Chapter

Women, Ergonomics and Repetitiveness

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Abstract

A fair comparison of the conditions in which men and women work is inconsistent, since although they are interacting with the same objects, means and conditions of work, there are differences in the way each gender work, so it condition that naturally the productive systems segregate and thus establish jobs typically "feminized" based on the best adaptation of women to repetitive work low load. From a physical and psychological point of view, female workers have greater exposure to low strength, repetitive motion of upper extremities that causes gender disparity with its health consequences. This chapter documents a study where females were found to have lower biomechanical negative effects in the upper extremities compared to similar male exposures and a higher rate of productivity, especially in tasks of low force demand. This can be attributed to the fact that men used more strength than what was strictly necessary to accomplish the task, mobilizing a greater number of muscle groups than women; females also showed a greater resilience to conditions of high repetitiveness that demanded high-quantitative psychological demands and still maintain productivity rates over time, evidencing also lower rates of rotation and absenteeism caused by musculoskeletal disorders.

Keywords: occupational risks, occupational diseases, cumulative trauma disorders, musculoskeletal system, gender ergonomics

1. Introduction

Biology has always been a determining factor in the definition of the social roles of men and women. From the earliest social organizations of *Homo sapiens*, women oversaw all aspects associated with reproduction: the raising of children, the maintenance of the domestic space, and the care of the elderly. Men were in charge of productive work, study, politics, and laws.

From a physical point of view, differences in gender structure and strength also marked important work differences, giving women roles that involve more repetitive tasks of low strength with upper limbs (basic agricultural tasks, food preparation, clothing, etc.), while the man took on the role related to tasks of handling of loads, walk long routes, and intensive application of force (hunting, fishing, war, etc.) [1].

According to Scott [2], the separation history between home and work emphasizes the functional and biological differences between women and men that end up legitimizing and institutionalizing these differences as the basis of social organization; this division of labor has been normalized.

"Sexual division of labor is universal, but it is specific to each society, and there is a long cultural variability, which shows that the link between work and gender depends on both cultural and biological differences between men and women" [3].

With the industrial revolution and Taylor's theories about the scientific organization of labor, mechanization and the scarcity of postwar male labor were circumstances that encouraged the intensive inclusion of women in manufacturing, beyond the sexual division of labor based on reproductive tasks. Female labor dominated many industries in the textile, electrical parts, and food sectors, in principle because of need, but in a second phase, due to the positive results found in terms of productivity in highly repetitive tasks [4].

This trend continues to be reaffirmed in the twenty-first century where the scenario of the manufacture of low-weight products, or sub-processes of small parts in more complex products, is carried out by the work of women. Especially in the Latin America region can be found many examples of industrial processes with a marked feminine predominance, such as the Mexican/Central American maquila or the textile production cooperatives in Brazil [5].

Then, some questions arise in relation to women, health, and repetitive work:

- For some jobs that involve repetitive tasks, companies prefer to hire women. Is this because of cultural gender considerations or factors such as increased productivity, availability, or showed efficiency?

- At an international level, there is a higher prevalence of MSD in the female population than in the male population. Is it because women are more susceptible, or are they more exposed than men?

- Are women physically and psychologically more suitable for repetitive work with lower marginal physical loads than men?

This chapter aims to provide experimental scientific evidence through the systematic review and application of valid instruments on this subject, from a perspective that considers the conditions of work, the health of women workers, and business productivity.

2. More gender balance, more productivity?

The World Bank also supports the thesis that companies would be more productive with more women. It does so through a report published in 2014 by the International Financial Group (IFC, of which the World Bank is a member). The report, entitled "Investing in Women's Employment: Good for Business, Good for Development" [6], emphasizes that investment in women's employment has led to greater productivity, greater employee loyalty, and a greater access to talent. It also presents concrete examples of how initiatives adapted to women (training, childcare support, health services) can improve business performance.

