Cipotânea, nº 51, Cidade Universitária – São Paulo (SP), Brazil – Zip Code: 05360-000 – E-mail: caromano@usp.br –
Finance source: None – Conflict of Interest: Nothing to declare – Presentation: Mar. 26th, 2018 – Accepted for publication: Mar. 16th, 2019 – Approved by the Research Ethics Committee of Hospital das Clínicas da Faculdade de Medicina of Universidade de São Paulo under protocol nº 0886/08.

RESUMEN | Este estudio tuvo como objetivo caracterizar las posturas inducidas por dos sistemas diferentes de silla-mesa y analizar sus efectos sobre la función pulmonar. Se trata de un estudio transversal, descriptivo, de tipo de un solo sujeto e intraseries (A-B, B-A), con recolección en días consecutivos. Quince voluntarios participaron en el estudio, y se utilizaron dos sistemas de silla-mesa: convencional (A) y experimental (B). La evaluación postural se realizó mediante fotogrametría en cada uno de los sistemas, con imágenes analizadas por medio del programa AutoCAD 2010. Posteriormente, se calcularon los ángulos de articulación de la postura media de las participantes en cada sistema. Los datos posturales y respiratorios se compararon considerando las diferentes posiciones adoptadas. El sistema de silla-mesa convencional promovió dos patrones posturales diferentes: uno presentó ángulos de articulación similares al sistema experimental, con resultados de espirometría similares, y el otro estándar presentó ángulos corporales de acuerdo con los patrones esperados con resultados de espirometría significativamente más bajos en VEF_1, VEF_1/CVF y FEF_{max}. El sistema experimental difería de los valores de espirometría de la postura ortostática informados en la literatura solo en FEF_{max}, lo que sugiere una similitud de la condición postural. Se concluyó que los muebles experimentales pueden mejorar la función respiratoria en la posición sentada cuando se comparaban con los muebles tradicionales, y pueden beneficiar a personas en condiciones especiales, como mujeres embarazadas, personas obesas y personas con enfermedades pulmonares crónicas.
Palabras clave | Postura; Mecánica Respiratoria; Espirometría; Ergonomía.

INTRODUCTION

Sitting is the posture most frequently adopted by human beings[1], being induced by the furniture used, which leads to the adoption of certain postural standards[2]. Thus, this position has direct effects on the musculoskeletal[3], respiratory[4], circulatory[5] and metabolic[6] systems, negatively compromising the human body when related to a sedentary lifestyle[7].

The time spent in the sitting posture has recently generated great interest among health researchers, employers and employees, as well as attracted significant attention from media outlets[8]. Recent internationally recognized health guidelines recommend that adults should reduce the daily number of hours they stay in this posture, which increases the risks related to sedentary lifestyles[9,10]. Sitting significantly affects the human respiratory mechanics, and when there is no back support, the activation of respiratory muscles is increased, resulting in increased current volume[11]. Regarding the inclined sitting posture, other aspects are also unequal such as the inhalation of particles, possibly due to changes in the regional distribution of ventilation between these postures[4].

The type of chair used affects the postural support, muscle activity, relief of intradiscal pressure, lung function, mobility and comfort[12]. In the sitting posture considered ideal by Western standards, the individual must keep the hips flexed at approximately 90°, which causes a correction or reversal of lumbar curvature[2], the anterior superior displacement of abdominal contents, and a decrease in the ideal position of the abdominal and diaphragm muscles, reducing their contraction capacity[13]. Respiratory function adapts to this position due to these changes, which is also affected by the type of back support and may generate a discrete constraint on thoracic expansion[13,14].

Given that different types of furniture can cause changes in respiratory function, the use of adapted types can minimize possible harmful effects of sitting posture in the respiratory mechanism. There are few studies on this subject. Thus, it is necessary to evaluate the different sitting posture parameters and their relationship with breathing.

The objective of this study was to characterize the postures induced by two different chair-desk systems and analyze the effects of these postures in lung function.

METHODOLOGY

Participants and ethical considerations

The study sample was defined by convenience and included 15 female volunteers. Inclusion criteria were: university students regularly enrolled in a public university, Caucasian, right-handed, healthy, sedentary, with a body mass index (BMI) between 18.5kg/m^2 to 24.9kg/m^2 [15]. The choice of the Caucasian population was related to differences in patterns of sitting posture derived from cultural habits[1] and possible variations in body structure by ethnic differences[16]. The decision to exclusively evaluate women considered the anatomical and physiological differences between the sexes that could affect the results.

All participants were informed about the procedures involved in the study and signed an informed consent form.

Statistical analysis

The power of the sample was calculated by the GPower 3.0 program. Sample size was calculated based on two variables (forced vital capacity and pelvis bending angle in sitting position), considering the statistical design of the F test for repeated measures (effect between and within groups), with moderate effect size (f=0.3), 80% statistical significance level and 5% alpha error, which resulted in n=15. Data collected were treated with descriptive statistical analysis, and Student's t test for comparisons between groups.

