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A case study of ergonomics encompassing white-collar workers: anthropometry, furniture dimensions, working posture and musculoskeletal disorders

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Abstract: Regardless of their specific business, white collar workers have some factors in common: they work seated without moving for a long time, they use certain arm and hand muscles excessively, and they tend to keep a poor body posture. The resulting Musculoskeletal Disorders (MSDs) produce discomfort, and even pain. This study aimed at an ergonomic assessment of white collars of a Portuguese company – to identify the most critical points in old furniture designs and working posture habits. An evaluation was done in the administrative department using a random sample; the anthropometric and furniture measurements were taken and compared. The RULA method was used to evaluate the risk arising from adoption of a poor posture at the workplace. The results obtained show a prevalence of symptoms of MSDs. The furniture is oversized in most cases. Adoption of a poor posture at the workplace requires a short-term intervention. There is a significant association between MSDs and wrong-dimensioned furniture, besides habit to adopt wrong postures. This company (as many other SME's) must change the old style office furniture by one with dimensions matching workers' anthropometry, and provide training on best practices to maintain good posture at work.

Keywords: office workers, occupational health, ergonomics, RULA, pain.

Um estudo de caso da ergonomia, abrangendo empregados de escritório: antropometria, dimensões de mobiliário, postura de trabalho e lesões músculo-esqueléticas

Resumo: Independentemente da atividade económica, os empregados de escritório executam as suas tarefas de forma similar: trabalham sentados sem se mover por um longo período de tempo, usam frequentemente os membros superiores em movimentos repetitivos, e tendem a ter uma má postura corporal na posição sentada. As lesões músculo-esqueléticas resultantes (LME) produzem desconforto, e até dor. Este estudo teve como objetivo a avaliação ergonômica na secção administrativa de uma empresa portuguesa. As medidas antropométricas dos trabalhadores e as dimensões do mobiliário foram determinadas e comparadas. O método RULA foi usado para avaliar o risco decorrente da adoção de uma má postura no local de trabalho. Os resultados produzidos mostram uma prevalência de sintomas de LME. O mobiliário está superdimensionado na maioria dos casos. A adoção de uma má postura no local de trabalho carece de intervenção a curto prazo. Há uma associação significativa entre LME, e o mobiliário utilizado, além de hábito de posturas erradas. Esta empresa (como muitas outras SME's) deve substituir o mobiliário de escritório por um outro cujas dimensões se ajustem às medidas antropométricas dos trabalhadores, e complementar com formação sobre as boas práticas como trabalhar sentado.

Palavras-chave: empregados de escritório, saúde ocupacional, ergonomia, RULA, dor.

1. Introduction

Approximately 25 % of the total workers in EU27 do repeatedly complain of backache, and ca. 23 % report muscular pains (EFIWL, 2002). Musculoskeletal Disorder (MSD) is a cause of major concern at workplace – not only because of the health effects on individual workers that disrupt their quality of life (Vos et al., 2013), but also because of the outstanding economic impact on business budgets and social costs (Podniece & Taylor, 2008).

White-collar workers, regardless of the business they are engaged in, share a few descriptors: they work seated without moving for a long time, use excessively a number of specific muscles of the arm and hands, and maintain a poor body posture (Dul and Weerdmeester, 2008). These factors account for MSD related to work, with occurrence and persistence of musculoskeletal pain at multiple body sites (Neupane et at, 2013; Podniece and Taylor, 2008). Sometimes, it is not possible to keep a correct posture – because the furniture is poorly designed and cannot be easily changed, or because the worker is already addicted to a wrong posture. However, even when work occurs under appropriate conditions, it is not recommended to maintain any position for long periods without a break – considering that a given muscle contraction for long hours produces discomfort or even pain (Westgaard & Winkel, 1997). For this reason, socially-aware companies are engaged in instructing their own workers on how to prevent such a sort of injuries (Neupane et al., 2013; Podniece & Taylor, 2008; Westgaard & Winkel, 1997).

