MASTER’S DEGREE IN
OCCUPATIONAL SAFETY AND
HYGIENE ENGINEERING

Dissertation presented for the award of the degree of Master
Occupational Safety and Hygiene Engineering
Faculty of Engineering of the University of Porto

PRESSURE-BASED ERGONOMIC ASSESSMENT OF SITTING POSTURES

Ana Rosa Anjos Lopes da Silva

Advisor: Professor Doctor Joana Cristina Cardoso Guedes (Faculty of Engineering of the University of Porto)
Co-adviser: Doctor Nilza Alexandra Gomes Ramião (Faculty of Engineering of the University of Porto)
Examiner: Professor Doctor Joana Carvalho dos Santos (School of Health of Polytechnic Institute of Porto)
Jury President: Professor Doctor Mário Augusto Pires Vaz (Faculty of Engineering of the University of Porto)

2023

Faculty of Engineering of the University of Porto

Rua Dr. Roberto Frias, s/n 4200-465 Porto PORTUGAL

VoIP/SIP: feup@fe.up.pt **ISN:** 3599*654

Tel.: +351 22 508 14 00 **Fax:** +351 22 508 14 40

URL: http://www.fe.up.pt **E-mail:** feup@fe.up.pt

ACKNOWLEDGMENTS

I want to express my sincere gratitude to everyone who has contributed to completing this Master's Thesis.

First and foremost, I am deeply thankful to my thesis advisor, Professor Doctor Joana Guedes, for their unwavering guidance, invaluable insights, and continuous support throughout the research process. Their expertise and encouragement have been instrumental in shaping this work. I am also grateful to Doctor Nilza Ramião for the amazing opportunity and for their valuable feedback and constructive suggestions. Their thoughtful input significantly enhanced the quality of this thesis.

A special thanks to the Occupational Safety and Hygiene Department of the Faculty of Engineering of the University of Porto and the Institute of Science and Innovation in Mechanical Engineering and Industrial Engineering for providing the necessary resources and facilities for conducting this research. The academic environment and resources offered have been crucial in completing this study. I would also like to thank the study participants for their goodwill in contributing to science.

I appreciate my colleagues and friends who have supported me during the highs and lows of this academic journey. Their encouragement and camaraderie have made this experience more fulfilling. A special thank you to Cláudia Torres, Renato Guedes, Daniela Alves, Tiago Bragança, José Marques, Rúben Teixeira, Catarina Rosado, César Ribeiro, and Carolina Coelho for being there since the primordial times and for always believing.

I want to express my deepest gratitude to my family for their unwavering support and understanding. Their love and encouragement have been my source of strength throughout this challenging but rewarding process. A huge thank you to my cousin Maria for all the help. From the bottom of my heart, Mother, Father and Little Sister, thank you for always bearing and believing in me!

Last but not least, I want to acknowledge the countless individuals who may not be mentioned here but have contributed to completing this thesis in one way or another. Your support has been invaluable.

Thank you all for being an integral part of this academic endeavour!

Ana Rosa Anjos Lopes da Silva

Master's Degree in Occupational Safety and Hygiene Engineering

December 2023

HIGHLIGHTS

1. Office work is an activity on the rise with job characteristics that might potentiate the appearance of musculoskeletal disorders.
2. Postures adopted by office workers might have a negative health impact and worsen musculoskeletal symptoms.
3. Using a pressure sensor covering the entirety of the chair seat, it is possible to assume the user’s leg and lower back position on the chair based on the value of average pressure, contact area and centre of pressure.
4. Using a pressure sensor alone it is not possible to distinguish postures in which users have the same leg and trunk position. supplementary information collected from the back of the chair would be required.

ABSTRACT

Introduction:

This research explores pressure-based ergonomic assessments focusing on sitting postures, acknowledging the relation between this behaviour and musculoskeletal diseases, particularly in offices. A historical overview of ergonomic practices lays the foundation, highlighting the evolution of technologies and methodologies in the quest for understanding musculoskeletal health implications. Therefore, the present study aims to develop a comprehensive pressure-based ergonomic assessment framework that integrates pressure metrics to assess sitting postures, considering factors such as load distribution, pressure points, and their implications for musculoskeletal health.

Methodology:

The methodology encompassed various assessment tools to investigate the intricate relationship between sociodemographic factors, work-related musculoskeletal disorders (WRMSDs) and ergonomic postures in an office environment. As such, a sample of 20 office workers were selected and a sociodemographic questionnaire was distributed. The Nordic Musculoskeletal Questionnaire was used to assess WRMSDs. The ergonomic assessment tool utilised was the Rapid Office Strain Assessment and ISO 11226:2000. The Xsens was used as a Motion Capture System to measure angles. The Tactilus pressure mat was used to gather pressure information.

Results:

The sample population was mainly females (55%) with an average age of 29,33 years old. 70% of participants reported neck and lumbar region pain or discomfort in the last 12 months before the study. In the previous seven days before the study, 50% still had neck pain or discomfort and 30% in the lumbar region. From the select postures, the most commonly adopted by participants was an upright posture with the different body sections supported. According to the ROSA method, the most damaging posture was when participants were seated in the middle of the seat without back support. According to ISO 11226:2000, all postures had asymmetric head and trunk postures. Using the pressure mat, it was possible to identify postures based on the leg and lower back position in the chair.

Conclusion:

In conclusion, this research positions pressure-based ergonomic assessments as a pivotal tool in promoting musculoskeletal health in posture assessment. Combining ergonomic assessment tools and pressure sensors is a reliable instrument for identifying awkward situations. Future research should be developed to explore the possibility of posture prediction when the leg and lower back positions are the same.

Keywords: Pressure Sensor, Ergonomic Assessment, Occupational Health, Sitting Postures, Musculoskeletal Symptoms.

TABLE OF CONTENTS

FIGURE INDEX

TABLE INDEX

ABBREVIATIONS

3D – Three Dimension

A – Average

AA – Arm Angle

AHP – Analytic Hierarchy Process

AP – Anteroposterior

AR – Augmented Reality

BMI – Body Mass Index

CANS – Complaints of Arm, Neck and Shoulders

cm – Centimetres

cm^2 – Square centimetres

CMDQ – Cornell Musculoskeletal Discomfort Questionnaire

DHM – Digital Human Modelling

EC – Ellipse's centroid

CEDEFOP – European Centre for the Development of Vocational Training

ECG – Electrocardiography

FSR – Force Sensitive Resistors

HA – Head Angle

HSE – Health and Safety Executive

ICM – Number of in chair movements

kg – Kilogram

LSST – Lateral Scapular Slide Test

m – Meters

m^2 – Square metres

Max – Maximum Holding Time

METs – Metabolic equivalents

MHT – Maximum Holding Time

Min – Minimum

MP – Mean Contact Pressure

MSDs – Musculoskeletal Diseases

MUEQ – Maastricht Upper Extremity Questionnaire

NA – Neck Angle

NDI – Neck Disability Index

NIH – National Institutes of Health

NMQ – Nordic Musculoskeletal Questionnaire

OCRA – Occupational Repetitive Actions

OSHA – Occupational Safety and Health Administration

Pa – Pascal

POF – Plastic Optical Fiber

PRISMA – Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols

Q1 – Quadrant 1

Q2 – Quadrant 2

Q3 – Quadrant 3

Q4 – Quadrant 4

Q-DASH – Quick-Disabilities of the Arm, Shoulder, and Hand

REBA – Rapid Entire Body Assessment

REC – Remaining endurance capacity

ROSA – Rapid Office Strain Assessment

RULA – Rapid Upper Limb Assessment

SD – Standard Deviation

SF-MPQ – The Short Form McGill Pain Questionnaire

SI – International System of Units

SP – Sway Path

SPMS – Sitting Posture Monitoring Systems

TA – Thorax Angle

VDU – Visual Display Unit

VR – Virtual reality

WD – Work Desk

WHO – World Health Organization

WRMSDs – Work-related Musculoskeletal Disease

PART 1

1 INTRODUCTION

Over the years, there has been a shift in how people live and their lives are designed and conducted. With technological advancements and transformations in the business world, a new era of office work has begun. This shift, although a way to potentiate connectivity and efficiency, also has steered a lifestyle characterised by extended periods of sitting time, which means a lifestyle that carries significant implications for our health and well-being. In other words, in modern times, humans spend an increasing amount of time seated at a desk in front of a computer, and even though it revolutionised contemporary work, it also raised concerns about the well-being and health of employees [1-5].

By conducting simple research online, it is possible to see that office work and the kind of job it involves aggregates different professions, such as administrative assistants, managers, bankers, accountants, physicians, programmers, and others, spread through different sectors, such as finance, healthcare, technology, education, and various industries. Therefore, office work can be classified as clerical work as it implies administrative tasks such as document preparation, reception, review and verification, transaction processing, record maintenance, data retrieval and compilation into files, calendar management of deadlines and significant dates to relevant parties, as well as keyboard utilisation for typewritten content creation and data storage or manipulation for data processing [6].