Furniture used

Two different chair-desk systems were chosen specifically for the hip angle induction. Conventional furniture (system A) corresponded to the classical concept of standard chair-desk system to remain in a sitting posture, in which the chair induces an angle of approximately 90° between the hip and knees[1,2,17]. The desk surface presented a right angle (90°) in relation to its vertical axis.

In the experimental furniture (system B), the experimental seat (kneeling chair) was chosen to maintain the lumbar curvature, increasing the hip bending angle[18], and the table presented a 20° surface inclination, providing greater visual comfort, induce less cervical flexion and providing better support for the forearms[19].

In system A, the wooden table was 1.00m high, and its surface was 1.00m x 0.80m, placed in horizontal axis. The chair had adjustable height, with a 30cm x 30cm seat, at 0° in relation to the horizontal axis, and adjustable height for the lumbar support. In system B the table surface presented a 20° inclination, and the chair was 50 cm high from the ground, 33cm x 43cm seat and 30° inclination in relation to the horizontal support for the knees, which presented 30cm x 43cm surface and 25° inclination in relation to the horizontal axis.

The sequence of use of each furniture system was defined by sorting by each participant. Two envelopes were prepared, and sequence 1 correspond to the following order: A-B, B-A, A-B, B-A, A-B; and sequence 2 to: B-A, A-B, B-A, A-B, B-A. The participants had prior individual contact with each of the furniture systems used in this experiment for a period of one hour, one month before the start of data collection for acclimatization and, during the experiment, they were instructed to take the most comfortable posture in each furniture, so as not to induce specific positions.

The time of stay in each furniture system was based on a study by Corlett & Bishop[20], according to which, maintaining an improper posture can last at most for 1 to 5 minutes until pain begins to appear. Since this study did not seek to analyze the comfort of the systems, an intermediate period of three minutes was chosen.

Data collection

The participants were divided into three groups, and each group participated for five consecutive days to conduct the evaluations.

During these five days, from 9 am to 11 am, the participants were received individually in a 4 x 6 m room with controlled lighting and constant temperature at 26 °C, dressed in bathing suits and their hairs were tied up.

Height and weight measurements were taken using clinical scale brand Filizzolla®, and the markings – by palpation – of anatomical landmarks to be evaluated used references cited in the tutorial of the program *Software para Avaliação Postural* (Software for Postural Assessment – SAPO)[21,22], the analyzed landmarks were: tragus, C7 vertebra, acromion, lateral epicondyle, distal ulna, greater trochanter of the femur, knee joint line, and lateral malleolus, which were labeled with stickers and 1 cm polystyrene balls on the right hemibody part[22,23].

Following, the participants rested lying in supine position[24] for five minutes, according to the recommendations of the *Consenso Brasileiro de Espirometria* (Brazilian Spirometry Consensus)[25]; after this period, the participants underwent a pulmonary function test in standing position using a Microquark spirometer of Cosmed Brand®. The examination in the standing posture was conducted to eliminate the possibility of any respiratory clinical complications in the day of the experiment, and was later used as data benchmark.

Following, the participants sat in the selected furniture system, rested for five minutes, underwent another pulmonary function test and performed a graphical activity for three minutes[26]. Another respiratory test was conducted at the end of this period.

This graphic activity – based on the reproduction of simple geometric designs such as squares and triangles – was developed specifically for this study, based on psychological tests reproducing geometric shapes with increasing complexity levels[26]. In this case, the focus was to maintain the participants' attention on the activity itself and not on the posture/furniture. After another five-minute rest period, the procedure was repeated on the second furniture system. The participants were then dispensed to return on the following day, at the same time. These procedures were applied by a single previously trained researcher.

Images were collected by filming the participants from the right side view using a Canon PowerShot® SX30 IS 14.1 megapixels digital camera, with 30 frames per second recording capability, positioned parallel to the ground level by one meter and half tall tripod, four meters away from the furniture used, both aligned using a level. Thus, the distance and height of the camera in relation to the participant were determined considering the physical characteristics of the collection site, the lighting and the technical characteristics of the equipment. Specifically in this study, the protocol proposed by the SAPO postural evaluation method does not allow good observation of the furniture, since it was not designed for this purpose.

The vertical reference was obtained from a plumb bob fixed to the ceiling, suspended one meter away from the posterior-lateral right angle of the table, after the chair.

After filming, photographs were selected by photographs by frames of each recording using the option "montage" in the Real Media Player Basic program, which allows images to be saved in JPEG format. The first frame corresponded to the starting position of the individual and, following, a frame was captured every five seconds, totaling 38 frames per experiment, 76 frames per day and 380 frames per participant, for 5,700 photographs taken in the full experiment.

Image analysis was performed using the AutoCAD® 2010 program for the measurement of angles related to the previously marked anatomical landmarks[27]. These angles were tabulated using the program Excel® 2010, estimating its simple mean and standard deviation, and determining the mean position of individuals in each furniture system.

Based on these data, a diagram characterizing the most common posture of each participant for each of the systems was prepared using the Compass and Ruler program, according to the group's mean posture with the sole purpose of facilitating the observation of the patterns found (Figure 1). Data comparison between groups used Wilcoxon's test and Student's t test.

