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SPINAL SAGITTAL ALIGNMENT, SPINAL SHRINKAGE, AND BACK PAIN CHANGES IN OFFICE WORKERS DURING A WORKDAY

Purpose: Prolonged sitting is a risk factor for the appearance of lower back pain in work. The aim of this study was to observe changes in spinal sagittal alignment, height and the perception of back pain in office workers in a workday.

Material and Methods: 41 office workers' (20 women) were enrolled into a cross-sectional study. Height, sitting height and degrees of thoracic kyphosis and lumbar lordosis, as well as perceived neck, lower and upper back pain were determined, before and after an 8- hour workday.

Results: At the end of the day, workers had a significant decrease (p = 0.000) in the height and sitting height, and upper back pain increased significantly (p = 0.023). In men's group, spinal shrinkage correlates with neck pain (r: 0.410, p=0.027), and lumbar lordosis degrees in women correlated negatively with upper back pain at the end of the day (r: -0.440, p=0.012).

Conclusions: Spinal shrinkage equally affects men and women who perform the same work. There are no changes in spinal sagittal alignment throughout the workday in office workers. Office workers increase pain in the upper back significantly at the end of the day.

Keywords: Occupational Back Pain, Ergonomics, Spine, Seated Work, Sitting height.

1. Introduction

In industrially developed nations, musculoskeletal disorders (MSDs) are progressively increasing and resulting in high costs to National Health Systems and companies. Studies have shown that these diseases increase as the average age of the society rises [1]. In Spain, MSDs are the main reason of disability in 2016, mainly caused by

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occupational ergonomic risks, being the lower back and the neck the most affected areas [2]. Moreover, sitting is one of the most common postures adopted by office workers, and one of risk factors of prolonged sitting position is the appearance of neck and lower back pain (LBP) [3–7].

Prolonged standing and sitting positions imply a sustained load for the spine. This sustained load added to circadian variation in human stature causes a significant loss of height [8–11], known as shrinkage. Shrinkage of the spine is greater when work is performed in a standing posture[8,9,12,13] which added to the movements of flexion and load handling implies a greater load on the spine than sitting position[14]. Besides that, sitting on a chair involves lumbar flexion relative to standing[15,16] which could generate a different compression in the support structures. Current studies indicate that sitting is not worse than standing for spinal disc degeneration or the incidence of LBP but it is unknown if the maintained sitting position causes changes in the sagittal alignment of spine [16–18].

The aim of this study was to assess how the height and spinal curves in the sagittal plane are affected by a prolonged working sitting position, to study its possible relationship with pain in the spine after the workday. The possible differences according to gender are also studied. The initial hypothesis is that a maintained sitting position in work would produce a decrease in height, in lumbar and thoracic curvature in the sagittal plane of office workers, and it would cause an increase in perceived back and neck pain.

2. Material and Methods

The evaluations of the participants were made in April-May of 2018.

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2.1. Study design and participants

Forty-one volunteer participants (21 men, 20 women) were recruited from a University and hospital office workers. The recruitment was among workers who spend 8 h in the office. Asymptomatic workers without diagnosed spine disease were included in the study. Exclusion criteria included people diagnosed with spine diseases, scoliosis and pregnant women. All participants were informed about the purpose and procedures of the study, as well as the possible risks and benefits of the study. Every procedure was conducted in accordance with the principles of the World Medical Association´s Declaration of Helsinki. The protocol was approved by the committee of ethics in research of the regional government [C.I. PI18/086].

2.2. Data collection

Data collection was carried out in the facilities of the hospital biomechanics laboratory and biomechanical assessment room at the university. Assessment of the participants was done by the same evaluator and with the same materials. The assessment was made in the first days (Monday, Tuesday or Wednesday) of the week to avoid the weekly overload. Measurements were taken at 08:00, and finally at 15:30-16:00, once the workday was completed.

For every measurement, the subjects had to take off their shoes and clothes, to measure their height, seated height, weight and spinal sagittal alignment. Finally, the workers completed the Visual Analogue Scale (VAS) about neck, upper and back pain.