But this labor reality, partly derived from the cultural division of labor and partly justified by the achievement of positive results in terms of productivity, has consequences in the health of working women. Although it may seem anachronistic, among the bases of the current work organization, we continue to find the Taylorist concepts that have been evolving in the ultra-specialization of workers to perform simple and highly repetitive tasks (conditioning and muscular learning) and introducing concepts such as variable compensation and production bonus [7].

Exposure to repetitive work has been systematically studied in the European Union and especially in Spain [8]. In the EU, 45% of workers declare to perform monotonous tasks, and 37% declare to perform repetitive tasks. In Spain, 64% of workers say they perform repetitive movements during part of the working day. Forty-five percent of the construction workers, 35% of the industrialists, and 30% of those in the services declare to perform them for more than half a day. The most known harmful effects of repetitive work are primarily musculoskeletal disorders of the back and upper limbs. But the repetitive work also has a great relation with another problem of which we cannot disconnect it: the labor stress and its repercussions on the health of the workers.

Repetitive work, besides its ergonomic implications and its more or less direct musculoskeletal consequences, has a central psychosocial significance. In addition to the cyclical realization of the same movements hundreds or thousands of times that forces the maintenance of uncomfortable positions, repetitive work also means a lack of variety tasks, few opportunities for learning, few things to decide, monotony, and boredom [9].

Repeating the same motion can cause injury, but injuries can take years to manifest, as opposed to an accident where the injury is seen immediately. Also, as chronic problems develop over a long period, many elements can interact. It is not in all cases that repetitive elbow movements result in tendon inflammation as one also has no evidence that women workers have a part-time job and have fewer problems than full-time workers. Musculoskeletal problems by repetition frequently are muscle and tendon inflammations such as tendinitis and bursitis. They may also treat deteriorations of cartilage and bones as in some cases of osteoarthritis and different types of spine and nerve compression problems such as carpal tunnel syndrome. These problems are found in both men and women. But several studies consistently show that women present these problems more frequently, and this situation is repeated in studies on the general population as in studies on different occupational groups [10].

If we follow the traditional model, we would say biological differences in size, muscular strength, and aerobic capacity in combination with a very demanding work are sufficient causes to explain these differences. In the last decade, the psychological characteristics of the individual and the psychosocial environment are discussed as causal factors that can modify the response of the organism. These factors may confuse interpretation of research data, turning more difficult to find relationships between causes and effects on health.

3. Why women have more MSD in upper limbs than men?

Zwart [11] and his colleagues collected data from a questionnaire answered by a large sample of German workers, men and women. For their analysis, they divided the data by age and the demand at work (heavy or light physical demands, mental demands, or mixtures of physical and mental demands). Data shows that men and women are affected by back problems, but women refer more frequent problems in the neck and upper limbs. Reviews performed by NIOSH [12] and Artazcoz [13] show several studies with the same situation.

A first approach to explaining these differences in women's working conditions and their exposure to risk factors are based in several beliefs, not all of which are sufficiently well-founded: smaller people have more problems, because tools are too big for small hands; the duration of work (in years of service) with a higher-risk exposure; women have less muscle strength than men, the same conditions have greater effects on them; family responsibilities combined with working conditions increase the risk; hormonal factors alone or in interaction with working conditions produce a greater risk; and women express their problems more psychologically, so women react more to organizational factors that combine with physical factors to produce musculoskeletal problems [14].

However, these explanations are apparently logical and do not support a more in-depth analysis. The most relevant factor is that it can make direct comparisons between the tasks performed by men and those performed by women. Men and women occupy different spaces in the labor market, a way to mark that one could almost speak of separate labor forces. In Sweden, only 10% of women and men work in mixed jobs [15]. This segregation means that men and women are not exposed to the same working conditions.