The collection of these data was performed by a computer technician, expert in AutoCAD® and user of the Compass and Ruler program.

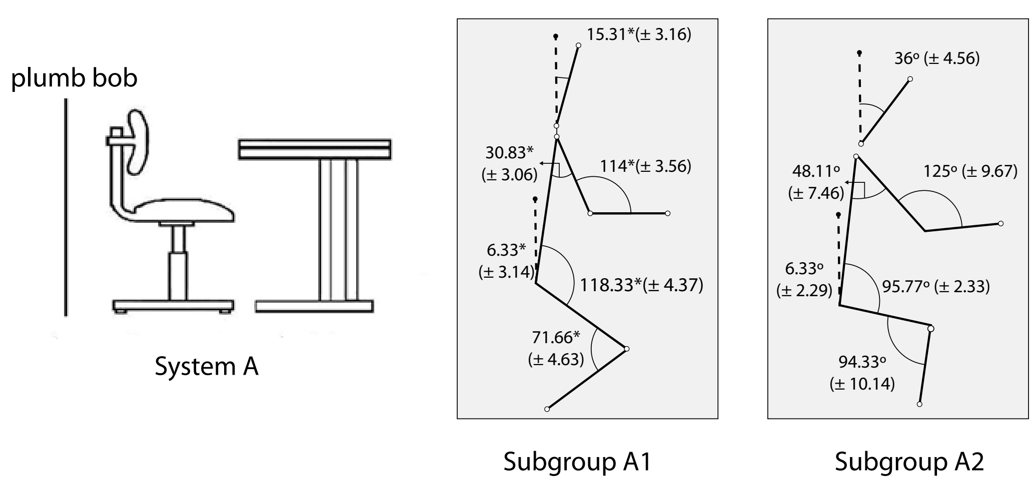

Figure 1. Postures induced by standard chair-desk system (system A)

Regarding the pulmonary evaluation, the tests followed the international standard, measuring forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), FEV_1/FVC relationship, forced expiratory flow between

25% and 75% of FVC (FVC25-75%) and peak expiratory flow (FVC_{max})[28].

This evaluation was performed by a pulmonologist specialized in pulmonary function test; the evaluator was blind to the study.

The values found were analyzed by calculating the means of each posture. Postural and respiratory data were analyzed to check the relationships between the different positions adopted by the participants, and if these resulted in changes in spirometric values.

RESULTS

Characterization of participants

The participants were characterized according to the following variables: age, height and weight, with 19.3±1.9 years (18 to 22 years) as the mean age, 162±2.3cm (149cm to 174cm) mean height, and 59.61±4.85kg (52.7kg to 67.5kg) mean weight.

Regarding the sequence of use of furniture systems, participants 4, 6, 8, 9, 13, 14 and 15 performed sequence 1, and participants 1, 2, 3, 5, 7, 10, 11 and 12 performed sequence 2.

Postural characteristics promoted by the two systems

Regarding the collection of data from postural angles, we conducted the statistical analysis using the programs Excel 2010, Minitab v.14 and Statistica v.8. The normality of each variable was tested by the Kolmogorov-Smirnov test, followed by Bartlett's and Levene's tests to confirm their homogeneity.

We prepared a joint diagram based on the postural angles (means and standard deviations) promoted by the systems A and B, representing the mean position shown by the members of each group. When analyzing these diagrams, two subgroups with distinct postural patterns were identified in system A, A1 and A2 (Figure 2).

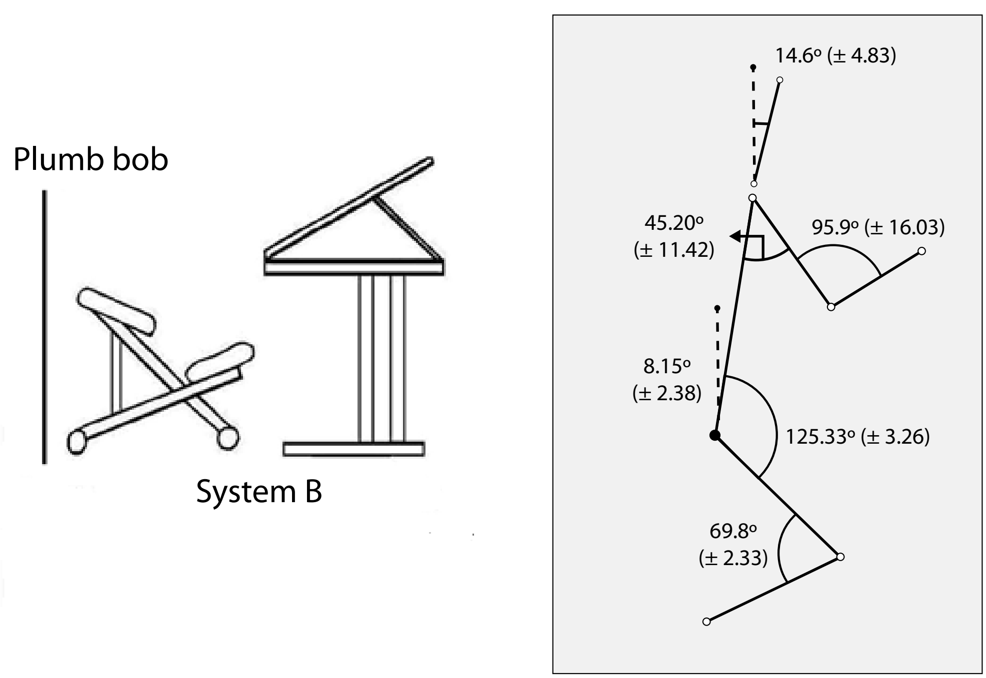

Figure 2. Posture induced by the experimental chair-desk system (system B)