2.3. Measurements

Spinal shrinkage (height and sitting height): Height (cm) was measured using a SECA® stadiometer model 206 (Seca Corp, USA) with a precision of 1 mm and a range of 130–210 cm, according to International Society for the Advancement of Kinanthropometry

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(ISAK) standards [19]. Assessment of standing or sitting height requires three repetitions of measurement to reduce variability[20]. All anthropometric measurements were taken by the same researcher, who is internationally certified in anthropometric testing and has 4 years of experience (ISAK level 1). The technical error of measurement, with a value of 0.15 (less than 0.1% of technical error of measurement), was analysed in advance. Participants were measured barefoot with their feet together, their backs in contact with the wall and facing forward in the Frankfort position. Height in sitting position was measured with the same stadiometer, following the ISAK regulation in which the subjects must remain with an angle between trunk and legs of 90°. For this, an adjustable stool, whose height was subtracted from the total height, was used. Pre–post work-time stature loss was calculated and used to reflect spinal shrinkage during the workday.

Body weight (BW): BW (kg) was assessed using a SECA® model 799 calibrated digital scale (Seca corp., USA) with precision of 0.1 kg and a range of 2–200 kg.

Degrees of thoracic kyphosis and lumbar lordosis: Curvature in the sagittal plane of the spine was evaluated with a SpinalMouse® device (Idiag, Switzerland). The MediMouse protocol was used, which measures from C7 to S3, and which later divides the programme into thoracic, lumbar and sacral degrees. Prior to measurement, the researcher identified locations by palpation and a frame with a dermal pencil. The C7 vertebra was located using the flexo-extension technique. S3 was located with the superior posterior iliac spine technique to locate S2 [21]. These marks were used for the post-day evaluations. Participants were assessed in a barefoot standing position, facing forward in a relaxed position, with the pelvis in a resting position, so as not to modify the parameters [22]. SpinalMouse is a non-invasive, validated and reliable method for assessing spinal curves [23]. Intraclass coefficients of 0.92 and 0.95 have been

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previously determined for measurement of curvature in the sagittal plane with SpinalMouse [24]. Data are sampled every 1.3 mm as the mouse is rolled along the spine, giving a sampling frequency of approximately 150 Hz. This information is then used to calculate the relative positions of each vertebra, angles between vertebrae and the total angle of sagittal plane curvature, using its own MediMouse® software (Idiag, Switzerland).

Neck, lower back and upper back pain: Record of pain was assessed using VAS. VAS is a scale that goes from 0 = no pain to 10 = the worst pain. VAS is the most used scale measure in back pain trials [25].

2.4.Statistical analysis

Data are presented as mean and standard deviation. The Shapiro-Wilk test was applied to check the normal distribution of the variables. Related samples *t*-test was used to compare the variables of the workers' physical characteristics before and after working. In the case of the pain variables, whose data had a distribution that did not meet the normality criteria, Wilcoxon's nonparametric signed-rank test was performed. Independent samples t-test was performed to analysis differences by gender at beginning of workday. In the case of the pain variables a Man Whitney U-test was performed. Two-way repeated measures ANOVA test was performed in order to analysis by time (pre and post) and gender. In the case of the pain variables a Wilcoxon's nonparametric signed-rank test was performed in each group by gender. Furthermore, the correlation between the studied variables has been analysed. Statistical analysis was performed using the Pearson and Spearman correlation coefficients.

The level of significance was set at $p < 0.05$. All statistical analysis was performed with IBM SPSS version 19.0 for Windows (SPSS Inc., USA).

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3. Results

Related to back pain, 19.5% (n=8) of the workers reported LBP after the workday, 22% (n=9) neck pain and 31% (n=13) upper back pain. Besides, office workers reduced their height (-0.65±0.4 cm) and sitting height (-0.6±0.4 cm) significantly throughout the workday and BW loss throughout the day was also significant (-0.15±0.39 kg). Finally, the degrees of spinal sagittal alignment did not change at the end of the workday in the thoracic (0±2.86º) and lumbar area (-0.22±3.18º). In the total group of office workers, there was a significant increase in upper back pain (+0.45±1.33) at the end of the day ($p = 0.023$).