From the point of view of body posture, the simplest way to avoid MSD is to take neutral positions – i.e. those in which the body segments are naturally aligned and properly supported (Dul & Weerdmeester, 2008; Westgaard & Winkel, 1997). For white-collars work specifically, it is possible to conceive a set of working postures characterized as: shoulders relaxed and arms along the trunk; forearms at an angle of 90º relative to the arms; slight tilt to the trunk back, using support for lower back; knees at about the same level of the hips; feet placed slightly ahead of knees and completely flat on the floor; head in line with trunk; and a bent for up to 5 degrees (Grandjean, 1987; Vos et al., 2013; Westgaard & Winkel, 1997).

From the point of view of furniture, the chair is perhaps the most critical element in any working environment – as long as it is supposed to provide the necessary support for the working posture (Congleton, 2004). The importance of a suitable chair will be fully realized if one considers that an office worker sits more than 80,000 hours during a regular lifetime (Westgaard & Winkel, 1997). The design of most chairs for work is based on a Gaussian curve of anthropometric measures, which includes the intermediate 95% of the total user population (Pheasant & Haslegrave, 2006). Hence, a chair designed to accommodate the 95% intermediate portion of each set may easily exclude some groups belonging to the remaining 5% (for each anthropometric feature). The obvious result will be a chair able to accommodate only a fraction of the worker population considerably below the 95% target potential users. Most desks models for work are unfortunately based on fixed dimensions, without any adjustability (Dul & Weerdmeester, 2008; Kroemer & Grandjean, 2001).

In addition, there are considerable differences among people in terms of shape and overall size of their bodies; even among individuals of the same sex, age and height, significant variations can be found in their body proportions (Barroso et al., 2005; Pheasant & Haslegrave, 2006; O'Sullivan et al., 2012) – e.g. two standing men with the same height

may appear to have different heights upon sitting, and the height of their elbows to the floor can vary up to 10 cm (Pheasant & Haslegrave, 2006). This issue is further complicated because the anthropometric data used by chair designers do not necessarily reflect the total adult population of users – thus making it almost impossible to determine the actual percent of users that are appropriately covered (Stumpf, Chadwick & Dowell, 2007).

However, even in the best fitting situations, the human body is not prepared to sit still for long periods of time (Kroemer & Grandjean, 2001; Roberston, Ciriello & Garabet, 2013). In fact, sitting is a posture that causes stretching of the muscles and ligaments in the spine; when this situation is held for long periods of time, a reduction of muscle activity will occur coupled with a decreased blood flow. Furthermore, the sitting posture also leads to an increase in intra-disc pressure (Dul & Weerdmeester, 2008; Kroemer & Grandjean, 2001; Neupane et al., 2013). On the other hand, the issues of discomfort/pain associated with sitting work for a long period of time are due not only to the fact that chair and desk were not designed specifically to the user at stake, but also to bad postural habits (Roberston, Ciriello & Garabet, 2013). These problems are overall responsible for back and shoulder pains, and muscle spasms that cause discomfort, and thus difficulty in concentrating on and performing work (Neupane et al., 2013; Vos et al., 2013; Westgaard & Winkel, 1997); hence, bad postural habits should be carefully analyzed, and the worker informed and formed on how to correct them (Roberston, Ciriello & Garabet, 2013).

A new round of regulations aims to reduce work-related musculoskeletal injuries, such as enforcement of adequate workplaces or jobs for workers complaining of injuries, as well as financial coverage for medical care. However, business groups are not that pro-active, claiming that such goals are too far-reaching, too expensive and unsupported by scientific evidence (Webber, 2001).

This study aimed at an ergonomic assessment of office workers in the administrative department of a representative Portuguese company; its major goal was to identify the most critical points in common furniture designs as they interact with working posture habits. There was a particular interest shown by the company in this specific study, because previous attempts by their administration board were hampered by lack of openness of its workers to information and formation regarding ergonomic aspects of their job and concomitant MSD.