Subgroup A1 (n=6) was composed by participants 2, 3, 8, 12, 13, 14, and subgroup A2 (n=9) by participants 1, 4, 5, 6, 7, 9, 10, 11, 15. In subgroup A2, the posture presented hip and knee flexion angles with values considered close to the ideal posture for the seated (about 90°), but with a sharp forward position for the head.

The postural pattern was similar for all participants in system B. The posture found in system B was similar to the one of subgroup A1, being characterized by open hip flexion angle (greater than 90°), a more closed knee flexion angle (smaller than 90°), and the head was not as positioned forward.

Characteristics of respiratory function in the different postures observed

Spirometry results were evaluated using Wilcoxon's test and Student's t test for paired samples, comparing the standing position with each of the evaluated furniture systems, the two furniture systems between each other, and the two subgroups found in conventional furniture. Results were considered significant when p≤0.05 (Table 1).

The data obtained in the pulmonary evaluation for each furniture system, in each of the five days, did not present statistically significant differences for any of the 15 participants, as expected. We thus used the mean of the individual values for each variable in each furniture system.

Table 1. Comparison of spirometric indices between the standing position and the systems A and B, system A x system B, and subgroup A1 x subgroup A2

Variable	System A x Standing position		p-value	System B x Standing position		p-value	System A x System B		p-value	Subgroup A1 x Subgroup A2		p-value
FVC (L)	4.25 ±0.88	4.27 ±0.89	0.91	4.29 ±0.87	4.27 ±0.89	0.36	4.25 ±0.88	4.29 ±0.87	0.45	4.29 ±0.54	4.23 ±0.57	0.49
FEV1 (L)	3.67 ±0.87	3.69 ±0.90	**<0.01**	3.69 ±0.80	3.69 ±0.90	0.28	3.67 ±0.87	3.69 ±0.80	**<0.01**	3.71 ±0.78	3.65 ±0.97	**<0.01**
FEV1/FVC (%)	85.01 ±5.2	86.11 ±5.2	**<0.01**	86.11 ±5.2	86.11 ±5.2	0.09	85.01 ±5.2	86.11 ±5.2	**<0.01**	86.15 ±5.5	85.12 ±5.6	**<0.01**
FEF25-75 (L/s)	4.28 ±1.22	4.3 ±1.2	0.55	4.32 ±1.8	4.3 ±1.2	0.55	4.28 ±1.22	4.32 ±1.8	0.26	4.35 ±1.62	4.2 ±1.25	0.28
FEF max. (L/s)	7.99 ±2.21	8.6 ±2.42	**<0.01**	8.54 ±2.38	8.6 ±2.42	**<0.01**	7.99 ±2.21	8.54 ±2.38	**<0.01**	8.34 ±2.33	7.97 ±2.3	**<0.01**

*FVC: forced vital capacity; FEV_1: forced expiratory volume in one second; FEF: mid-expiratory flow (25-75%) obtained in FVC maneuvers.; FEF_{max}: Maximum expiratory flow during the FVC maneuver; and L/s: liters per second.

Considering the sitting posture in system A and the standing position, a significant difference was observed with increase in FEV_1, FEV_1/FVC% and FEF_{max} in standing position in relation to traditional furniture, whereas FVC and FEF25-75% showed no statistical differences between the two postural conditions.

Regarding the experimental system compared to the stating position, significant change was observed only for FEF_{max}, which is greater in the standing position.

Comparing the data of the experimental and conventional sitting positions we observed that, except for FVC and FEF25-75%, all other parameters showed a statistically significant reduction in the conventional position.

In the comparison between the two subgroups found on the conventional furniture system, statistically significant differences were observed in FEV_1, FEV_1/FVC% and FEF_{max}, with subgroup A1 presenting higher values than subgroup A2.

Changes in spirometric parameters in different postural conditions were replicable in both furniture systems, considering the five-day experiment, the intraclass reliability coefficient (IRC) ranged from 0.95 to 0.99; according to Landis & Koch[29], these values are considered indicators of excellent repeatability, indicating good technical quality of collection, explained by using expert evaluators.

DISCUSSION

This study further develops the analysis of the relationship between the sitting posture and functional changes induced by it[26], and assessed whether different furniture systems may induce changes in respiratory function. By analyzing the postures found in the two furniture systems studied we expected that system A would induce a position of approximately 90° of hip and knee flexion[1], however it was noted that six participants (40%) – subgroup A1 – presented a posture significantly different than expected, but similar to the results found in a classic study by Grandjean & Hünting[30], which reported that the subjects had variations in the seated position depending on the activity and the time spent in the position, considering that participants would move forward in the chair seat during writing activities, tilting the trunk forward and supporting the forearms on the desk.