[t]Table 1 near here [/t]

3.1. Analysis by gender

The characteristics of the participants showed significant differences between men and women at the beginning of the day. Women showed lower values for the variables height, sitting height, BW, and thoracic kyphosis ($p<0.01$). Women had higher values of pain in the upper back than men in the first assessment ($p=0.030$).

Intra-group analysis shows significant decreases in height and sitting height measures after workday in both groups. Thoracic kyphosis and lumbar lordosis values did not change significantly in both groups. BW was significantly modified in the group of men but not in that of women.

Inter-group analysis by gender revealed no significant increase in pain for the areas studied: neck, upper and lower back. Inter-group analysis by gender showed that women had significantly higher values of upper back pain at the end of the day ($p=0.030$). Spinal shrinkage was not different between men and women at the end of the workday. [t]Table 2 near here [/t]

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3.2. Correlations

There were no significant correlations between pain outcomes and morphological modifications of the spine and spinal shrinkage in total group of office workers.

Analysis in men´s group showed a significant positive correlation between height difference (spinal shrinkage) and neck pain at the end of the workday (r: 0.410, p=0.027). This correlation was not observed in the women's group.

The degrees of lumbar lordosis in women office workers correlated negatively with upper back pain at the end of the day (r:-0.440, p=0.012). This correlation was not observed in the men's group.

4. Discussion

4.1. Spinal Shrinkage

In relation to shrinkage during the workday, office workers' height decreased significantly, by 0.65 cm (SD ± 0.40 cm). The sitting height loss was also significant (0.6 ± 0.40 cm). These results coincide with the results of Gao[26]. This author observed that workers in the sitting position during a workday decreased their height 0.56 cm (SD± 0.27). Van Deursen et al. [8] measured spinal shrinkage of healthy adult population exposed to a sitting position for 1 h, finding a decrease in 0.50 cm (SD± 0.06) in height. The shrinkage found in the study of Van Deursen et al. [8] is lower than this research. This difference could be due to the assessment was not made considering a real workday with duration of 8 h. There is no large difference between spinal shrinkage observed in sitting for 1 h and that observed for 8 h in this study.

In a study performed with assembly line workers who were 8 h in prolonged standing, a spinal shrinkage of 1.25 cm (SD± 0.54) was found [10]. This greater shrinkage in relation to office workers could be due to the work tasks and prolonged maintained

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standing. Igic et al. [27] observed a shrinkage of 1.43 cm (SD± 0.06) during a workday in healthy office workers. The values found in this study are greater than those found in our study. This is possibly because they were measured during a whole day and not only during the workday. In addition, in research of Igic et al. [27], it is not specified which job position each of the workers performed. In addition to the 8 h of work in prolonged sitting, the rest of the day was spent in standing or sitting, and it would increase more the decrease in height. Reilly et al. [11] found a variation in human stature of 1.93 cm during a 24 h period. This circadian variation could be altered by the task done during the workday. The work could aggravate the loss of height and is a factor to consider in the reduction of occupational risks.

Shrinkage in this research represented 0.38% of stature. In study of Gao [26] a similar percentage of 0.35% was found. Results of the present study do not show differences between the loss of height suffered by men and women office workers at the end of the work day. Mechanism of "spinal shrinkage" equally affects men and women who perform the same work. This difference had not been analysed in previous studies.

4.2. Body Weight

BW decreased significantly in office workers at end of the day (-0.15±0.39 kg). Assembly line workers in 8 h also decreased significantly their BW at end of the workday (-0.32±0.45 kg)[10]. This BW loss could be greater due to specific physical demands of the job. This variation could be due to the circadian rhythm of the body, excretion, secretion and the dietary intake during the workday. These assessments have not been taken into account in the present study. Intra-group analysis showed a significant decrease in BW in men but not in women. These differences could be studied in future research to propose more appropriate preventive actions depending on the gender of the workers.

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4.3.Spinal Sagittal Alignment

Degrees of spinal sagittal alignment did not change at the end of the workday in the thoracic and lumbar area. Ozkunt et al. [28] studied a workday (10 h shift) in 35 healthy hospital employees (16 men) in a hospital environment. Not significant changes were found in lumbar lordosis and thoracic kyphosis throughout the day. In assembly line workers during a workday (8 h shift), significant increases were observed in lumbar lordosis and thoracic kyphosis[10]. In this research, 40 workers (6 women) increased thoracic kyphosis 0.9º (SD±2.79º) and lumbar lordosis 1.27º (SD±3.24º). This change, which has not been observed in office workers could be explained by the work in sustained standing as well as the repetitive movements and load handling in the assembly line.