This case study is of the utmost importance to SME – which have traditionally and consistently refused to apply the results and recommendations of similar studies performed abroad, claiming that the underlying conditions lie too apart from the specific socio-economic environment prevailing in Portugal to merit any further attention.

2. Methods

The current study was conducted in an administrative department of a representative company in charge of the organization of industrial exhibitions and cultural shows. A random sample based on workers interested in engaging in study was used (19 men and 27 women). These 46 workers usually perform their functions sitting, and work essentially with computer, telephone, calculator and paper. They perform mainly the following tasks: sending documents by post or electronically, preparing forms and proposals for events, as well as allocation of exhibitors, mode of access to the event, commercial contacts,

advertising and management of exchange of information by e-mail. All desks models for work are based on fixed dimensions without any adjustability.

Workers answered two questionnaires: one to characterize the group of individuals, as well as the organizational work, and the other concerning information about discomfort/pain on different body regions (Echternach, 1987).

All anthropometric and furniture measurements were taken using a “Harpenen” anthropometer (Holtain, UK) (Barroso et al., 2005). Three static anthropometric dimensions were recorded for each individual, and the average considered for statistical treatment. Definition of measurements was those by Dul and Weerdmeester (2008) and Kroemer and Grandjean (2001).

Rapid Upper Limb Assessment (RULA) was applied in three different days, twice each day, to assess the working posture and the putative risk of MSD (McAtammey & Corlett, 1993). The observational method was applied because no permission was given to photograph and /or film the workers.

Statistical analysis of the data was performed using SPSS software, v. 20.0. Non-parametric tests were used because the data were not normally distributed. The Pearson Chi-Square test for independence was applied to determine whether there was a significant association between variables.

3. Results

The overall characteristics of the sample are: the men were on average 44.6±6.8 years old, and had 1.72±0.06 m in height and 72.1±14.3 kg in weight; and the women were on average, 36.4±6.8 years old, and had 1.62±0.06 m in height and 56.1±6.3 kg in weight. Most women (89%) had Body Mass Index (BMI) classified as normal weight (18.5 < BMI < 24.9), and none could be considered obese. However, 5% of men were considered obese (BMI>30.0), 47% of the men were classified as overweight (25.0<BMI < 29.9), and 42% lied within the normal weight range. About 40% of the workers did not engage in any physical activity, irrespective of gender. Most people were right-hand writing (80% men and 90% women).

The overall characteristics of the organizational work taken are described as follows: the worker seniority was higher on average for men (14.5±6.2 years) than for women (10.6±5.6 years). Approximately one third of the workers worked more than 40 hours in the office, independently gender; most men did two 5 min-breaks per day, whereas women did only one. No men missed work, and only 7% of women had 10-24 days of absenteeism.

Considering that different models of chairs and desks were found at the workplace, Table 1 presents the mean (and corresponding standard deviation) of the dimensions of the office furniture, according to gender of user.

Table 1
Dimensions of the different furniture models used by men or women

		Man		Woman	
Furniture	Dimension (cm)	min-MAX	Mean ± SD[1]	min-MAX	Mean ± SD
Chair seat	Depth	43 – 48	46.3 ± 1.7	43 – 49	45.6 ± 1.2
	Height	41 – 52	48.5 ± 2.8	44 – 59	49.1 ± 3.7
	Width	44 – 49	48.4 ± 1.2	44 – 50	48.7 ± 1.3
Chair back	Height	48 – 54	49.8 ± 2.1	44 – 63	49.3 ± 4.1
	Width	42 – 45	43.5 ± 1.4	42 – 48	44.4 ± 2.6
Desk	Height	72 – 77	72.8 ± 1.3	71 – 92	73.2 ± 3.8
	Width	160 – 305	245.7 ± 65.7	122 – 349	247.8 ± 72.2
	Depth	74 – 300	124 ± 75.8	60 – 80	78.3 ± 4.3
	Thickness	3 – 4	3.2 ± 0.5	2 – 4	2.9 ± 0.4

[1]SD – Standard Deviation.