Data available by CEDEFOP for 2021 considering the business services, that include "banking and finance; insurance; professional services (such as those provided by lawyers, accountants, engineers, computer programmers and analysts, advertising and marketing professionals, etc.; business services; and arts and recreation", estimates that 44,185,000 people are employed in this sector when considering the 27 Country Members of the European Union. Most of the population that enrols in this type of work are between the ages of 25 to 49 years old, followed by individuals between 50 to 64 years old, and the age range with fewer individuals is between 15 and 24 years old (60,00%, 29,00%, and 7,00%, respectively). By analysing the growth prospects for 2035, all countries will register higher employment in this sector.

In this way, more people tend to spend more hours of work seated, engaging in sedentary behaviour. This type of behaviour can be defined as any activity that requires an energy expenditure of basal metabolic rate (1,0 to 1,5 METs) in a sitting or reclined posture [6-11]. Accordingly, it is documented that the average office worker spends approximately 6 hours per day seated, which represents up to 80% of the workday in a sedentary position. This means a high level of sedentarism combined with a low level of physical activity [1, 3, 10, 11]. Consequently, there has been a rise in concerns regarding this kind of job since it is proven it can cause different health problems such as obesity, cardiovascular disease, diabetes, mental health challenges, and musculoskeletal disorders [2, 3, 5, 11-13].

In office work, associated with the sedentary behaviour that users are forced to adopt due to the tasks this type of job requires, there are other behaviours that can also negatively impact workers' health. These negative impacts will mostly affect the musculoskeletal system. Musculoskeletal health pertains to the functioning of the locomotor system, encompassing intact muscles, bones, joints, and adjacent connective tissues. Musculoskeletal conditions are typically characterised by pain (often persistent) and limitations in mobility and dexterity, reducing people's ability to work and participate in society. Pain experienced in musculoskeletal structures is the most common form of non-cancer pain. These symptoms affect the system and are characterised by impairments in the muscles, bones, joints, and adjacent connective tissues, leading to temporary or lifelong limitations in functioning and participation. They can be characterised as short and temporary conditions, such as fractures, sprains and strains, or long-term diseases, such as chronic pain, fibromyalgia or tendinitis [14].

Considering the entire workforce, musculoskeletal diseases are one of the most debilitating disorders for today's workers. These conditions affect the individual with the health problem and the company, increasing the economic pressure of employing an individual with limitations. According to data provided by the World Health Organization (WHO) relating to 2022, around the world, the population with musculoskeletal symptoms is approximately 1.71 billion, and this is the major contributor to restricted movement and agility, resulting in premature withdrawal from the workforce, diminished levels of welfare, and decreased engagement in societal activities [15].

The ergonomic risk factors associated with the appearance of musculoskeletal disorders have different origins. Sometimes harmful situations are related to individual behaviours, but in other cases, they are connected to work conditions. Individual behaviour, user posture, the time spent seated and the number of active breaks play an essential role in determining the health impacts on workers' health [16, 17]. Other factors to be considered are related to the ergonomic characteristics of the workstation itself. In some situations, the equipment provided to workers is not recommended, as the characteristics do not allow a proper workstation setup or are not the most suitable for the job [16, 18].

Identifying risk factors in offices is extremely important as it is the primary prevention line against the health impacts caused by harmful work conditions or improper behaviours. This is possible through various risk assessment methods that analyse work factors such as workload, worker position while performing the tasks, working hours, techniques, and workstation layout and setup. This ought to be an easy and straightforward way to fight musculoskeletal risk factors and promote a healthy and safe work environment [19].

2 THEORETICAL FOUNDATION

In the current professional context, a substantial amount of time is dedicated to office responsibilities, so applying ergonomic principles is paramount. This chapter aims to establish a study theoretical groundwork for understanding ergonomic issues in office work. The goal of exploring fundamental concepts, principles, and research discoveries in office ergonomics is to understand the musculoskeletal risk factors associated with this profession, the causes, assessment methods available and preventive measures.

2.1 History of Ergonomics in Office Work

In the early stages of Ergonomics, it was referred to as Human factors, as it focuses on understanding the interactions between humans and their environment and the tools and equipment used. The primary objective is to design and organise workspaces, products, and systems, optimising human performance, safety, and comfort [20, 21]. Accordingly, The International Ergonomics Association defines Ergonomics as "the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design to optimise human well-being and overall system performance". As such, the history of ergonomics in office work is related to the evolution and the dissemination of this kind of work worldwide and the realisation of the importance that work conditions have on individuals' wellness and productivity [22, 23].

Office work has been present in human life for centuries, like in the case of the Medici bank, but in those times, there was little concern about the workstation conditions as long as it was practical for the ones using it. In the late 19th century to the early 20th century, with the introduction of the typewriter in offices, there was a reshaping in the work performed, and office ergonomics began to emerge [24, 25].

With the introduction of Taylorism in the business world, principles of scientific management influenced office organisation and ergonomics, emphasising efficiency, which led to the investigation of the most efficient layout of offices and the design of ergonomic office furniture [26, 27]. Different types of businesses followed the Taylor method; tasks were split into more specific assignments, often forcing workers to undertake repetitive actions. Offices were organised to form lined-up rows, allowing continuous workflow and vigilant supervision by managers, many of whom occupy private offices, optimising the space available and granting a larger area for more desks [25].

After World War II, ergonomic considerations worldwide took a different turn, as awareness increased on how work conditions can affect humans and how they perform [28]. In this period, the study of body size, reach, strength, and capacity to process information began in the ergonomic field. In this way, it was possible to improve the relationship between workers and their offices [21, 29, 30]. Furthermore, there were two different lines of ergonomic evaluation followed, particularly Engineering Ergonomics (focuses on adapting the workplace to individuals) and

Cognitive Ergonomics (focuses on the mental workload, work duties and software interface) [21]. This was when the office layout changed to desks placed in an open space layout to promote interaction and cooperation between workers, establishing a non-hierarchical environment [25].

With the introduction of computers in the corporate world, new ergonomic challenges appeared since this kind of equipment had bid dimensions. Workers reported and experienced discomfort and repetitive strain injuries, which led to increasing concern regarding office workers' health. Consequently, more studies were conducted to fulfil the ergonomic principles of adapting the workplace to the worker rather than the other way around [20, 22, 31]. Governments and organisations began to develop ergonomic guidelines and standards for office environments. These guidelines covered chair design, keyboard placement, and lighting [32].

By conducting more ergonomic studies of the ergonomic conditions involved in office work, ergonomic products and furniture started to be present in offices, respecting the ergonomic guidelines established, such as keyboard placement, the height and characteristics of chairs, and the correct posture or behaviour regarding prolonged sitting and continuous monitor use [20]. Office ergonomics continued to be challenged as technology evolved, with new equipment shaping the workstation and work organisation, like mobile phones, laptops, and monitors of small dimensions [22]. Employers became more aware of ergonomics' benefits in reducing injuries and improving productivity [33].

Nowadays, the ergonomic line followed in offices involves a holistic perspective of the work developed, in the sense that it considers the physical and mental aspects of work, adopted in the more traditional work assessment and the work environment [34]. Hence, the traditional ergonomic approach includes the lighting, sound, layout, and social and collaborative nature of the job performed at the offices. Today, office ergonomics is a well-established field that continues to evolve as technology, work practices, and the understanding of human factors advance. It plays a vital role in creating work environments that promote employee health, well-being, and performance [21]. Corporates understand how valuable it is to have trained and formed individuals in this field, as it is proven to improve the health of the collaborators and the productivity of the company [34].

2.2 Workstation Elements

Office workstations are composed of elements that, although considered separate items, interact with each other, so a symbiotic relationship is of most importance [35, 36]. Therefore, a typical office workstation has different objects, such as a desk, chair, monitor, keyboard, mouse, telephone, and accessories. All elements must align to enable its user to maintain a correct setting posture, as presented in Figure 1.

Figure 1 – Ergonomic Sitting Posture.

2.2.1 Desk

A desk can be characterised as a work surface that usually has a standard height, fulfilling the majority of workplaces and individuals. In some cases, it is possible to acquire adjustable desks, therefore covering a more significant number of individuals, as it allows smaller and taller subjects to regulate the desk height to their specific features and needs. An essential characteristic of these elements is that they should have enough space to accommodate all the other aspects without compromising the user's health, and therefore, respecting the recommended distances and the zone of convenient reach. It should also allow sufficient leg space to the front and sides [35-37].

2.2.2 Monitor

Nowadays, office work involves the usage of a Visual Display Unit (VDU), which refers to a computer monitor or screen that displays visual information. Considering this type of equipment, it ought to enable its users to adjust its height; therefore, it must be height adjustable. This way, users can place the height within eyesight, which is reported as the most suitable position to prevent MSDs and promote a better sitting posture. It also should be at a distance from its user within the convenient reach [38-42].

According to the Computer Ergonomic Guide developed by OSHA [43], the correct posture of the monitor is:

1. Placed in front of the user, and the top line of the screen must be at the level of the eyes;
2. When seated, the user must set the monitor at a comfortable distance;
3. Avoid glare or reflation on the screen surface.