Within a single economic sector, women occupy different jobs than men; for example, in women's clothing factories in Canada, women work by sewing and ironing clothes, while men are pattern cutters. In the automotive industry, women sew seat linings, while men handle the assembly of vehicles. Even when men and women occupy the same position, the tasks performed are different. In a turkey meat industry, men and women worked in the same production chain; however, men worry about hanging the animal and making large cuts (descading, large cuts, peeling), while women make small cuts (wings, breast, legs) and did the finishing work (cut off excess fat, clots, etc.).

Men and women have different sizes and so, also different reaches. Because of this, they can perform their tasks differently. Karlqvist [16] in his study showed that women work with the computer keyboard in postures more uncomfortable than men because the length of their arms is smaller. However, after many years of female employment in certain productive sectors, furniture, tools, and workplaces have been modified to the dimensions of their workers (anthropometric adaptations), not only obeying gender differences, necessary for implementing productive technologies in other countries (anthropotechnology). In this way, the jobs have been adapted over time to the working population, so that in the positions traditionally occupied by women, the physical configuration is mostly adapted, so these positions could be more injurious to a population with different anthropometric characteristics, including male labor population.

Another reason that may explain the differences between men and women is the work history at long term. Torgén et al. [17] showed that on average, women did not change their physical workload over a 24-year period, while men gradually decreased it. It seems that women stay longer in the same jobs, and it exposes them more time to the same risk factors. Also, when the damage occurs, female workers develop strategies to avoid pain and to be able to work. When men are in these situations, they are more likely to drift toward other positions. The proportion of men doing repetitive work in slaughterhouses decreases with age, while age does not influence the proportion of women in repetitive work. What it probably wants to say is that men withdraw from those jobs.

Other factors that increase the risk of musculoskeletal problems are the lack of rest. Women combine wage labor with housework and complain more often that they are fatigued. Most researches show that women spend more hours on domestic, unpaid work and that this increases with the number of children in the family [18]. The physical and mental demands of domestic/unpaid work are stronger for women than for men (**Figure 1**) and may increase the risk of musculoskeletal problems. This dual presence, both physical and psychosocial, increases the exposure of women to the effects of work and creates an imbalance between the productive and reproductive periods of work and rest that has an impact on the health of women. However, this factor also refers to the greater resilience of women to physical and mental stress caused by work.

Women report more symptoms than men regardless of the region of the body being studied. For example, in a review of computer work and musculoskeletal problems, Punnet and Bergqvist [19] showed that women report more complaints but have fewer