In what concerns ergonomic evaluation of the adequacy of furniture to the worker's body, Figure 1 and 2 indicates the differences between the anthropometric dimensions of user and the corresponding furniture dimensions, as often done in the literature (Dowell, 1995; Stumpf, Chadwick & Dowell, 2007; Westgaard & Winkel, 1997).

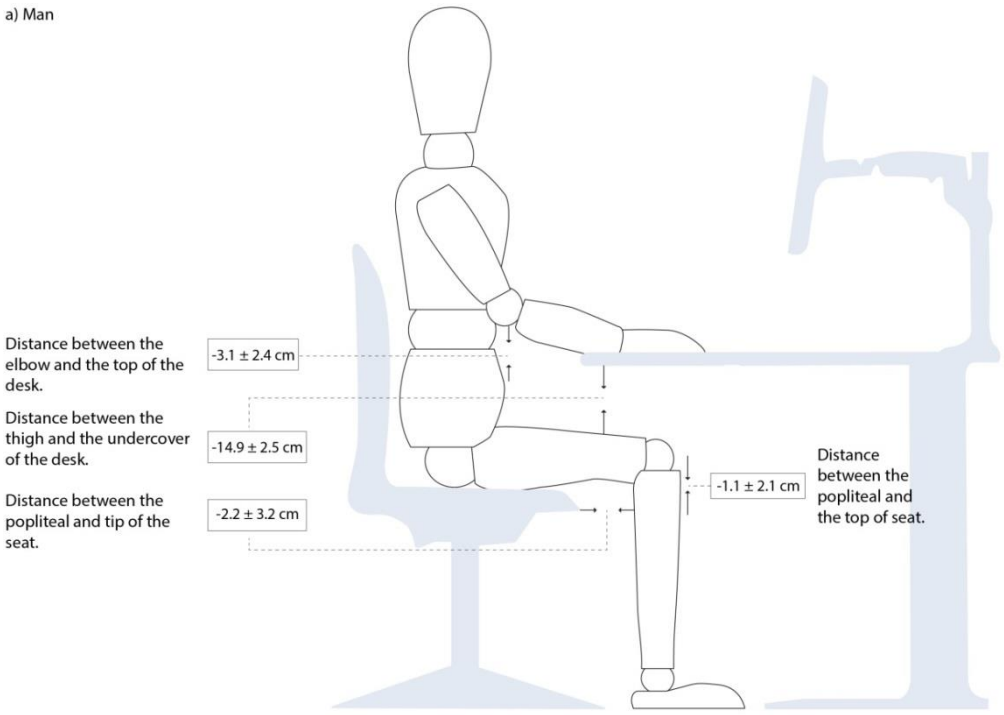

Figure 1 – Values (mean ± standard deviation) found for differences between anthropometric and office furniture measurements (man).