Considering the analysis of variations in the sitting posture, Lee et al.[31] demonstrated through the evaluation of the pressure on the chair seat promoted by 30 healthy participants, that the imbalance in the seat negatively affects body stabilization, even when individuals support on a single side of the body to rest or perform functional tasks.

Subgroup A2 is characterized by a sharp forward movement of the head (36°±4.56°), unlike the other postures (subgroup A1 and system B), which showed similar values (15.31°±3.16° and 14.6°±4.83°, respectively). None of the postures presented flexion angles of shoulders and elbows within the recommended parameters in the studied literature, i.e., 25° of shoulder flexion and 90° of elbows flexion[32]. In a study by Pheasant et al.[33], 100 sitting subjects were evaluated with different neck positions. Their results show that, depending on the variation of the neck position, the strength of the shoulders may even be reduced, which can also compromise function and performance in tasks.

In this study, subgroup A2 showed higher values for flexion of shoulders. It is believed that this position, coupled with the previously reported forward head position, may induce greater prostration of the shoulder blades in the sitting posture.

The trunk flexion found in this study is consistent with the information found in the literature[34] for the use of inclined desks (7°). The results were higher in system B (8.15°±2.38°), which was expected given the forward inclination of the chair seat, reducing the weight bearing on the ischial tuberosities, partially transferring it to the knees and favoring the maintenance of lumbar curvature, as well as reducing the activity of paravertebral muscles[17].

The hip flexion observed in system B is similar to the one found in the so-called "neutral body posture", which is 128° (±7°)[35]. This position represents the position of least stress of the musculoskeletal system, preserving the spine's curvatures. In a recent study, de Lima e Sá Resende et al.[36] showed through the evaluation of 19 healthy women that the distribution of body weight in the sitting posture has impacts on the musculoskeletal system, and ergonomic or postural re-education interventions can lead to reduction in pain. The flexion was found in furniture system B was 125.33° (±3.26°), followed by subgroup A1, 118.33° (±4.37°), and finally subgroup A2, 95.77° (±2.33°); thus representing the posture with greater postural overload. The latter group presented the expected values for this flexion, as well as in knee flexion with 94.33° (±10.14°) values, considering previous studies[32,37,38].

For this parameter (knee flexion), data from system B and subgroup A1 were studied in comparison to other researched studies, which ranged from 90° to 133° of flexion[1,17,30,34], whereas the values found in this study were 69.8° (±2.33°) and 71.66° (±4.63°), respectively.

Although this study did not specifically evaluated changes in lumbar lordosis, Bettany-Saltikov et al.[18] report that the kneeling chair with 20° inclination enables the maintenance of the lumbar curvature when compared to a conventional chair.

Thus, analyzing the postures found in relation to hip flexion, and the positioning of both the head and shoulders, we can state that the sitting posture found in subgroup A2 is the one that induces the posture with the lowest biomechanical efficiency of the respiratory muscles. Regarding the respiratory function results, it was observed in this study that spirometric results were better in the postures in which the lumbar curvature is closer to the one found in the standing posture.

These results are similar to those reported by Lin et al.[39], who investigated the effects of the sitting posture in respiratory function and lumbar lordosis in four different positions and found higher values in the standing position, followed by an experimental furniture system and, finally, the conventional furniture system. The focus of that study was, however, the increase in lumbar curvature without alteration in the hip flexion angle, contrary to what is presented in this study.

We must highlight the fact that the respiratory muscles – especially the diaphragm – are crucial in maintaining a posture, and reducing its postural action can favor its participation in the respiratory activity. In the sitting posture, the posterior muscles of the trunk and pelvis are elongated from the thigh position at 90°. Such stretch also extends to the posterior pillars of the diaphragm insertion, and when shortened impose overload to all muscles involved with breathing, especially if the person sitting is obese or pregnant since a complementary cranially displaced mass will exist and serve as resistance to inspiration. This posture leads to the use of an anteriorly displaced sitting posture on the seat (simulating the semi-seating posture), which extends the hip flexion angle, releasing the abdome[14].

This study indicates changed parameters in different postures, characterizing its relationship with different chair-desk systems (something little studied previously), enabling the evaluation of the effects of these postures in lung function. The experimental furniture system suggested in this study demonstrates benefits on lung function in individuals during their stay in the sitting posture.

Various studies report the importance of the head positioning in relation to the decrease in the expansibility of the upper respiratory tract[39,40], since, although the forward head movement (flexion of the lower cervical spine while extending its upper portion) facilitates the entry of air, it impairs the biomechanical relationship between the flexor and extensor neck muscles. However, a systematic review conducted by Gurani et al.[41] showed that literature on this subject is limited, of low quality, and there is little evidence available regarding the effect of head posture in the dimensions of upper respiratory tract.