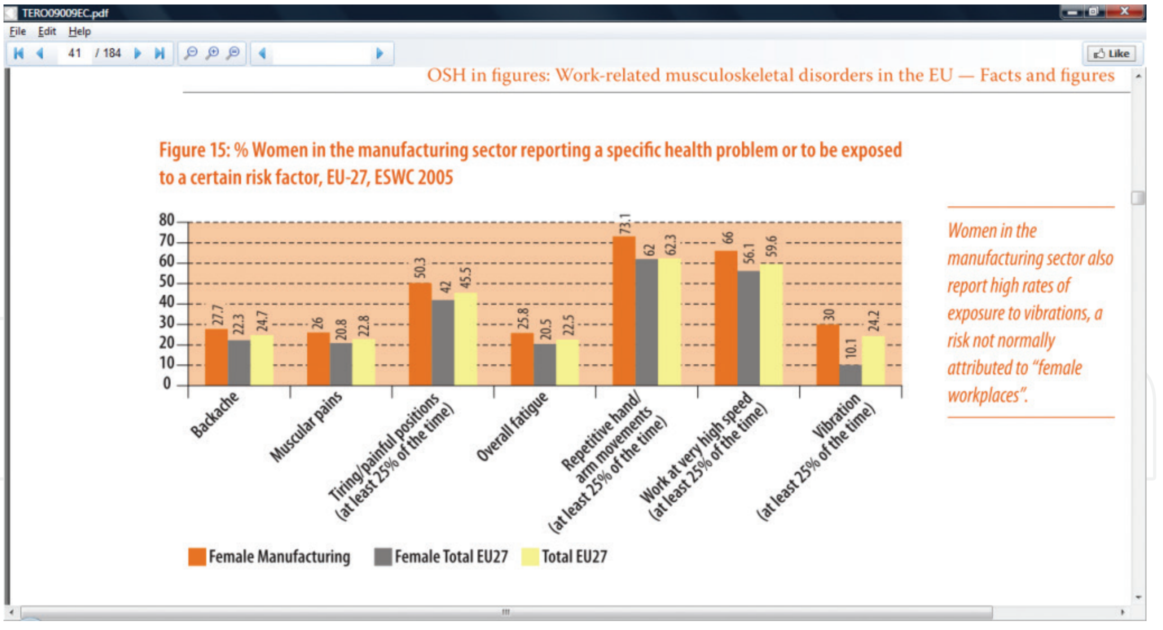

Figure 1.
Percentage of women workers reporting a specific health problem, by risk factor exposition, EU-27, ESWC 2005.

clinical diagnoses than men. One explanation may be that the perception of pain differs between men and women. The perception of pressure pain is more developed in the woman. It could be seen as a weakness, but in reality it proves to be a protective factor which produces a preventive action from the woman at the first symptoms (could be a pre-pathological stage) that induces her to change the way of working.

An experimental, cross-sectional study was conducted between 2015 and 2016 with a semi- probabilistic sample composed of 300 workers (150 women and 150 men) from three industrial plants in Valencia, Venezuela; Santa Cruz de Aragua, Venezuela; and Tijuana, Mexico, in sectors of electrical fan manufacturing, snack packaging, and assembly of hydraulic connections (**Figures 2** and **3**).

The study correlates three variables, considering the biomechanical performance in terms of force and movement range: job hazards (biomechanics, repetition and postures; psychosocial, quantitative psychological requirements), workers' health assessment, and average labor productivity.

Biomechanical risk for repetitiveness was assessed by the OCRA index method [20]. Postural risk was assessed using the OWAS method [21]. Psychosocial risk was assessed using the ISTAS/COPSOQ method [22], specifically through the section on quantitative psychological requirements. The health assessment focused on the

Figure 2.
Gender differences in daily paid/unpaid work. Global Gender GAP Report 2017.

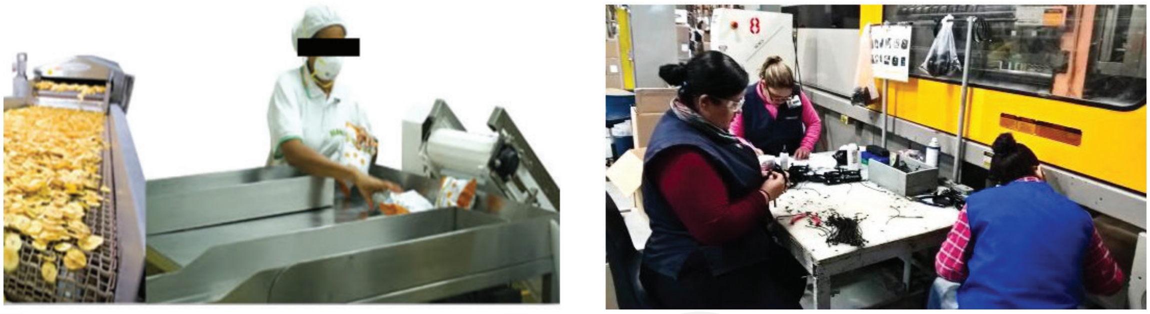

Figure 3.
Snack packaging (Venezuela) and hydraulic connections (Mexico) assessed processes.

functional status of the upper limbs, especially the wrists and forearms (search for initial states of De Quervain pathology, carpal tunnel syndrome, trigger fingers, bursitis, etc.) it performed using dynamometry and goniometry, and also applying Kuorinka questionnaires [23] to identify painful symptoms. We also tested the functional status of the legs, required by the posture of sitting and prolonged standing. Health outcomes were assessed according to the number and severity of injuries. The level of mental load impairment was assessed using the Maslach Burnout Inventory [24]. Productivity was extracted directly from the payroll system (production bonds).