2.2.3 Keyboard and Mouse

To operate a VDU, the user must use a keyboard and a mouse. With the evolution of technology, many offices have wireless keyboard and mouse sets. To avoid an awkward angle between the wrist and hand, the keyboard must be placed respecting the distance between the shoulder, and the upper and lower harm should form a 90° angle or marginally higher [35, 39, 40, 43, 44]. Regarding the mouse, it must be within the desk's reaching area, avoiding the need to stretch and avoiding uncomfortable or problematic postures by users. The design must grant gripping and clicking user comfort. As such, the keyboard and mouse are expected to be closely located [35].

According to the Computer Ergonomic Guide, developed by OSHA [43], the correct posture for the keyboard and mouse is:

1. Set operated as one;
2. Shoulders relaxed and elbows near the body;
3. Elbows bent at a 90° angle or marginally higher;
4. The second line of keys (counting from the "space" key) must be at elbow height or insubstantially lower.
5. Wrists straight and making small circles;
6. Place the entire hand over the mouse;
7. Use the mid-section of the finger to click on the mouse key.

2.2.4 Chair

A key element in workstation elements is the chairs that must be selected considering specific characteristics because they are similar to desks. They must be comfortable and fulfil most individuals. In that way, it should be equipped with seat height adjustment mechanisms that ideally must permit an adjustment from 0,38 m to 0,53 m, satisfying the needs of most individuals and the taller and smaller ones. It also should have backrest adjustment mechanisms that support a substantial portion of the back, accompanying the natural curvature of the back, adjustable to its user, and the material should have the capacity to mould around its operator. The seat pan can have a mechanism that allows it to slide, which permits the user to extend the length of the seat, providing additional support for the one who needs it. Additionally, it ought to possess armrests functioning in a way that grants forearm support without obstructing the user's movements. Moreover, all mechanisms ought to be intuitive and straightforward, allowing their handler to use them to their advantage [35, 36].

According to the Computer Ergonomic Guide developed by OSHA [43], the correct sitting posture is:

1. Feet resting comfortably on the floor or a footrest, and knees slightly lower than the hips;
2. A 0,0508 m to 0,1026 cm gap between the back of the knees and the front edge of the seat;
3. The curve of the chair fits into the deepest part of the curvature of the lower back;
4. The back of the chair must be upright or tilted back for comfort;
5. Shoulders are relaxed, and the armrest is slightly below the elbows. The armrest must not interfere with the freedom of movement.

2.3 Ergonomic Risk at Offices

Considering the ergonomic risk associated with office work, it is essential to contemplate all office equipment, as the interaction between the worker and all workstation elements will be crucial in assessing the ergonomic risk of the determined situation. Accordingly, misalignment and positioning of the work equipment will potentiate the risk of the appearance of these diseases [12, 13, 45, 46]. As such, working in an office may contribute to the development of musculoskeletal complaints among office workers, in which the tasks performed, and the office routine will directly impact the body regions affected [12, 43, 46]. Work-related MSDs (WRMSDs) are responsible for almost 50,00% of absences caused in offices, resulting in the loss of work hours and increasing work costs [17, 46]. This problem affects not only the individual but also those around him, such as the organisation and society, as well as may interfere with the individual personal life and affect the quality of life [16, 46, 47].

The job performed in an office implies working with a VDU typing or reading documents and physical activities that require the worker to twist, bend, reach, carry or move around the office. The leading cause of WRMSDs involves repetitive movement, static posture, prolonged sitting and awkward postures, which are significantly associated with intradiscal pressure [16, 47]. One of the body regions where office workers report more symptoms is the upper body part. This body region involves different body parts, such as the head, neck, left and right shoulder, left and right elbow, left and right forearm, left and right wrist/hand, and the trunk [13]. As such, WRMSDs are the most prevalent ergonomic risk factor associated with sedentary behaviour in this type of job. Consequently, almost 60,00% of office workers report pain or discomfort in the upper back region [16, 17, 48, 49]. Although WRMSDs are not only related to physical factors, such as repetitive movements, awkward postures, and inappropriate workstation, but also to psychosocial factors, such as high job demands, excess of control or lack of autonomy in the tasks performed, absence of social support from pears, instability and imbalance between personal and professional life [50, 51].

The neck and shoulder region complaints are associated with prolonged and repeated VDU use and inappropriate furniture setup. One of the most frequent MSDs in the office environment is complaints of arm, neck, and shoulders (CANS), a consequence of repetitive stress on the body's soft tissues, including muscles, tendons, and nerves, sustained either in their professional roles, such as computer professionals or during extracurricular activities. Common issues involve tendons, like rotator cuff tendonitis, and disorders related to peripheral nerve entrapment, such as carpal tunnel syndrome [50, 51]. The correlation between neck pain or discomfort and forward head inclination angle suggests that VDU users tend to be in a non-neutral neck position. The prevalence of laptops in the work environment makes it impossible to adjust the monitor height, which forces users to flex their necks continually. The angle of the neck also affects other body regions, such as the trunk region, divided into the upper and lower back. This body region is also highly affected by the posture, whether the back is supported, the inclination angle, how long the posture is maintained and how many breaks workers take. In office work, there is a relation between the number of breaks workers take and the prevalence of WRMSDs, in which the fewer the breaks, the higher the pain and discomfort, and the higher the recovery time [16, 47, 52-54].

Therefore, it is extremely important to fulfil the ergonomic conditions requirements in offices to avoid MSD symptoms among the workers performing this job. In this sense, ergonomic analysis must be conducted in offices to prevent the occurrence of bad office behaviours, instructing employees and employers on good practices to adopt and by identifying all ergonomic risk factors present, associated with equipment, postures adopted, and sedentary behaviour [16, 54].

2.4 Systematic Review on Office Work Ergonomics

The present state-of-the-art review seeks to find existing knowledge on office work ergonomics. As such, the objective of this research was to document existent studies conducted by other authors where the main focus was office work and seated postures; collect data regarding ergonomic tools available for office work; gather information about the methods utilise to do a complete characterisation of the study sample; compile details about of common sitting postures adopted in offices and risk assessment or identification tools; assemble information about dynamic ergonomic assessment tools of seated work; and systematise information regarding musculoskeletal work-related disorders.

The following literature review was conducted according to the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-10) [55]. To filter the articles relevant to this specific research, inclusive criteria were established based on the research goals of doing an ergonomic characterisation of office and seated professions, considering the methods available, the postures adopted, the type of seating apparatus, and job characteristics. All articles were included, even the ones in the publication stage; conference papers and articles regarding professions not enrolled in office work were excluded. All articles performed in field or laboratory conditions and literature reviews aiming to characterise office work, human-chair interaction and musculoskeletal disorders associated with seated work were included. The selected ones analyse office work through risk assessment methods and sensor application in the chairs. If the sitting office equipment differed from the one described, it was also excluded. Only articles published between 2018 and 2023 were accepted; all must be in English. The selected keywords were Office workers, Office, Seat, Seated, Prolonged sitting, Ergonomic, Ergonomic risk, Posture, Work posture, Awkward posture, Musculoskeletal disorders, and Musculoskeletal Disease. The keywords were combined as presented in Table 1, in SCOPUS and Web of Science.

Table 1 – Combination of Keywords and Research Data Base.

Data Base	Keyword Combination
SCOPUS	"Office workers" AND "Ergonomic risk"
	“Office workers" AND "Work posture"
	"Office workers" AND "Awkward posture"
	Seated AND Ergonomic
	Seated AND Posture AND Ergonomic
	Seat* AND (Musculoskeletal AND (Disorders OR Disease)) AND Office
	"Prolonged sitting" AND Ergonomic
Web of Science	"Office workers" AND "Ergonomic risk"
	“Office workers" AND "Work posture"
	"Office workers" AND "Awkward posture"
	Seated AND Ergonomic
	Seated AND Posture AND Ergonomic
	Seat* AND (Musculoskeletal AND (Disorders OR Disease)) AND Office
	"Prolonged sitting" AND Ergonomic

The research was divided into 4 stages:

- **Stage 1** – Insertion of keyword combinations in the “Article title” field of the different databases and the inclusion criteria were selected in the filters (time range, type of document and language);
- **Stage 2** – Selection of articles considering the title;
- **Stage 3** – Selection of articles based on the abstract;
- **Stage 4** – Selection of the article regarding the methodology applied. All duplicates were eliminated.

Figure 2 is the flowchart of the decision process. As stated before, in both databases selected, the combination of keywords was introduced, and the inclusion criteria filters were applied to clean the research results. Afterwards, a pre-selection was made considering the article title. If the respective title had important information for the present state-of-the-art review, the article moved to the next phase, which was analysed considering the abstract. If the methodology and scope were within the field of interest, the article content was analysed fully, and the article was or was not included in the research. After all articles were selected, the duplicates were eliminated.

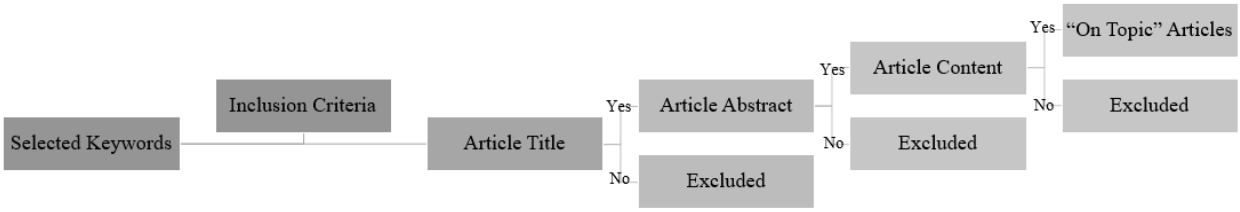


Figure 2 – Flow chart of the decision process.