The results of the present study show a greater thoracic kyphosis (+6.0º) in men than women at the beginning of the workday. This difference was statistically significant. On the other hand, women have a greater lumbar lordosis angle (+3.5º) than men, but this difference is not significant.

In the present study, angles between 20 ° and 40 ° were considered normal for thoracic kyphosis [29] and angles between 20° and 45° were accepted as normal reference for lumbar lordosis [30].

There is a controversy in values of sagittal spinal alignment between men and women. While some studies have shown no difference in lumbar lordosis [31–33], others have found larger angles in women [17,34,35].

Every woman who participated in the study had normal angles in the thoracic and lumbar sagittal alignment. Values in the lumbar area at men´s group are as reference, but at thoracic area, mean of values showed hyper kyphosis. In addition, it was observed

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as a trend that men increased the thoracic angle at the end of the day, worsening the thoracic sagittal alignment.

In men´s group, the thoracic and lumbar angles increase slightly at the end of the workday, while in women the opposite occurs. The tendency of decrease in the sagittal angles of the spine of women office workers makes the back flatter at the end of the day. Although these changes are not significant, this trend can be seen. This information could be useful to prescribe compensatory exercises and stretches in the office population. De Carvalho et al. [15] found that males had significantly more anterior pelvic rotation and extended intervertebral joint angles in all kind of chairs studied. The difference in position of the pelvis during a sitting work between genders could help to understand the spinal sagittal alignment in each gender.

4.4.Back Pain

The percentage of office workers with pain was 19.5% for lower back, 22% for neck and 31% for upper back at the end of the work day. Celik et al. [1] described pain during the last 12 months in office workers. The percentages obtained are lower than those found in the study of Celik et al. [1], where the office workers reported 55.1% lower back pain, 52.5% neck pain and 53% upper back pain. Cagnie et al. [36] observed a prevalence of neck pain in office workers of 45.5% for 12 months. Daneshmandi et al.[4] observed a prevalence of neck pain and LBP of 53% for 12 months in office workers. Percentage of office workers who developed pain during the workday is less than that of these studies, because only the measurement was performed during one day.

Women had significantly higher values of pain in the upper back compared to men at the beginning and end of the day. Celik et al. [1] also observed significant differences in upper back pain and LBP reported in the last 12 months between men and women.

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Both groups increased pain at the end of the day in the upper and lower back, without being significant. In the neck area, the men increased their pain, and the women did not get worse.

In the men's group, pain in the neck correlated significantly in a positive way with spinal shrinkage analysed in the work environment. It appears that men, who lost more height in the work, were those manifesting greater neck pain at the end of the day. In future research, strategies to prevent spinal shrinkage in men office workers may decrease pain in the neck area too. Interventions aimed at reducing height loss, can focus on exercises of vertebral decompression, stretching, hydration and active breaks, including standing and walking movements throughout the workday[13,37]. The degrees of lumbar lordosis in women office workers correlated negatively with upper back pain at the end of the day (r:-0.440, p=0.012). This finding shows that women, who had lower lumbar lordosis, had higher levels of upper back pain at the end of the day. Chun et al. [38] observed an association between attenuated lumbar lordosis and LBP comparing a group of people with and without LBP. No studies have been found that relate a flatter lumbar lordosis with upper back pain. Strategies aimed at reducing upper back pain, can focus on exercises to preserve the lumbar lordosis and avoid the lumbar flexion that produces a flattening of the lordosis[39]. These exercises can be focused on the stretching of the hamstrings, the activation of the lumbar extensor muscles and anterior pelvic tilt[39].

4.5. Limitations and future research

One of the main limitations of the study is the small number of subjects in the sample. Moreover, study has been performed during a workday. It would be interesting to evaluate several workdays. Finally, analysis between workers in the maintained standing position and those in maintained sitting position would be interesting in future

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research, as well as analyse possible differences in the spinal sagittal alignment in people who perform the same tasks in standing or sitting position in a workday. Could spine adaptations be different between men and women in other works with greater physical demands?