Hand dynamometry (**Figure 4**) assessed the biomechanical performance to measure the interaction between the hand and objects, making a follow-up by day and week. Also, the workflow was video recorded to assist the repetition counter and to apply the measure of movement arches, using a computer-based photo-goniometer.

Variables were correlated, and it got several odds. First, conditions of biomechanical risk were correlated with the occurrence of musculoskeletal disorders. Second, mental load at work, correlated with the emotional exhaustion of the subjects. A third correlation analysis was carried out on the combined effect of biomechanical and psychosocial risks with the occurrence of musculoskeletal disorders, by gender. The synergetic effect of physic and mental work load was assessed through the performance analysis to state cause-effect relations.

Finally, a longitudinal analysis of the productivity (including absences due to rest and rotation of personnel) of each gender was performed, from the perspective of marginal returns and the Cobb-Douglas [25] model curve.

Women were found to have had a lower biomechanical involvement in the upper limbs in the presence of a similar exposure to the male, having, on average, a higher rate of productivity, especially with low force demands, performing repetitive tasks involving a prehensile effort of less than 15 N or manual loads of less than 50 Gr per repetition.

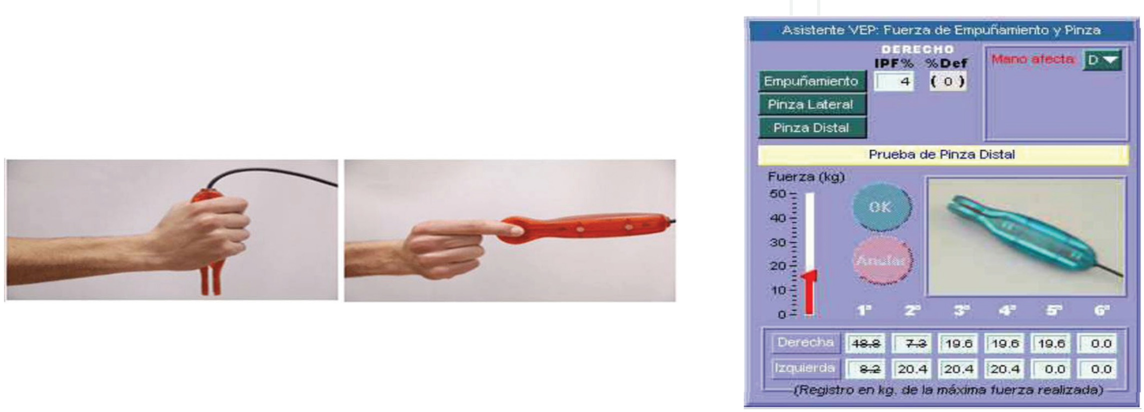

Figure 4.
PC-based hand dynamometer used (probe detail).

It was found that the working conditions (biomechanical and psychosocial) were the same for each gender group in each work facility, but there is a difference that should be considered in the results, since the frequency of technical actions (repetitive movements) was slightly higher in the female group than in the male group, for which the OCRA indexes were also higher in the group of women, and a higher exposure risk was found.

With more repetitiveness, the mental load is also higher, so there is also a greater psychosocial risk in the group of women. The evaluated work stations denoted conditions of high monotony associated with drowsiness, psychic laxity, decreased performance, reduced adaptability, low reactivity, and high variability of heart rate. Hypovigilance conditions were also observed, accompanied by reduced performance in terms of perception and detection of signals, fundamentally in light monitoring tasks. Thus, for both groups, a similar influence of external factors (mental contraite) was found but with a marked difference in the way it affected genders (mental astreinte).

In terms of musculoskeletal affections, greater presence of biomechanical and psychosocial risk would be expected. However, although the pain perception was slightly higher in the female group, the health evaluation found a greater number of lesions in the male group, some with functional limitations.