In stage 1, all articles were documented using Microsoft Excel version 2307. In Stage 2, the research data, the research platform, the researched combination of keywords, the author/s, the date of publication, and the article's title were also documented. The abstract and keywords were recorded for the articles selected for Stage 3. The methods and results were detailed for the articles chosen for Stage 4. The reasons for exclusion or inclusion were also recounted. After the final selection, all articles were exported using EndNote version 20.4.1.

As mentioned above, the selected combination of keywords was introduced in two research databases, SCOPUS and Web of Science, and the articles were chosen considering the inclusion criteria. In Table 1, presented in Appendix I, you can find the resumes of the articles found, considering the inclusion criteria and the combination of keywords. Table 2 shows the results of the two databases used, considering the total combination of keywords selected and the inclusion criteria. Considering both databases, a total of 1511 results were obtained. Applying the date filter (2018 – 2023), the results were 568. Through the document filter (article), it was possible to decrease the research results to 428. The source type (journal) allowed us to filter the results to 427. Filtering the results based on the language (English), 419 documents were analysed. After the document analysis, 52 papers fulfilled the state-of-the-art objectives.

Table 2 – Resume of research results considering the total of research keywords.

Research Database	Keywords	Date	Document	Source	Language	On Topic
Scopus	504	179	127	126	124	27
Web of Science	1007	389	301	301	295	25
Total	1511	568	428	427	419	52

To select the “On topic” articles, the flow chart decision process described in Figure 2 was performed, and the results are presented in Figure 3. Considering the pre-selection, 418 articles were analysed based on the title, of which 167 moved to the next stage, and 251 were eliminated. Regarding the abstract, 103 articles were moved to the next step, and 64 were excluded. Through the content analysis, 52 articles were included, and 51 were excluded. After removing 28 duplicate articles, 24 were included in the systematic review. Two documents required a deeper analysis, although it was impossible to obtain access to the full-text version at the time.

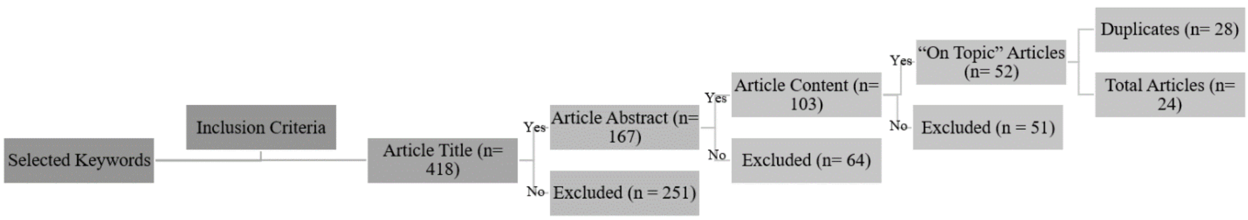


Figure 3 – Results of the flow chart decision process.

As was stated before, the present systematic review followed the PRIMA Statement procedures. Therefore, in Figure 4, the PRIMA Statement flow diagram follows the same reasoning as the decision tree presented in Figure 3.

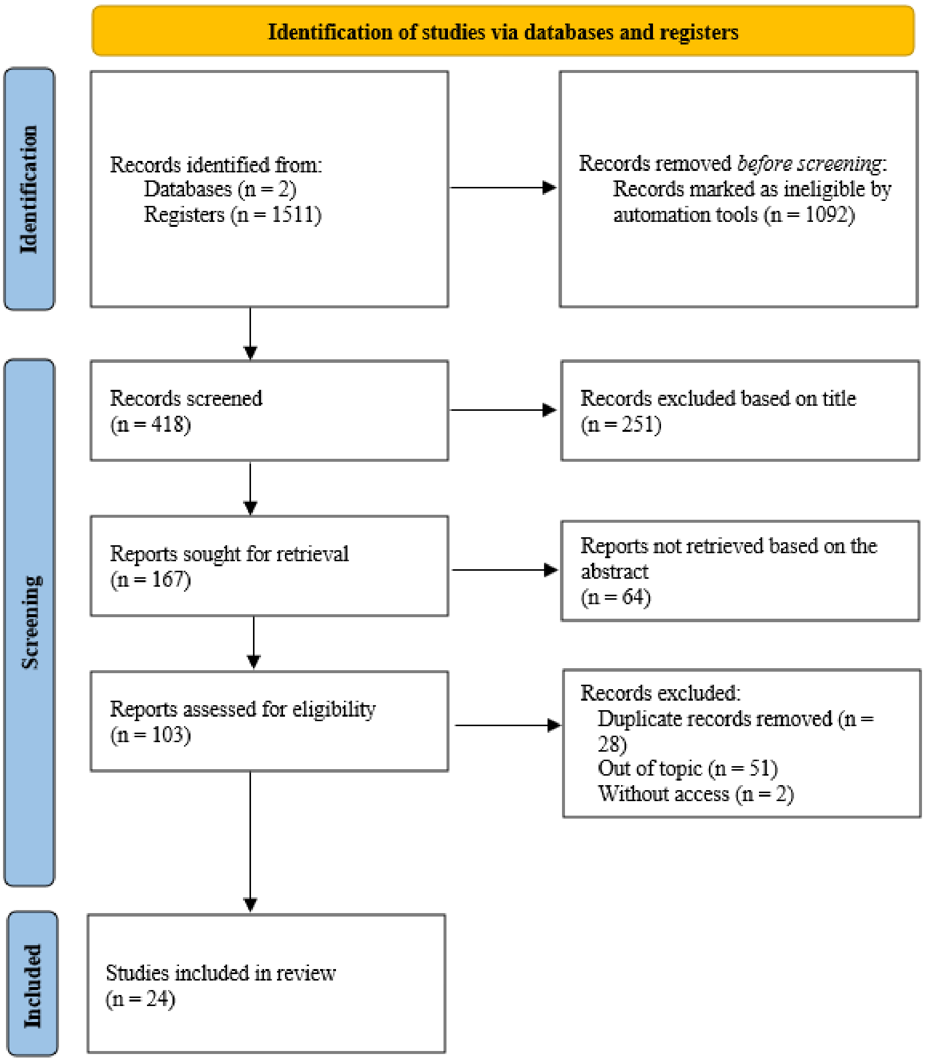


Figure 4 – PRISMA Statement Flow Diagram.

The studies selected are presented in Table 3, considering the findings of other authors, with the resume of the articles selected, the purpose of the study, and the postures tested when applied. The results and the discussion were made bearing in mind the methodology and evaluation made, the posture tested or observed and the health impacts on subjects that those postures or behaviours may have.

Table 3 – Systematic Review Article Synthesis.

Article	Purpose	Method	Postures tested
[56]	Combine in a single cost-effective solution, the monitoring and control of user posture and sitting time through an instrumented office chair	Application of 15 sensors in an office chair and performance evaluation of the system conducted	(1) Correctly seated; (2) Slouching forward; (3) Slouching forward with the hips wrongly positioned; (4) Seat back also with the hips wrongly positioned; (5) Leaning on the right side; (6) Leaning to the left side
[57]	Development of a smart chair system equipped with load and ECG (electrocardiography) cells able to predict user posture and monitor the cardiovascular system, respectively	Placement of 3 load cells in the chair seat placed in a triangular shape and ECG cells in the armrest and performance evaluation of the system conducted	(1) Upright sitting; (2) Slouching; (3) Leaning forward; (4) Leaning backward; (5) Leaning left; (6) Leaning right; (7) Right leg crossed; (8) Left leg crossed
[45]	Estimate the recommended ergonomic duration for maintaining different sitting postures in an ergonomically adjusted workstation	Application of a demographic questionnaire and of the 10-point Borg CR10 rating scale do assess discomfort; evaluate 17 common static sitting postures for 4 min and estimate the maximum holding time and rate discomfort	Neck Angle: (1) Neutral (0º); (2) Mild Flexion (15º); (3) Moderate Flexion (30º); (4) Extension (-20º); (5) Lateral Bending (15º); (6) Rotation (15º); Trunk Angle: (7) Middle Position (0º); (8) Middle Position (0º); (9) Mild Flexion (15º); (10) Moderate Flexion (30º); (11) Extension; (12) Lateral Bending (15º); (13) Rotation (15º); Knee Angle: (14) Neutral (90º); (15) Flexion (60º); (16) Extension (120º); (17) Leg Crossing
[51]	Determine the ergonomic risk factors present in offices related to complaints in the CANS	Application of the Maastricht Upper Extremity Questionnaire (MUEQ) and ROSA (Rapid Office Strain Assessment) method to collect information about MSD and ergonomic risk assessment evaluation	NA
[58]	Compare the differences between a home office and an ergonomic workstation	Used of a Motion Capture System to record movement and RULA (Rapid Office Stain Assessment) to assess risk level	NA
[59]	Investigate the sitting behavior of office workers using ergonomically adjusted workstations	Posture recording and classification by the method developed by Graf, Guggenbühl [60] and RULA	NA
[61]	Determine which is the most effective solution to improve the body posture while seated	Literature review using the Analytic Hierarchy Process (AHP) and PUGH matrix	NA
[62]	Develop and implement invisible and non-intrusive plastic optical fiber (POF) sensor cells to monitor the posture and evaluate the ergonomic behavior of a seated person	Implementation of 4 POF sensor cells in and office chair and assess system performance in 5 posture prediction	(1) Correctly seated; (2) Leaning forward; (3) Leaning forward with the hips wrongly positioned; (4) Leaning on the right side; (5) Leaning to the left side
[63]	Characterize movement patterns during a prolonged sitting bout and to determine their relationship with musculoskeletal pain	Application of a demographic and occupational questionnaire to collect user data; Placement of a pressure sensitive mat to quantify seat pan pressure and trunk sway parameters	NA