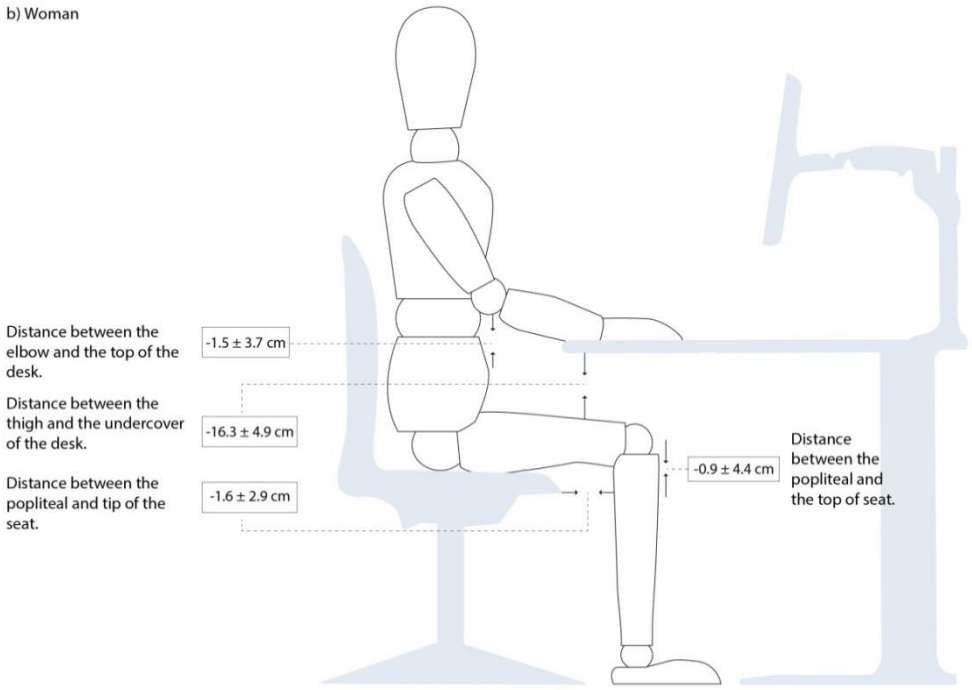

Figure 2 – Values (mean ± standard deviation) found for differences between anthropometric and office furniture measurements (woman).

The levels of the RULA permit inference about the urgency to change the mode of work of a person as a function of the risk of injury. Table 2 presents the RULA step scores obtained for both genders.

Table 2
Percentage of worker according to RULA step scores and gender

		RULA scores[1]			
RULA Step	Gender	1 or 2	3 or 4	5 or 6	7
Arm and wrist analysis	Man	0	47	48	5
	Woman	0	32	68	0
Neck, trunk and leg analysis	Man	0	52	37	11
	Woman	3	18	75	4
Final analysis	Man	0	53	47	0
	Woman	0	25	75	0

[1]RULA SCORE: 1 or 2 = Acceptable; 3 or 4 investigate further; 5 or 6 investigate further and change soon; 7 investigate and change immediate.

All white-collars in our sample – of both genders, had perceived discomfort/pain during performance of their profession on the previous year. The areas of the body most often associated with said discomfort/pain are shown in Figure 3.

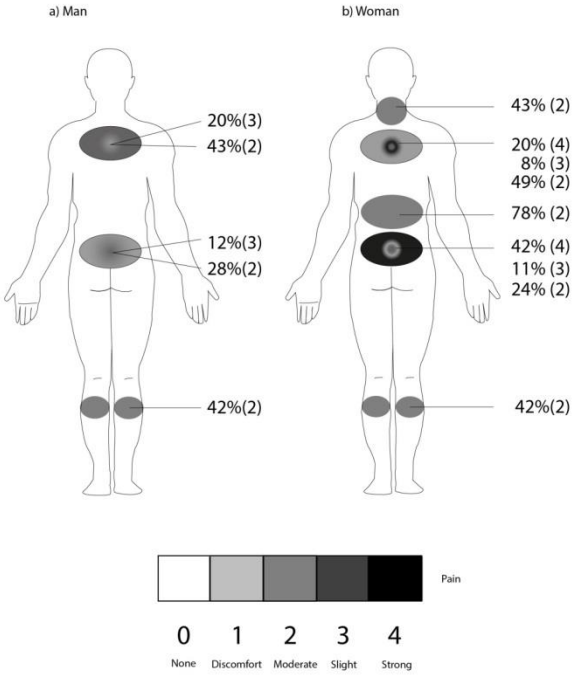

Figure 3 – Percentage of workers 'perception on discomfort/pain during last year, according to gender and intensity of pain.

The significance levels found for the Pearson Chi-Square test for independence between variables are shown in Table 3. This statistical analysis aids in discussion on the main risk factors of MSDs for this type of workers.

Table 3

Matrix of the significant associations between furniture/anthropometric characteristics, RULA scores, and body region complaints.