5. Conclusions

Office workers suffer a significant increase in upper back pain at the end of the workday. This result shows the need to implement physical exercises programs that could reduce the pain of workers in the short and long term. Lumbar and thoracic sagittal alignment did not change significantly after a workday in maintained sitting. Office workers lose height (spinal shrinkage) throughout the workday in a significant way. No significant differences were found in the spinal shrinkage between men and women. Men showed a significant correlation between spinal shrinkage and neck pain at the end of the day. Lumbar lordosis in women office workers correlated negatively with upper back pain at the end of the day. Future prospective studies could analyse whether women with flatter sagittal alignment could have a higher risk of upper back.

Conflict of interest statement

The authors have no conflicts of interests to disclose.

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Table 1. Participants' characteristics pre- and post- workday (N= 41).

	Pre-day			Post-day			Post–pre difference			
Variable	M		SD	M		SD	M		SD	*p*
Height (cm)	170.03	±	8.05	169.38	±	7.97	−0.65	±	0.40	0.000*
Sitting height (cm)	89.78	±	3.55	89.17	±	3.52	−0.60	±	0.40	0.000*
Body weight (kg)	70.05	±	13.31	69.91	±	13.28	−0.14	±	0.39	0.028*
Thoracic kyphosis (°)	43.02	±	7.45	43.02	±	8..35	0.0	±	2.86	1.000
Lumbar lordosis (°)	21.70	±	6.96	21.48	±	7.54	−0.22	±	3.18	0.661
Pain variable	M		SD	M		SD	M		SD	*p*
Neck	0.50	±	1.35	0.55	±	1.38	+0.05	±	1.04	0.296
Upper Back	0.52	±	1.63	0.98	±	1.91	+0.45	±	1.33	0.023*
Lower Back	0.45	±	1.36	0.63	±	1.87	+0.17	±	1.32	0.624

* $p<0.050$

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Table 2. Participants' characteristics pre- and post- workday by gender (N= 41).

	Men (n=21)			Women (n=20)			ANOVA		
Variable	Pre	Post	Post-Pre	Pre	Post	Post-Pre	F	*p*	η^2
Age (years)	37.71(7.05)	-	-	40.75(8.63)	-	-			
Height (cm)	176.63(5.07)^A	175.96(4.95)	-0.67(0.41)^B	163.11(3.30)^A	162.48(3.19)	-0.63(0.39)^B	0.105	0.747	0.003
Sitting height(cm)	92.49(2.36)^A	91.85(2.38)	-0.63(0.41)^B	86.94(2.02)^A	86.36(1.95)	-0.58(0.39)^B	0.178	0.676	0.005
Body weight (kg)	78.80(11.88)^A	78.55(11.96)	-0.25(0.34)^B	60.86(7.13)^A	60.84(7.18)	-0.02(0.42)	3.592	0.065	0.084
Thoracic angle (°)	45.95(6.12)^A	46.19(7.38)	+.61(2.76)	39.95(7.61)^A	39.70(8.16)	-0.25(2.55)	0.292	0.592	0.007
Lumbar angle (°)	20.23(6.13)	20.85(6.72)	+.23(3.17)	23.55(7.28)	22.45(8.23)	-1.10(3.41)	3.150	0.084	0.075
Pain variable	Pre	Post	Post-Pre	Pre	Post	Post-Pre			
Neck	0.25(0.72)	0.44(1.17)	+0.18(0.76)	0.75(1.78)	0.68(1.59)	-0.07(1.29)	-	-	-
Upper back	0.03(0.15)^A	0.40(1.05)	+0.36(1.01)	1.04(2.25)^A	1.59(2.41)	+0.55(1.63)	-	-	-
Lower back	0.68(1.80)	1.01(2.51)	+0.33(1.80)	0.22(0.59)	0.23(.66)	+0.01(0.44)	-	-	-

M (SD); ^{A} Significant differences inter-group ($p<0.050$); ^{B} Significant differences intra-group ($p<0.050$), η^2: Effect Size

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