Felcar et al[42]. reports that such forward movement causes a medial rotation of the shoulder, depressing the chest and changing both the respiratory pace and capacity. This position may be one of the factors that justify, at least partially, the reduction in FEV_1 values in subgroup A2, which showed greater angles of forward head movement and shoulder flexion. Knowing that FEV_1/FVC is changed whenever one of its parameters is altered, when FEV_1 is reduced, the relationship between them is also reduced. On the other hand, Antunes et al.[43] evaluated 30 healthy men, in seating, and supine and prone lying positions. Their results showed that peak expiratory flow is affected depending on the body posture, being considerably higher in sitting individuals when compared to the other evaluated positions. The differences in diaphragm contractility in the different lying positions can be attributed to gravitational forces acting on the diaphragm and on the abdominal viscera and displaced to back or front of the body and upper torso. Thus, there is a physiological response of the diaphragm and abdominal wall subsequent to the action of these forces, including the increase in venous return, the force of gravity acting on the ribs, and the restraint imposed by the stretcher in the prone position. In the sitting or standing postures, gravity moves the diaphragm and abdominal viscera to an inferior position[44-46].

According to West[47], FEF_{max} is an effort-dependent volume, and is affected by the position of the body. Therefore, considering that in the standing position the respiratory muscles are in an advantageous mechanical position in relation to the sitting position since the lower limbs are positioned against the abdomen thus displacing the viscera upwards, the data found in this study are consistent with this statement, given that FEF_{max} was higher in the standing position than in all other positions, with the posture induced by system B as the one closest to its values (8.6±2.42 and 8.54±2.38, respectively), and this was the only parameter in which these two positions (standing and experimental system) showed a significant difference.

CONCLUSION

The conventional chair syste, induced two different postural patterns, one of which showed similar joint angles to system B, with similar spirometric results. The second group presented body angles in accordance with our predictions, and significantly lower spirometry results in FEV_1, FEV_1/FVC and FEF_{max}. System B differed from the standing position only in FEF_{max}, suggesting a similar situation.

Based on the experimental results presented herein, the experimental furniture system was shown to be a viable tool to help the respiratory function of these individuals while in the seating position. Chairs focused on improving posture commercially known as semi-sitting chairs are available in the market, and the adaptation of desks is quite simple; thus, enabling adjustments for better posture.

Study limitations and outlook

For the deepening of this study, we suggest the following considerations: if the stay in the sitting posture for longer periods presents greater variations than those found in this study; to consider the influence of staying in sitting posture for long periods in specific populations like workers and students; to analyze, by means of cohort studies, if the body is able to compensate for these changes without major clinical implications; and lastly, to assess the adequacy of furniture to benefit people in special conditions such as pregnant women, obese individuals and people with chronic pulmonary diseases. Studies with different furniture systems can also be conducted, especially with longer observation periods.

REFERENCES

1. Lis AM, Black KM, Korn H, Nordin M. Association between sitting and occupational LBP. Eur Spine J. 2007;16(2):283-98. doi: 10.1007/s00586-006-0143-7
2. Claus AP, Hides JA, Moseley GL, Hodges PW. Is "ideal" sitting posture real? Measurement of spinal curves in four sitting postures. Man Ther. 2009;14(4):404-08. doi: 10.1016/j.math.2008.06.001
3. Daneshmandi H, Choobineh A, Ghaem H, Karimi M. Adverse effects of prolonged sitting behavior on the general health of office workers. J Lifestyle Med. 2017;7(2):69-75. doi: 10.15280/jlm.2017.7.2.69
4. Sa RC, Zeman KL, Bennett WD, Prisk GK, Darquenne C. Effect of posture on regional deposition of coarse particles in the healthy human lung. J Aerosol Med Pulm Drug Deliv. 2015;28(6):423-31. doi: 10.1089/jamp.2014.1189
5. McManus AM, Ainslie PN, Green DJ, Simair RG, Smith K, Lewis N. Impact of prolonged sitting on vascular function in young girls. Exp Physiol. 2015;100(11):1379-87. doi: 10.1113/ep085355
6. Healy GN, Winkler EAH, Owen N, Anuradha S, Dunstan DW. Replacing sitting time with standing or stepping:

associations with cardio-metabolic risk biomarkers. Eur Heart J. 2015;36(39):2643-49. doi: 10.1093/eurheartj/ehv308