		Body region discomfort/pain									
Variable category	Variable	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
Worker characteristics	Gender	.676	.461	.466	.194	.090	**.048**	.232	.314	.524	.524
	Age	.532	.454	.632	.827	.771	.662	.555	.417	.655	.655
	BMI	.976	.743	.334	**.003**	.876	.641	.905	**.048**	**.000**	**.000**
	Handwriting	**.023**	.943	.877	.727	.977	.963	.905	**.013**	**.025**	**.025**
	Seniority years	.314	.689	.494	.060	.666	.837	.673	.388	.100	.100
	Working hours per week	.177	.800	.803	.105	.358	.477	.365	.462	.355	.355
	Number of breaks per day	.928	.158	.515	.871	.437	.708	**.006**	**.001**	.550	.550
	Physical activity	.557	.985	.914	.695	.055	**.042**	.359	.693	.579	.579
RULA scores	Arm and wrist analysis	.947	.782	.974	.875	.290	.309	.908	.829	.957	.957
	Neck, trunk and leg analysis	.137	.010	.100	.806	.119	.226	.647	.502	.994	.994
	Final	.282	.405	.148	.411	.070	.055	.295	.213	.725	.725
Furniture dimensions	Seat height	.985	**.000**	**.000**	.952	**.000**	**.002**	**.005**	**.005**	**.002**	**.002**
	Seat depth	.768	.401	.566	.169	.569	.548	.511	.588	.311	.311
	Seat back height	.552	.097	.431	.337	.699	.560	.413	.700	.198	.198
Furniture/anthropometric characteristics	Difference between buttock/back knee distance and seat depth	.165	.124	.241	.648	.191	.257	.071	.144	.078	.078
	Differences between desk and elbow height	.579	.207	.174	.117	.224	.388	**.010**	**.035**	.473	.473
	Lumbar space	.302	.564	.913	.836	.094	.090	.670	.525	.820	.820

[1]**Bold number** indicates that the association between variables is significant at $p<0.05$.

A1 – Front head; A2 – Posterior head and neck – left side; A3 – posterior head and neck – right side; A4 – posterior back;, A5 – dorsal zone – left part;

A6 – Dorsal zone – right part; A7 – Lumbar zone – left part; A8 – Lumbar zone – right part; A9 – Posterior leg – left part; A10 – Posterior leg– right part.

4. Discussion

The anthropometric characteristics of the male and female workers that participated in this study are within the dimensions proposed by Barroso et al. (2005) for the Portuguese worker population. In general, absenteeism is rare, and one third of sample works longer than 40 hours per week – this might be explained by the pressure of losing their job considering that they are employed for quite some time. About 40% of people did not practice physical activity at all, and about 50% of men exhibit overweight; this reveals their low awareness for general well-being. Additionally, one concludes by inspection of Figure 2 that the most affected body areas are: posterior back, lumbar zone and posterior zone of both legs. These results are consistent with those reported elsewhere (Roberston, Ciriello & Garabet, 2013; Serranheira et al., 2003).

Data presented on Table 1 is in agreement with the fact that desks and chairs in offices of a large number of SMEs present different fixed dimensions (owing the significant high standard deviations); as well the furniture design is still old type with no possibility for adjustment. There is a general consensus that the seat should have a depth between 38 and 43 cm for accepted chair comfort (Dowell, 1995; Stumpf, Chadwick & Dowell, 2007; Westgaard & Winkel, 1997). One found that the chairs typically have a depth above that defined as comfortable (84% of the cases for male, and 93% of the cases for female workers); however, no seat had a depth below 38 cm. Recall that seat depths greater than 43 cm would not permit shorter workers to effectively use the lumbar support of the chair back, so a complaint of pain in their lower back is likely to occur (Grandjean, Hünting & Pidermann, 1983).