Article	Purpose	Method	Postures tested
[56]	Combine in a single cost-effective solution, the monitoring and control of user posture and sitting time through an instrumented office chair	Application of 15 sensors in an office chair and performance evaluation of the system conducted	(1) Correctly seated; (2) Slouching forward; (3) Slouching forward with the hips wrongly positioned; (4) Seat back also with the hips wrongly positioned; (5) Leaning on the right side; (6) Leaning to the left side
[64]	Design an orthopedic chair for people with musculoskeletal disorders, considering ergonomic principles and active sitting function	Use of the Xsens 3D motion tracking system to analyze body segments depending on the chair	(1) Leaning forward; (2) Leaning forward with knees wrongly positioned; (3) Leaning forward with knees crossed; (4) Slouching
[17]	Evaluation of Musculoskeletal disorders (MSDs) and their ergonomic risk factors among office workers	Application of the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) to assess musculoskeletal symptoms and the ROSA as ergonomic risk assessment tool	NA
[65]	Develop an effective real-time posture monitoring system, able to predict user posture and send feedback	Placement of 12 pressure sensors in the seat and 12 distance sensors on the back of the chair evaluate system performance	(1) Leaning on the seatback while keeping the back straight; (2) Detaching the back from the seatback and keeping the trunk erect; (3) Flexing the trunk forward about 4 degrees (slouch); (4) Leaning against an armrest with lateral bending (left); (5) Leaning against an armrest with lateral bending (right); (6) Sitting on the leading edge with convex trunk; (7) Leaning back with hips slightly forward (slump); (8) Legs crossed (left); (9) Legs crossed (right); (10) Rotating the trunk about 20 degrees (left); (11) Rotating the trunk about 20 degrees (right).
[54]	Investigate the differences and benefits between active breaks and postural shift in reducing sitting discomfort and shortened duration in recovery from neck and low back pain	Comparation of a custom-designed apparatus and a placebo seat pad between two groups with a follow-up after 12 months, The Borg CR-10 scale to determine perceived discomfort, Modified Nordic questionnaire, Work-related (physical) factors, and Thai version of the Job Content Questionnaire, Demographic and occupational questionnaire	NA
[66]	Evaluate the effect of promoting rest breaks and postural shifts to prevent neck and low-back pain	Comparation of a custom-designed apparatus and a placebo seat pad between two groups with a follow-up for 6 months, The Borg CR-10 scale to determine perceived discomfort; Modified Nordic questionnaire, Work-related (physical) factors, Thai version of the Job Content Questionnaire, and a Demographic and occupational questionnaire	NA

Article	Purpose	Method	Postures tested
[56]	Combine in a single cost-effective solution, the monitoring and control of user posture and sitting time through an instrumented office chair	Application of 15 sensors in an office chair and performance evaluation of the system conducted	(1) Correctly seated; (2) Slouching forward; (3) Slouching forward with the hips wrongly positioned; (4) Seat back also with the hips wrongly positioned; (5) Leaning on the right side; (6) Leaning to the left side
[67]	Design, develop and implement a novel user-friendly smart seat cover to monitor sitting posture	Placement of a Sitting Pressure Sensor (SPS) into an office chair to monitor 3 postures for 30 min (10 min/posture) and evaluate model performance	Sit up with their back straight, shoulders pushed back, and buttocks aligned to the rear most part of the seat, such that their back is straight in line with the backrest (normal or mild asymmetry); (2) Sit cross legged with right leg over the left knee (moderate asymmetry); (3) Sit leaning high to right side, cross-legged with right leg over the left knee in a severe asymmetry posture (severe asymmetry)
[48]	Examine the risk factors of MSDs in offices and compare the differences between two groups in different intervention programs	Application of ROSA before and after intervention, Demographic and occupational data, and the Nordic Musculoskeletal Questionnaire (NMQ)	NA
[53]	Compare ergonomic risk factors and work-related psychosocial factors in visual display units (VDU) users with and without MSDs	The NMQ, the Effort-Reward Imbalance Model and Over-commitment Questionnaire, and ROSA	NA
[68]	Detect different sitting postures with a small number of sensors and little data processing prior to the use of the classifier algorithm	Placement of 6 Force Sensitive Resistors (FSR) in the chair seat and test 7 postures	(1) In an upright posture, with the back supported by the chair's backrest and the buttocks placed at the back of the seat; (2) In a reclined position, with only the upper part of the back resting on the back of the chair and the buttocks resting on the front part of the seat; (3) With the torso bent forward, elbows resting on the legs, back completely separated from the backrest; (4) With the torso inclined laterally to the right, armrest supporting part of the weight; (5) With the torso inclined laterally to the left, armrest supporting part of the weight; (6) In an upright posture, similar to posture 1, but with the right leg crossed over the left; (7) In an upright posture, similar to posture 1, but with the left leg crossed over the right
[69]	Identify the characteristics of perceived discomfort and different magnitudes of postural shifts during a 4-h sitting period and to examine the association between perceived discomfort and number of postural shifts at different magnitudes	Rate the perceived body discomfort using Borg's CR-10 scale in 10 body regions and placement of a seat pressure mat device	NA
[47]	Determine the prevalence of musculoskeletal disorder-related issues and to analyze the association of pain symptoms with risk factors	Questionnaire about pain, a flexibility test (sit-and-reach test) and RULA	NA

Article	Purpose	Method	Postures tested
[56]	Combine in a single cost-effective solution, the monitoring and control of user posture and sitting time through an instrumented office chair	Application of 15 sensors in an office chair and performance evaluation of the system conducted	(1) Correctly seated; (2) Slouching forward; (3) Slouching forward with the hips wrongly positioned; (4) Seat back also with the hips wrongly positioned; (5) Leaning on the right side; (6) Leaning to the left side
[70]	Evaluate the reliability of measures of upper body postural behavior during sustained office work	Use of three axial wireless motion sensors for 1h; Made calculations for 4 Angles (HA – Head Angle, TA – Thorax Angle, AA – Arm Angle, NA – Neck Angle) of the mean angle displacement, cumulative angular travel, angle duration, composite upper body posture duration (for NA and TA)	(1) Sitting upright; (2) Sitting looking straight ahead and holding their arms to the side, and palms of the hands facing forwards *
[16]	Determine the major ergonomic issues, to compare the two ergonomic assessment tools (RULA and REBA), and to develop a model that correlates working condition, work posture and computer workstation design with their negative effects on musculoskeletal system	CMDQ, REBA (Rapid Entire Body Assessment) and RULA	NA
[71]	Determine scapular positioning at rest and different anatomical planes, the assessment of pain, postural changes and the functionality of upper extremity that is caused by the lack of ergonomic principles	RULA, Lateral Scapular Slide Test (LSST), The Short Form McGill Pain Questionnaire (SF-MPQ), Quick-Disabilities of the Arm, Shoulder, and Hand (Q-DASH); Neck Disability Index (NDI); Cervical and upper thoracic postures with photography	NA
[49]	Identify the prevalence of MSDs and ergonomic risks	The NMQ, RULA and ROSA	NA

NA – Not applicable.

*Postures adopted to calibrate the equipment.

Therefore, considering the methodology used, different authors resorted to questionnaires to characterise the population regarding sociodemographic characteristics and job-related information. The data collected is related to age, height, weight, Body Mass Index (BMI), marital status, education level, dominant hand, involvement in regular weekly sport/physical activities, job experience, job schedule, time spent seated, and so on. This way, by asking participants simple information regarding their individual and work aspects, it is possible to portray the sample and set the population attributes, defining groups that enable data treatment and posterior analysis [16, 17, 47-49, 51, 54, 63, 66, 69, 71].