7. Lakerveld J, Loyen A, Schotman N, Peeters CFW, Cardon G, Van Der Ploeg HP, et al. Sitting too much: a hierarchy of socio-demographic correlates. Prev Med. 2017;101:77-83. doi: 10.1016/j.ypmed.2017.05.015
8. Biddle SJH, Bennie JA, Bauman AE, Chau JY, Dunstan D, Owen N, et al. Too much sitting and all-cause mortality: is there a causal link? BMC Public Health. 2016;16:635. doi: 10.1186/s12889-016-3307-3
9. Tremblay MS, Warburton DER, Janssen I, Paterson DH, Latimer AE, Rhodes RE, et al. New Canadian physical activity guidelines: Appl Physiol Nutr Metabol. 2011;36(1):36-46. doi: 10.1139/H11-009
10. Bull F, Biddle S, Buchner D, Ferguson R, Foster C, Fox K, et al. Physical activity guidelines in the UK: review and recommendations. Loughborough: Loughborough University; 2010. [cited 2019 July 5]. Available from: https://mmu.rl.talis.com/items/C14E750E-74FF-8D6B-6668-2E054926EE97.html
11. Cavalcanti AG, Lima CS, de Sá RB, Reinaux CM, Braz Júnior DS, Teixeira AI, et al. Influence of posture on the ventilatory pattern and the thoraco-abdominal kinematics of patients with chronic obstructive pulmonary disease (COPD). Physiother Theory Pract. 2014;30(7):490-94. doi: 10.3109/09593985.2014.901458
12. Li C-T, Chang C-H, Huang J-H, Tsai K-H. Comparison of various sitting postures on pulmonary function, lumbar curvature, and comfort evaluations. Int J Biosci BiochemBioinforma. 2014;4(5):331.doi: 10.7763/IJBBB.2014.V4.365
13. Badr C, Elkins MR, Ellis ER. The effect of body position on maximal expiratory pressure and flow. Aus J Physiother. 2002;48(2):95-102. doi: 10.1016/S0004-9514(14)60203-8
14. Lee L-J, Chang AT, Coppieters MW, Hodges PW. Changes in sitting posture induce multiplanar changes in chest wall shape and motion with breathing. Respir Physiol Neurobiol. 2010;170(3):236-45. doi: 10.1016/j.resp.2010.01.001
15. Ricardo DR, Araújo CGSd. Body mass index: a scientific evidence-based inquiry. Arq Bras Cardiol. 2002;79:70-8. doi: 10.1590/S0066-782X2002001000007
16. Trudelle-Jackson E, Fleisher LA, Borman N, Morrow JR, Jr., Frierson GM. Lumbar spine flexion and extension extremes of motion in women of different age and racial groups: the WIN Study. Spine (Phila Pa 1976). 2010;35(16):1539-44. doi: 10.1097/BRS.0b013e3181b0c3d1
17. Makhsous M, Lin F, Bankard J, Hendrix RW, Hepler M, Press J. Biomechanical effects of sitting with adjustable ischial and lumbar support on occupational low back pain: evaluation of sitting load and back muscle activity. BMC Musculoskelet Disord. 2009;10:17. doi: 10.1186/1471-2474-10-17
18. Bettany-Saltikov J, Warren J, Jobson M. Ergonomically designed kneeling chairs are they worth it? : Comparison of sagittal lumbar curvature in two different seating postures. Stud Health Technol Inform. 2008;140:103-6. doi: 10.3233/978-1-58603-888-5-103
19. Kavak ST, Bumin G. Os efeitos da postura de pega do lápis e de diferentes modelos de mesa sobre o desempenho na caligrafia de crianças com paralisia cerebral hemiplégica. J Pediatr. 2009;85:346-52. doi: 10.2223/JPED.1914
20. Corlett EN, Bishop RP. A technique for assessing postural discomfort. Ergonomics. 1976;19(2):175-82. doi: 10.1080/00140137608931530
21. Ferreira EAG. Postura e controle postural: desenvolvimento e aplicação de método quantitativo de avaliação postural [tese]. São Paulo (SP): Universidade de São Paulo. 2005;1-114. doi: 10.11606/T.5.2006.tde-20092006-142252
22. Ferreira EAG, Duarte M, Maldonado EP, Burke TN, Marques AP. Postural assessment software (PAS/Sapo): validation and reliabiliy. Clinics. 2010;65:675-81. doi: 10.1590/S1807-59322010000700005
23. Santos MM, Silva MPC, Sanada LS, Alves CRJ. Análise postural fotogramétrica de crianças saudáveis de 7 a 10 anos: confiabilidade interexaminadores. Rev Bras Fisioter. 2009;13(4):350-5. doi: 10.1590/S1413-35552009005000047
24. Domingos-Benício NC, Gastaldi AC, Perecin JC, et al. Medidas espirométricas em pessoas eutróficas e obesas nas posições ortostática, sentada e deitada. Rev Assoc Med Bras. 2004;50(2):142-7.doi: 10.1590/S0104-42302004000200028
25. Pereira CAC. I Consenso sobre espirometria. J Pneumol. 1996[cited 2019 July 5];22(3)105-164. Available from: jornaldepneumologia.com.br/PDF/Suple_179_57_I%20CONSENSO%20BRASILEIRO%20SOBRE%20ESPIROMETRIA%201996.pdf
26. Caromano FA, Nunes Sobrinho FP. Caracterização da postura sentada em dois mobiliários diferentes e a influência no desempenho em um teste gráfico: estudos de casos. Rev Ter Ocup USP. 2001;12: 40-7.
27. Romero-Franco N, Montano-Munuera JA, Jimenez-Reyes P. Validity and reliability of a digital inclinometer to assess knee joint position sense in a closed kinetic chain. J Sport Rehabil. 2017;26(1):1-5. doi: 10.1123/jsr.2015-0138
28. Miller MR, Hankinson J, Brusasco V, Burgos F, Casaburi R, Coates A, et al. Standardisation of spirometry. Eur Respir J. 2005;26(2):319-38. doi: 10.1183/09031936.05.00034805
29. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics. 1977:159-74. doi: 10.2307/2529310
30. Grandjean E, Hunting W. Ergonomics of posture-review of various problems of standing and sitting posture. Appl Ergon. 1977;8(3):135-40. doi: 10.1016/0003-6870(77)90002-3
31. Lee DE, Seo SM, Woo HS, Won SY. Analysis of body imbalance in various writing sitting postures using sitting pressure measurement. J Phys Ther Sci. 2018;30(2):343-6. doi: 10.1589/jpts.30.343
32. Cagnie B, Danneels L, Van Tiggelen D, De Loose V, Cambier D. Individual and work related risk factors for neck pain among office workers: a cross sectional study. Eur Spine J. 2007;16(5):679-86. doi: 10.1007/s00586-006-0269-7
33. Pheasant S, Haydt R, Gottstein T, Grasso A, Lombard N, Stone B. Shoulder external rotator strength in response to various sitting postures: a controlled laboratory study. Int J Sports Phys Ther. 2018;13(1):50-7. doi: 10.26603/ijspt20180050
34. Oyewole SA, Haight JM, Freivalds A. The ergonomic design of classroom furniture/computer work station for first graders in the elementary school. Int J Ind Ergon. 2010;40(4):437-47. doi: 10.1016/j.ergon.2010.02.002
35. Congleton JJ, inventor; Jerome J. Congleton, assignee. Neutral body posture chair. In: Google Patents; 1985. United States