The height of the desk should be adequately dimensioned, so that a vertical regulation between 58 cm and 71 cm should be possible; if the desk surface needs to be fixed, then it should lie 70 cm above the floor (Westgaard & Winkle, 1997). All working desks are fixed, and do not comply with the recommended values in the literature (96% in either gender) – see Table 1. Additionally, negative values were found between elbow and the top of the desk, for both genders (see Figure 1 and 2). If the working surface is too high, it might causes arm spreading from the torso, and concomitant rising of the shoulders. Adams and Hutton (Adams and Hutton, 1988) have demonstrated that the activity levels of the upper spine and of the spine extensors increase when one works on an excessively high desk. This realization is corroborated by the values obtained for the difference between elbow height and desk height (see Figure 1) – which indicate that, for most cases, the elbows are below the desk level (95% for men and 79% for women) thus causing said arm rising. This situation could be improved by having an adjustability mechanism in chair height, with footrest for shorter workers.

The width of the desk should be at least 60 cm, and its thickness should not be above 3 cm (Dul & Weerdmeester, 2008); both these prerequisites are met in most desks. The office was equipped with very wide desks that are not so often found today – this is so because of their older design.

The depth of the desk should be above 80 cm at foot level, according to Kroemer and Grandjean (2001), or 100 cm according to Dul and Weerdmeester (2008). Desks in this study are rectangular, and thus with a constant depth; most do conform to the aforementioned reference values in the case of male workers, but 21% of the female workers cases do not conform – undersized desks were indeed found (see Table 1).

There should be some free space for the thighs, so a minimum distance of 1.7 cm is to be assured between the upper part of the seat and the lower part of the desk (Kroemer & Grandjean, 2001). This condition is satisfied in this study, and a reasonable amount of free space is available – as expected, because the desks are on average too high for their users (as previously mentioned).

From inspection of Table 2, one concludes that in most cases the RULA scores indicate that most workers are working with a posture that could raise a moderate risk of injury. The addiction of the employee to a wrong posture might explain the discomfort/pain essentially in the posterior head and neck, posterior back and posterior legs – which are the parts of the body undergoing largest deviation from correct positioning.

The results obtained in this study are indeed consistent with the complaints of workers regarding their lumbar body area (see Figure 3). In addition, the back side of the knees should not touch the anterior limit of the seat surface (Grandjean, Hünting & Pidermann, 1983; Westgaard & Winkel, 1997); owing to oversizing of the chair seat depth relative to the buttock/back knee distance, one found negative values (80% for men and 75% for women; see Figure 3) – so the chairs used by most workers, irrespective of gender, should be re-dimensioned in terms of seat depth.

Any chair should have a mode for vertical regulation of the seat, so that sitting workers can keep their feet lying on the floor. The recommended range for vertical regulation varies among authors: between 35 and 53 cm (Dowell, 1995), or between 38 and 54 cm (Dowell, 1995; Stumpf, Chadwick & Dowell, 2007; Kroemer & Grandjean, 2001), so as to be able to accommodate both short and tall workers. One realized that chair seat height did not match the user in most cases, especially for women which are typically shorter. As shown in Figure 2, the values obtained for the differences between the heights of the back knee region and the seat are mainly negative (63% in the case of male workers, and 50% in the case of female workers).

Therefore, the height of the chair seat is not adequately adjusted to the distance between the back knee and the floor; this could be easily improved by replacing the old type model chairs by new ones, with possibility for adjustability in the chair. The workers who cannot lie their feet on the floor will have their blood circulation in the lower limbs hampered if such a situation is maintained for long periods of time, with consequent discomfort (Dowell, 1995; Grandjean, Hünting & Pidermann, 1983). This realization may probably account for the complaints received from both genders, regarding the posterior zone of their legs (see Figure 3).

The chair surface should be as wide as possible to allow heavier workers and with wider hips to have their thighs duly supported. Westgaard and Winkle (1997) have suggested 43 cm as minimum value; in our study, all chairs abide to this heuristic rule.