Among the causes of the observed phenomena, it can be attributed to the fact that men used, on average, more strength than strictly necessary for the accomplishment of the task (which was evidenced with the dynamometer), mobilizing a greater number of muscle groups than those used by the female group.

Another observed phenomenon is that the male group always started the day (weekly and daily) with peaks of productivity (higher than the average productivity of the female group), but this was decreasing throughout the day and week; however, the productivity of the female group remained more constant and finally was, on average, slightly higher than male group.

The group of women also showed a greater resilience to conditions of high repetitiveness that impose high-quantitative psychological demands and still maintain productivity rates over time, which did not happen in the group of men, evidencing also lower rates of turnover and absenteeism due to musculoskeletal disorders.

Women showed a more constant productive rate over time, since the repetition factor hardly changed during the weekly lapses, while the male group showed a marginal productivity distribution similar to the Cobb-Douglas (**Figure 5**) function.

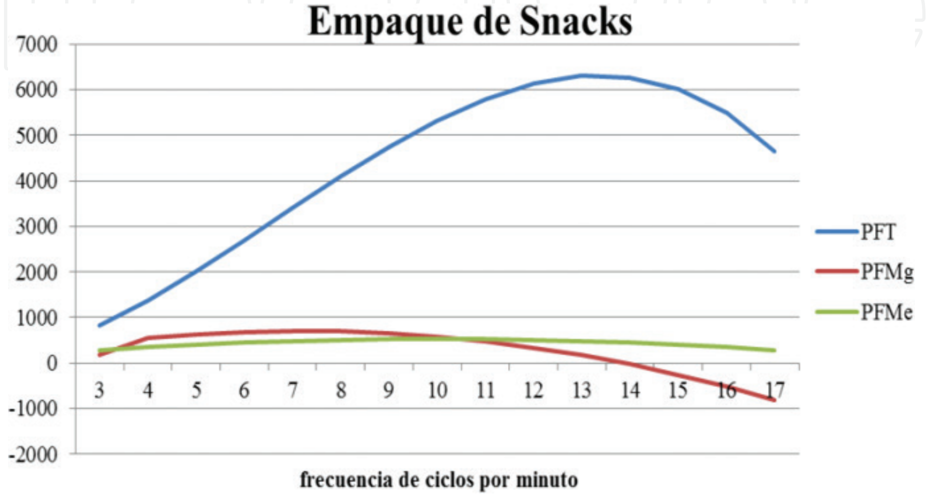

Figure 5.
Cobb-Douglas curves: total product, marginal product, and average product.

A more longitudinal analysis of the marginal productivity per worker in the last year shows even more definitive results, with the female sample having an annualized productivity 18.3% higher than the male sample, considering the effect of absence, rest, and labor rotation.

4. Conclusions and final ideas

The comparison between men and women in labor terms is not fair. Both genders perform different tasks, with different expositions, different patterns of rotation, and different resources to face the work. Probably, both gender are based on a differents patterns but complementaries.

Several studies show a major biomechanical affectation in female group than male group of workers in a great variety of industrial tasks [26]. But at least performing repetitive tasks involving a prehensile effort of less than 15 N or manual loads of less than 50 Gr per repetition, these results are not caused by a gender weakness but a higher-risk exposition in both ways: in short-term time, because women perform more repetitions monthly than men; and in long-term time, because they can support repetitive loads of work for longer time, so they remain for longer time in the repetitive job workplaces.

These results are consistent with Tomaskovic-Devey [27], which results show that exposure to repetitive work is more frequent among working women; and it is consistent with Kilbom [28], whose results show that a greater proportion of women than men suffer problems especially in the upper limbs; finding out that occupations at high risk of musculoskeletal problems in upper limbs, the majority had a mostly female workforce. Results are consistent with NIOSH too, showing that "female gender was a significant predictor of tendinitis."

Although the incidence and prevalence for some authors have not yet been established for De Quervain's disease, some report prevalence between 2.5 and 8% in women of the total working population. Women are more frequently affected than men (8:1 ratio), and the age of onset is between 30 and 60 years [29].