patent 4552404. 1985 Dec 11. [cited 2019 July 5]. Available from: www.freepatentsonline.com/4552404.html

36. de Lima e Sá Resende F, Vanti C, Banchelli F, Trani JGB, Oliveira JBA, Villafañe JH, et al. The effect of global postural reeducation on body weight distribution in sitting posture and on musculoskeletal pain: a pilot study. Med Lav. 2017;108(3):187-96. doi: 10.23749/mdl.v108i3.5458

37. Thompson BJ, Whitson M, Sobolewski EJ, Stock MS. Effects of age, joint angle, and test modality on strength production and functional outcomes. Int J Sports Med. 2018;39(2):124-32. doi: 10.1055/s-0043-121149

38. Babaei H, Razeghi M, Choobineh A, Pakshir H, Rajaeifard A, Rezaian J. A new method for calculating saddle seat height with an emphasis on optimal posture based on trigonometric relations. Int J Occup Saf Ergon. 2016;22(4):565-71. doi: 10.1080/10803548.2016.1191223

39. Lin F, Parthasarathy S, Taylor SJ, Pucci D, Hendrix RW, Makhsous M. Effect of different sitting postures on lung capacity, expiratory flow, and lumbar lordosis. Arch Phys Med Rehabil. 2006;87(4):504-9. doi: 10.1016/j.apmr.2005.11.031

40. Efendiyeva R, Aydemir H, Karasu H, Toygar-Memikoglu U. Pharyngeal airway space, hyoid bone position, and head posture after bimaxillary orthognathic surgery in Class III patients: long-term evaluation. Angle Orthod. 2014;84(5):773-81. doi: 10.2319/072213-534.1

41. Gurani SF, Di Carlo G, Cattaneo PM, Thorn JJ, Pinholt EM. Effect of head and tongue posture on the pharyngeal airway dimensions and morphology in three-dimensional imaging: a systematic review. J Oral Maxillofac Res. 2016;7(1):e1. doi: 10.5037/jomr.2016.7101

42. Felcar JM, Bueno IR, Massan ACS, Torezan RP, Cardoso JR. Prevalência de respiradores bucais em crianças de idade escolar. Cienc Saude Coletiva. 2010;15:427-35. doi: 10.1590/S1413-81232010000200020

43. Antunes BO, de Souza HC, Gianinis HH, Passarelli-Amaro RC, Tambascio J, Gastaldi AC. Peak expiratory flow in healthy, young, non-active subjects in seated, supine, and prone postures. Physiother Theory Pract. 2016;32(6):489-93. doi: 10.3109/09593985.2016.1139646

44. Brown C, Tseng SC, Mitchell K, Roddey T. Body Position Affects ultrasonographic measurement of diaphragm contractility. Cardiopulm Phys Ther J. 2018;29(4):166-72. doi: 10.1097/cpt.0000000000000083

45. Druz WS, Sharp JT. Activity of respiratory muscles in upright and recumbent humans. J Appl Physiol Respir Environ Exerc Physiol. 1981;51(6):1552-61. doi: 10.1152/jappl.1981.51.6.1552

46. Malbrain ML, De Laet I, De Waele JJ, Sugrue M, Schachtrupp A, Duchesne J, et al. The role of abdominal compliance, the neglected parameter in critically ill patients: a consensus review of 16. Part 2: measurement techniques and management recommendations. Anaesthesiol Intensive Ther. 2014;46(5):406-32. doi: 10.5603/ait.2014.0063

47. West JB. Fisiologia respiratória: princípios básicos. Porto Alegre: Artmed; 2013. ISBN-10: 8565852741