On the other hand, through the application of questionnaires, it is also possible to collect data regarding the participants to collect data regarding the participant's perceived discomfort or pain. One of the methods available is the NMQ, which covers various body regions, can be applied in various occupations and provides a general overview of musculoskeletal issues but lacks in-depth details, inquiring about the last 7 days and 12 months [18, 48, 49, 53, 58, 66]. Another is the CMDQ, which focuses on discomfort associated with computer-related tasks and provides specific information about discomfort caused by job demands. For the last week, ask to detail how many times it happened, how uncomfortable it was, and how it affected job performance [16, 17, 47]. The MUEQ is designed to evaluate physical workload and discomfort associated with repetitive or physically demanding upper extremity tasks and inquires participants about job tasks, physical discomfort, and other relevant factors, offering specific insights into upper extremity issues [51]. The Borg CR-10 scale to determine perceived discomfort – is helpful, as it is a numerical scale that ranges from 0 to 10 for expressing discomfort or exertion that is usually applied to quantify intensity [54, 66]. The study conducted by Depreli and Angin [71] used questionnaires different from those mentioned above, such as the LSST, to identify scapular dyskinesis or altered scapular movement patterns. They also used the SF-MPQ, which describes and measures the quality and intensity of pain experienced. The VAS permits a simple and quick way for individuals to rate their pain on a graphic scale. Through the Q-DASH, it was possible to measure the functional limitations of individuals with upper extremity musculoskeletal conditions, and the NDI measured how neck pain affects the everyday life and activities of participants. To assess the ergonomic risk, there are different tools available, such as the ROSA [17, 48, 49, 51, 53], which involves a quick observational checklist to identify ergonomic risk factors of the workstation in its entirety, the RULA [16, 49, 58, 71], that focuses on analysing the posture of workers during tasks that involve repetitive movements or sustained periods of upper body activity, and the REBA [16, 59], designed to assess the entire body posture of workers during tasks to identify potential ergonomic issues. It is also possible to use online tools such as the OSHA eTool evaluation checklist [16].

Symptomatology

Throughout the studies, participants identified common body parts, but the neck was the one being referenced by most participants. For example, in the study conducted by Mianehsaz, Tabatabaei [17], considering the last seven days before the study, the neck was identified by 67,60% of the participants. This information agrees with other studies in the sense that Redivo and Olivier [53] had 33,90% reporting symptoms in the same area, as well as 57,20% in the study conducted by Singh and Singh [47], and 75,71% in the article published by Chowdhury, Aghazadeh [16] always for the same period. Depreli and Angin [71] used the NDI and discovered that 40,30% reported pain problems in this body region. Consequently, even though the methods applied were different, the results were similar. Comparing the results obtained for the last 12 months before the study, the information was parallel, as 67,10% of the participants of the study developed by Motamedzadeh, Jalali [48] also pointed this area, as well as 69,10% in the case of Redivo and Olivier [53], 55,20% identified by Mohammadipour, Pourranjbar [49]. The pain felt in this region can be explained by the positioning of the monitor that will influence the positioning of the head (in some cases, forces the user to look up or down about the line of sight, depending on if it is too high or too low), the absence of document holder or headphones. This misplacement or absence of work equipment may lead users to extend or bend the neck at inappropriate angles compromising their health [49, 51]. Considering the position of the monitor, the ROSA was applied by Mianehsaz, Tabatabaei [17], which obtained a score for the Monitor and Phone of 2,22 ± 0,68, Iram, Kashif [51] of obtained 2,98 ± 0,72. In the research conducted by Motamedzadeh, Jalali [48], all groups obtained a ROSA Monitor and Phone score of 4,10 ± 0,11 before intervention (2 weeks before the study) and 2,75 ± 1,49 after intervention (9 months after the study). Therefore, it is possible to presume the cause-effect relation between positioning the different apparatuses that compose the office work, particularly the VDT, with the neck. Tahernejad, Razeghi [45] asked participants to maintain 17 postures, commonly adopted in offices, for 4 minutes and found that participants with a moderate flexion angle in the neck felt the highest discomfort score with an MHT (Maximum Holding Time) of 1,61 minutes, in addition, the lowest discomfort score is registered in a neutral posture.

Another body sight that may be jeopardised by the work equipment's poor positioning, particularly the mouse's distance to the keyboard, is the shoulder area [51]. Some studies also identify this region as one of the most reported regions where participants felt pain or discomfort when considering the last seven days before the study, in which 51,60% of the participants evaluated by Mohammadipour, Pourranjbar [49] identified it as the main cause of discomfort, 42,00% in the study of Iram, Kashif [51], 38,50% of the subjects inquired by Singh and Singh [47], and 27,90% of the sample analysed by Redivo and Olivier [53]. This body region is also mentioned in the last 12-month period before the study, by 57,40% of the inquired by Redivo and Olivier [53] and 51,60% by Mohammadipour, Pourranjbar [49]. The research conducted by Chowdhury, Aghazadeh [16] found that 78,94% and 84,21% of people who had wrong head and neck posture and had incorrect arrangement of VDT (Visual Display Unit) reported neck, upper back and shoulder pain. These results corroborate the results obtained by Mohammadipour, Pourranjbar [49], who found a correlation between the monitor and telephone score in ROSA (position of the monitor and telephone) and neck pain among RULA D score (neck angle adopted) with neck pain, and RULA C score (shoulder position) and shoulder pain. This means that the posture adopted, and consequently, the angle formed between body segments is directly connected to the manifestation of MSD symptoms or complaints in the neck [49].

The back region**,** divided into the Lower and Upper back, was also recognised as a cause of distress. Considering the last seven days and the lower back region, in the study coordinated by Chowdhury, Aghazadeh [16] 64,00% of participants identified this region, as well as 46,2% in the research developed by Singh and Singh [47], 13,20% by Redivo and Olivier [53], and 59,50% in the case of Mianehsaz, Tabatabaei [17]. Mianehsaz, Tabatabaei [17] also identify the upper back, mentioned by 55,00% of the subjects and in the study of Redivo and Olivier [53], 16,20%. Considering the last 12 months and the lower back region, 64,40% of the participants of the research conducted by Motamedzadeh, Jalali [48] reported symptoms in this region and 41,20% in the case of Redivo and Olivier [53]. Considering the upper back region, 72,40% of the participants in the experiment led by Mohammadipour, Pourranjbar [49] reported pain or discomfort, as well as 63,00% in the case of Motamedzadeh, Jalali [48], and 39,10% in case of Redivo and Olivier [53]. The back region can be affected by many aspects of the workplace, and through the application of the ROSA method and Mohammadipour, Pourranjbar [49] found a positive correlation between MSDs in the upper and lower back and the monitor score. Pain or discomfort in the lower back region also correlates with the ROSA chair and RULA D score [49]. Accordingly, the back region is directly connected to the trunk's angle to maintain a certain position. Tahernejad, Razeghi [45] found that the highest discomfort score reported by subjects was registered for moderate forward trunk inclination (30°) with an MHT of 1,78 minutes and the lower discomfort score when the trunk is supported in a backward position, with a recommended MHT of 5,92 min. The MHT recommended for this position was higher than recommended for a neutral trunk or upright sitting postures. Considering the middle trunk, assuming a neutral posture and mild forward inclination (15°), the results were similar regarding discomfort score, and the MHT was 2,55 minutes and 2,53 minutes, respectively.

In the office world, employees often adopt awkward postures because many need the proper equipment, such as appropriate chairs with adjustable height, seat depth and armrests, and tables with sufficient space to accommodate all the material while respecting the reaching zone. This forces the user to adopt unhealthy postures, which are impossible to maintain in time. Another case scenario is that, in some cases, employees do not possess the knowledge to set the equipment correctly and do not know how to position the equipment in a self-beneficiary way. Therefore, workers should be given the tools and the knowledge to set the workstation most ergonomically and be the first agent in preventing MSDs related to office work [48, 49, 51].

Pressure Sensor

Another way to prevent the appearance of MSDs among office workers and avoid pain or discomfort symptoms is to develop a system that automatically detects the user posture to assist them in the decision process of the posture to adopt. As such, Tavares, Silva [56] placed 15 analogue sensors (four load cells on the seat for pressure monitoring, four FSR on the backrest for pressure monitoring, one accelerometer for rate monitoring, one body temperature sensor, and five other environmental sensors) in a chair, and tested six commonly adopted office postures. He found that the sensors could predict user position with 100 % confidence considering their position and performance, were able to cover users with different characteristics in terms of height and weight, the accelerometer gave, to some extent, higher values than the reference sensor with a detected error of 18%.

Pereira and Plácido da Silva [57] used Sitting Posture Monitoring Systems (SPMS) 3 load cells in a triangular configuration and conductive nappa electrodes to monitor heart rate through an ECG signal. They tested eight common office postures for 1 minute. Considering the first six postures, the classification model had an excellent performance in the metrics evaluated, over 97,40%, and could predict the five postures proposed without significant differences between accuracy in the test dataset and the validation accuracy. Considering the eight postures, it had a decreased overall accuracy compared to the validation accuracy because of the misclassification of the 7th and 8th positions and the 1st and 2nd positions. However, the k-NN (k-Nearest Neighbour) models still presented an accuracy of 85,80% to 87,60%, depending on the number of neighbours considered. The observation is underscored by the ECG segmentation's above-average performance and accuracy rates, which exceeded 90% and 85%, respectively, proving to be a reliable system for predicting postures and measuring heart rate.