The arm support should be vertically adjusted, so that both shoulders can be relaxed (Dowell, 1995; Grandjean, Hünting & Pidermann, 1983; Westgaard & Winkle, 1997). None of the chairs studied possessed such vertical regulation of its arms – and there are even armless chairs.

It has been found that white-collars prefer high chair back, because most such workers like to occasionally stretch and recline their bodies; therefore, a high chair back is more efficient to hold the trunk weight, as compared to a low chair back (Kroemer & Grandjean, 2001). The chair back height should at least be 50 cm measured vertically above the seat level (Idem); the chairs studied do conform to this rule. On the other hand, those authors claim that the back support surface should be at least 30.5 cm wide; the

chairs considered do abide to this suggestion as well. All chairs do not possess a lumbar support, so complaints of discomfort and/or pain in the lumbar zone are expected (see Figure 3).

From inspection of Table 3, one found that Body Mass Index (BMI) is significantly associated with worker perceived pain on posterior back, lumbar zone, and posterior legs. Excess weight places mechanical and metabolic strain on bones, muscles and joints. Osteoarthritis of the knee and hip are both positively associated with obesity, and obese patients account for one-third of all joint replacement operations. Obesity also increases the risk of back pain, lower limb pain, and disability due to musculoskeletal conditions (Anandacoomarasamy, Fransen & March, 2009; Spryropoulos et al., 2009).

A significant association between numbers of breaks and pain on lumbar zone was found. One strategy to reduce extended workplace sitting, particularly in relation to reduced incidence and/or severity of musculoskeletal symptoms, is increasing the number of breaks from sitting time (Healy et al., 2012). This ideal situation is not found in this workplace; more than half women only take one break during an entire shift, although the men take two.

No significant associations between RULA scores and body region complaints were obtained. The lack of association can be result of potential adaptations by workers, changing postures frequently, and influence by other factors – such as overweight, low physical activity, and reduced breaks per day, as mentioned before. One also unfolded statistically significant association between seat height and discomfort/pain in: posterior head and neck, dorsal zone, lumbar zone, and posterior legs. A seat with adequate height may prevent the worker from using the armrests – or take advantage of the contours of the back, thus allowing partial transfer of the weight exerted on the spine, and thus reducing health problems (Andersson & Ortengren, 1974; Occhipinti et al., 1985). The aforementioned mismatch between elbow and desk height (measured from floor), coupled with the lack of support in the chair for the lumbar region, may explain the association between discomfort/pain on lumbar zone and desk heights.

5. Conclusions

Workers of the administrative department studied felt discomfort to moderate pain – mainly in the back and posterior zone of the legs. These complaints derive from a poor design of the chair (too high, too deep, and without lumbar zone support) and poor design of the desk (too high); these should accordingly be changed, so as to better fit the individual anthropometric characteristics of the worker. The workers' opinion before purchase of furniture entertains a good set of results (CNE, 2001).

The risk of MSDs brought about by an inadequate working posture is moderate, but workers are still to be informed and educated about the related ergonomic issues – especially after the furniture has been optimally designed. Obviously that any alteration of the posture is an individual option, that should thus be taken freely. It was proven that one short session with supervisors about ergonomic working environment to get positive effect on the feedback of workers (Eklöf, Ingelgård & Hagberg, 2004; Eklöf & Hagberg, 2006). However, these researchers highlight the importance of well-informed and motivated leaders, which is also a necessary prerequisite for effective participatory ergonomics.

The incidence of back pain is obviously lower when more frequent breaks per day are made. Such breaks should be taken advantage to do some physical exercising as workplace gymnastics (such as stretching and relaxation exercises); the importance of exercise in preventing MSDs is by far well documented (Mendes & Leite, 2004).

This study does validate with a representative Portuguese worker sample strong evidence of ergonomic problems at work that may eventually lead to quantifiable avoidable expenses in the case of a company where good practices are not yet fully welcome by both workers and managers. However, further studies are warranted encompassing other companies and more workers, to extend the conclusions already drawn.

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