Hobby [30] tested the effects of age and gender on the results of surgery for carpal tunnel release in 97 patients with a diagnosis of CTS. Evaluation was performed before the release and 6 months after surgery. Women reported more symptoms and postoperative disability than men.

These researches show that repetitive work is more frequent among feminized positions, and musculoskeletal disorders in upper limbs are more frequent, pointing to an obvious correlation. But these studies do not inquire about the technical justifications for these phenomena and only describe them. This chapter is not intended to delve into the results of prehensile strength, acceleration of movements, or comparative productivity between genders (which are found in more detail in another article by the authors [25]) but to express conclusions that may be useful to understand probable causes of the phenomena studied and thus explore measures that minimize the effects of repetitive work in women.

This study does not show a greater biomechanical resistance of the feminine articular systems in relation to the masculine ones, but it shows a greater "muscular intelligence" in the accomplishment of the repetitive tasks, which acts as a protective factor and enhances productivity. This feature is based on energy savings and biomechanical resources in each technical action, applying the pressure and acceleration and moving just the required to complete the task. These savings permit performing repetitive tasks for a longer time and reducing the damage to articulations. Performing repetitive actions in a healthy way, without damage, have several productive consequences: taking a maximum advantage of the learning curve, with a better adaptation to muscular/cognitive level and with notable effects in productivity.

There is another implication of the findings, which is related to the validity of sampling in risk assessment. OCRA has proven to be a valid and reliable method for assessing the risk of repetitive tasks; however, one cannot speak of an index of risk associated with the task of, for example, packaging. Each worker has a different rhythm, so the frequency multiplier changes. But it not only changes from worker to worker but also changes the factor at the beginning of the day than at the end of the day and also within each week.

Another disruptive factor is the strength, acceleration, and the way the movements are made. OCRA considers technical actions, but this can be done by mobilizing different muscle groups, with significant variations of strength, acceleration (force is related to mass and acceleration), and associated fatigue. Therefore, repetitive work evaluations, especially when establishing work-gender relations, should be done by gender-based and serial sampling.

One of the most interesting results in this research is related to the different ways men and women face repetitive work. It is clear that women could maintain constant work rhythms, due to better energy management in terms of strength and ranges of movement. However, the group of men showed consistent behavior when starting cycles with greater force but applying less force throughout the day and the week. The range of motion in the male group behaved inversely proportional to that of the applied force, showing ranges of motion and activation of a greater number of muscle groups as the force diminished, in the time. Biomechanically, this situation can be explained as a physical compensation, which uses more muscle groups than necessary to assist fatigued groups. It is not clear why this happens. The answer seems to be not related to the biomechanical sphere, but to a series of conditioning factors of human behavior, determined by psychological, social, and cultural issues. It was not within the scope of this research to deepen the identification of these conditions, but it seems a very promising line of research that can be derived from these findings.

What seems to be clear is that it is not due to special anatomical conditions, although the development of "muscle intelligence" may be linked to a mechanism of evolutionary adaptation, since historically the woman has been performing tasks more repetitive than the man attending to the theory of the cultural division of labor [31]. This adaptation could also intervene in the mental sphere. Thus, from a macroergonomic point of view, the female population was more resilient: able to sustain the work rhythms over time, which allows increasing labor availability and human reliability and minimizing turnover.

Then, a fair comparison of the conditions in which men and women work is inconsistent, since although they are interacting with the same objects, means, and conditions of work, the way each gender work is different, and it conditions that productive systems self-segregates naturally, establishing jobs typically "feminized" based on the best adaptation of women to low-load repetitive work, so this segregation seems to be justified for productive reasons, and not cultural in all cases.

However, if these protective factors are identified, it can be incorporated into the working procedures as part of an action plan to prevent the ergonomic and psychosocial risks from which both genders can benefit.

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Conflict of interest

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