Tavares, Silva [62] tried a different approach and placed 4 Plastic optical fibre (POF) pressure sensors (one in the right and one in the left ischial tuberosities, and one in the right and other in the left thigh) and guess five positions. It could predict with 96,60% accuracy positions 1, 3, 4 and 5. It couldn't indicate posture 2 because it is an intermediate between 1 and 3, which becomes difficult to predict with sensors in the chair pan alone. Nonetheless, it proposes an excellent alternative to other sensors in the market since it is a simple and low-cost system with lower complexity and high efficiency.

Luna-Perejon, Montes-Sanchez [68] studied the possibility of placing 6 FSRs (force-sensitive resistors) in a chair pan, tested seven postures for 15 seconds each, and used an ANN-Based Machine Learning Classifier. The results show that the model's low complexity enables integration into embedded systems and real-time execution, and, among the developed techniques, it features the fewest sensors yet maintains an 81% effectiveness in classifying seven distinct positions. As with other sensors, this one also has limitations in distinguishing between an upright position and one with the back not resting on the backrest.

In the study conducted by Jeong and Park [65], 12 pressure and 12 distance sensors were placed in a chair (on the chair pan and back, respectively) and used the k-NN model as SPMS to test 11 positions for 10 seconds, in a mixed system. When considering the pressure sensors alone, the overall accuracy was 59,00%, the distance sensors were 82%, and the pressure and distance sensors were 92%. Therefore, the higher performance possible for this system is when the two types of sensors are contemplated, as they permit insight into the user distance from the chair back, which is presented as a limitation in the studies previously mentioned.

In the research developed by Anwary, Cetinkaya [67], six pressure sensors (one in the right, another in the left shoulder, one for the right, another for the left lower back, and one right other for the left thigh) integrated into a smart cover to assess three postures with different levels of asymmetry, 10 minutes each. Therefore, they concluded that the average pressure is equally distributed through all locations for the first posture (normal sitting posture). In the second posture (moderate asymmetry), subjects adopt a seated position where their right leg is crossed over the left knee, resulting in higher sitting pressure on the left side and for the third position (severe asymmetry), subjects sit in a posture leaning predominantly to the right side, with their right leg crossed over the left knee, so the majority of the sitting pressure is concentrated on the left side. There is minimal pressure on the right side. The goal was to develop a fuzzy rule-based system that takes input from four inputs and outputs one result, categorising the asymmetry level (mild, moderate, or severe). It considered the mild asymmetry ranges from ±0~25% with an MHT of 15 min, the moderate asymmetry ranges from ±26~65 % with an MHT of 10 min, and the severe asymmetry ranges from ±66~100 % with a maximum sitting time of 5 min.

Arippa, Nguyen [63] used a pressure mat to quantify seat pan pressure and trunk sway parameters over time to analyse prolonged siting. The results indicate that time contributed to increased perceived discomfort and time, with a notable impact on the buttock area. Analysing the patterns of movement over time, the EC (ellipse's centroid) shifted in a forward direction over time (statistically significant differences from baseline after 42.5 min), the maximum displacements of COP (centre of pressure) in the AP (anteroposterior) direction were also negatively correlated with time as the ICMs (number of in chair movements). In the gluteus region, the average pressure values significantly decreased over time (higher than baseline after 117.5 min of sitting). Meanwhile, mean pressure values in the thigh region significantly increased over time (higher than baseline after 57.5 min of sitting).

Consequently, more important than adopting the correct posture, it is also important to maintain it for the right period. This aspect is demonstrated by Arippa, Nguyen [63] by comparing two groups: one that changed at least once during the trial period (stand up or change position) and another that presented postural shifts. Results indicate a significant effect of the group on subjective discomfort ratings of the sitting bones and edge of the seat. No differences were reported between groups in MP (Mean Contact Pressure). Despite differences in trends over time for overall and partial MP, the overall MP was found to significantly increase for prolongers, while no significant trend was found in the case of breakers. Making the correlation between the patterns of movement and perceived discomfort, significant associations were found between MP and sitting bones and overall discomfort for prolongers. At the same time, breakers showed significant negative associations between sitting, bone discomfort and SP (sway path) and positive relationships between discomfort in the buttock area and MP in the thigh region. Although the results of the study conducted by Waongenngarm, van der Beek [66] and Akkarakittichoke, Waongenngarm [54], that proposed and evaluated an ergonomic intervention with a 6 to 12-month follow-up, respectively, show that by adopting healthier work behaviours, specifically active breaks and postural shifts shortened recovery time for two months in the case of the group that did not receive ergonomic intervention and of 1 month to the other group, as they can reduced recurrent pain rate by 65–78% in comparison with the group without intervention, reduction of individuals reporting neck or lower back pain, in case of the 12 month follow up.

Through the research conduct, the study of the ergonomic conditions present in offices arises, as it is a work field where participants are proposed to perform awkward sitting postures due to the job characteristics that are often maintained for extended periods and can aggravate the risk of developing MSDs symptoms of diseases, particularly in the neck, back region, and upper [16, 17, 45, 48, 51, 53, 54, 58, 59, 61]. A solution that comprises both a prevention and action system, able to predict the user position and send alerts or make corrections, is an appealing alternative in the office context, as it intends to relate the angles adopted and the pressure exerted to maintain a particular posture, possible through the application of different types of sensors and using other methods [56, 57, 61-65, 67-70].

2.5 Ergonomic Risk Assessment Methods Available for Office Work

To prevent work-related MSDs and promote a healthy work environment, several legal documents should be enforced and considered. Therefore, to prevent and detect early risk evidence of damaging factors, applying risk assessment methods takes on an extreme priority [72, 73]. These risk assessment methods are under four different categories: subjective decision, systematic examination, direct measurement and through digital human modelling (DHM) [72, 74-76], as presented in Figure 5.

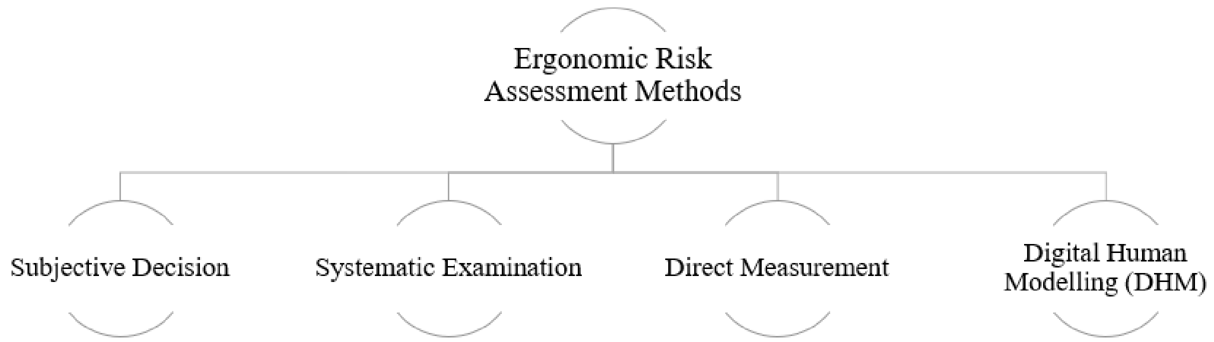


Figure 5 – Ergonomic Risk Assessment Methods.

2.5.1 Legal and Regulatory Framework

Considering the job performed at an office, several legal documents can be consulted. As such, the established in Law No. 7/2009, of February 12th, must be obliged as it sets the primary legislation governing employment relationships in Portugal. It covers various aspects of employment, including contracts, working hours, leave, termination, and other aspects of work [77]. There is also Law No. 102/2009, which establishes regulations for promoting safety and health in the workplace by Article 284 of the Labour Code, as approved by Law No. 7/2009 of February 12th, with subsequent amendments by Law No. 42/2012 of August 28th, and altered for the second time by Law No. 3/2014, of January 28th [78]. Considering Decree-Law No. 243/86, of August 20th, the general regulation for hygiene and occupational safety in commercial, office, and service establishments can be consulted and must be applied [79].

Considering workplaces, there is Decree-Law No. 347/93 of October 1st, which transposes into the domestic legal order Directive 89/654/EEC of the Council, dated November 30th, concerning minimum safety and health requirements for the workplace [80]. In Law No. 113/99 of August 3rd, the general regime of labour infractions, through the definition and classification of infractions related to the breach of specific legislation on safety, hygiene, and health at work in certain sectors of activities or certain professional risks are defined [81]. Through Ordinance No. 987/93 of October 6th, the minimum safety and health requirements for workplaces are established [82].

When considering all work equipment, Decree-Law No. 50/2005, of February 25th, transposes into the domestic legal order Directive 2001/45/EC of the European Parliament and of the Council, dated June 27th, concerning the minimum safety and health requirements for the use of work equipment by workers, and repeals Decree-Law No. 82/99, of March 16th [83]. When considering equipment equipped with a display screen, Decree-Law No. 349/93, of October 1st, transposes into the domestic legal order Directive 90/270/EEC of the Council, dated May 29th, concerning minimum safety and health requirements for work with display screen equipment [84]. In Ordinance No. 989/93 of October 6th, the minimum safety and health requirements for work with display screen equipment are defined by [85].

2.5.2 Subjective Decision Methods

As such, the subjective decision methods correspond to the individual perception of the employee through a self-rated exposure analysed via interviews, questionnaires, or journals. Therefore, this represents a low-cost alternative, as it requires few resources (pen, paper, computer, etc.). Participants are asked different questions, which are analysed based on established parameters or guidelines [72]. There are several online methods available, such as:

- OSHA Computer Workstations: Provided by the U.S. OSHA, this online tool guides users through a series of questions to assess the computer workstation setup and provide recommendations for enhancements [43];
- Washington State Ergonomics Checklist: developed by the Washington State Department of Labour and Industries, this checklist covers various aspects of office ergonomics, including computer setup, chair and desk adjustments, lighting, and more [86];
- Cornell University Ergonomics Web: Cornell University offers an interactive online assessment tool that helps users evaluate their computer workstation, chair, and accessories. It provides personalised suggestions for adjustments [87];
- HSE Workstation Checklist: Provided by the Health and Safety Executive (HSE) in the UK, this checklist covers factors such as chair adjustability, monitor placement, keyboard use, and so on [88].

On the other hand, there are also available methods that do not seek to prevent the appearance of MSDs because they do not identify the risk factors but allow the classification of individual discomfort or pain related to work, such as:

- The NMQ is a widely used tool for assessing musculoskeletal discomfort and symptoms among workers, designed to identify and quantify the prevalence of musculoskeletal issues in different body regions, especially those related to repetitive or physically demanding work. The questionnaire typically consists of a series of questions that inquire about discomfort, pain, or other symptoms experienced by individuals in specific body regions (e.g., neck, shoulders, back, wrists) over a defined period, last twelve months or seven days [89];

- The CMDQ: similar to the NMQ, the CMDQ aims to identify and quantify the prevalence of musculoskeletal issues, but it often includes more detailed questions about specific tasks, postures, and ergonomic factors that might contribute to discomfort through a series of questions that inquire about discomfort, pain, or other symptoms experienced by individuals in various body regions, inquiring about the frequency of symptoms, the tasks or activities that trigger the discomfort, and any perceived ergonomic risk factors [90];
- 10-point Borg CR10 rating scale: used to assess an individual perceived exertion or effort during physical different activities, that provides a simple and reliable method for individuals to rate their perceived exertion during specific actions, from 0 to 10, with corresponding verbal descriptors [91].

2.5.3 Systematic Examination Methods

Considering systematic examination methods, it is possible to perform a methodical risk evaluation based on observations and exposure assessment employing a checklist-oriented approach. Usually conducted by an ergonomic expert, this assessment entails rating exposure levels for various risk factors. This means that following a predefined checklist with pre-established exposure levels, it is possible to quantify the risk via an overall score and compare it with the defined risk levels. Accordingly, there are different methods available:

- REBA: assesses the postures and movements of workers to identify ergonomic risks associated with musculoskeletal disorders. It provides a systematic approach to evaluating office tasks and suggesting corrective actions [92];
- RULA: like REBA, RULA focuses on upper limb and neck postures during office tasks. It evaluates risk factors related to posture and recommends interventions to reduce discomfort and strain [93];
- ROSA: is a tool that aims to identify potential ergonomic issues related to computer workstation setup and tasks commonly performed in office settings, typically involving a quick observational assessment that considers various factors contributing to ergonomic strain (workstation setup, keyboard, and mouse usage, monitor placement, chair adjustability, and more) [94];
- Strain Index: evaluates the physical demands of tasks by considering factors such as force, frequency, and duration of activities, helping to assess the risk of musculoskeletal disorders [95];
- Occupational Repetitive Actions (OCRA) Checklist: a method designed to assess the risk of repetitive movements and postures, useful for office tasks involving data entry, typing, and other repetitive actions [96, 97];

2.5.4 Direct Measurement Methods

Direct or direct observation methods entail a measurement result from a mechanical or electronic apparatus. This presents a low-cost and efficient analysis method in which the results represent actual worker conditions and state values. These methods are valuable for assessing ergonomic factors such as biomechanics, anthropometrics, physiological responses, and physical work environments [72, 98-101]. Therefore, through these methods, it is possible to establish a relationship between the level of exposure and the response of individuals and predict the risk level category [72]. Thus, there are different methods available, such as:

- Anthropometry: ergonomic office assessment with data about the physical dimensions of individuals that help in designing workstations, furniture, and equipment that accommodate a diverse range of body sizes and shapes, reducing the risk of discomfort and injury [102];
- Inclinometers: measure angles and orientations, used to assess joint angles and body postures during work tasks, helping to evaluate the risk of awkward postures and recommend adjustments [101, 103];
- Electromyography (EMG): used to measure electrical activity in muscles during physical tasks, helping to identify muscle fatigue, workload, and muscle imbalances, which are essential for understanding the demands of a job and designing interventions to reduce strain [101];
- Force Sensors: can measure the forces applied by workers when interacting with tools or equipment, crucial for assessing the strength required for tasks, helping design ergonomic tools and workstations that minimise excessive force, such as load cells or strain gauges [99];
- Pressure Mapping: applied to measure pressure distribution on seating surfaces, essential for designing ergonomic chairs and seats to prevent pressure sores and improve comfort [104];
- Motion Capture Systems: It uses cameras and sensors to record workers' movement in 3D space, assists in analysing body movements and postures during tasks, and provides insights into ergonomic improvements, which are especially useful for studying complex movements or tasks [105].

2.5.5 Digital Human Modelling (DHM) Methods

DHM is a field of ergonomics that involves creating computer-based representations of the human body and its movements. DHM methods use computer simulations to evaluate and optimise the ergonomic design of products, workstations, and environments. These methods are valuable for assessing posture, reach, visibility, and accessibility. By simulating and visualising human work, DHM tools facilitate the modelling and evaluating aspects such as anthropometry, forces, movements, and muscular exertion. This enables quick and effective virtual testing and comparison of alternative product and workstation design ideas. In biomechanical risk assessment, commonly used risk assessment methods are typically integrated into these tools. Consequently, physical and ergonomic conditions can be objectively confirmed and assessed from the initial design stage and continuously throughout the product development. This material serves as a foundation for decision-making, enabling proactive solutions to address ergonomic concerns [72, 98, 106-109] .

3 PROBLEM STATEMENT AND STUDY GOALS

In contemporary work environments, sedentary activities prevail, as individuals spend prolonged hours seated. This leads to an increased risk of developing a musculoskeletal disorder or other health issues. While ergonomic interventions are critical in addressing these concerns, current assessment methodologies often need more precision in understanding the dynamic impact of sitting postures on the human body. As such, the existing ergonomic assessment methods mostly focus on static analyses of sitting postures, neglecting the dynamic interplay of pressure distribution on the body during extended periods of sitting. A comprehensive and integrated pressure-based assessment framework needs to improve our ability to evaluate the ergonomic implications of diverse sitting postures holistically.

Consequently, there is a pressing need to develop an advanced methodology incorporating pressure dynamics for a nuanced understanding of the relationship between sitting postures and musculoskeletal well-being. This type of methodology becomes essential in a world where the global workforce increasingly adopts sedentary work practices, and the repercussions of inadequate sitting postures on health have become more pronounced. This research holds significant implications for occupational health and ergonomic assessment fields.

The study aims to develop a methodology for analysing the ergonomic risk associated with the sitting position. By bridging the gap between pressure-based assessments and ergonomic design, this thesis aspires to pave the way for innovative solutions that address the multifaceted challenges associated with postures adopted in office work.

Consequently, the present study proposes to:

1. Collect information about musculoskeletal symptoms in the office population: Gather information about participant characteristics;
2. Use Ergonomic Risk Assessment Tools to characterise the risk level: Evaluate the workstations considering ergonomic risk analysis available for the specific context;
3. Develop a Comprehensive Pressure-Based Ergonomic Assessment Framework: Create a robust framework that integrates pressure-based data to assess sitting postures, considering factors such as load distribution, pressure points, and their implications for musculoskeletal health;
4. Identify Sitting Postures using a Pressure Sensor: Identify sitting postures through pressure-based ergonomic assessments;
5. Explore Pressure Metrics for Postural Analysis: Research and establish a set of pressure metrics that can effectively quantify the impact of different sitting postures, providing insights into the distribution of pressure on various body regions;
6. Investigate the Relationship Between Postures and Musculoskeletal Health: Conduct in-depth research to understand the correlation between postures adopted while sitting and the occurrence of musculoskeletal issues, providing valuable insights for preventive strategies and interventions.

4 MATERIALS AND METHODS

The present chapter serves as the cornerstone for the empirical foundation of the research, providing a comprehensive overview of the tools, techniques, and procedures employed in the investigation. This section is pivotal in offering transparency and reproducibility to the study, as it outlines the systematic approach taken to address the research questions and achieve the objectives set.

4.1 Study Design and Participants

The following analysis counted 20 participants working in an open-space office. No limitations were imposed considering gender, age, height, and weight. The study occurred between August 21st and October 22nd in an open-space office, presented in Figure 6. All participants agreed to informed consent before participating, and the study's objectives were explained. Regarding the informed consent, all participants were informed that the information was confidential and only the research team had access to the detract information. Participation was voluntary, and participants were required to work in an office and stay seated for at least 4 hours of the workday. No limitations were imposed on the job experience, although the results were organised considering this factor.

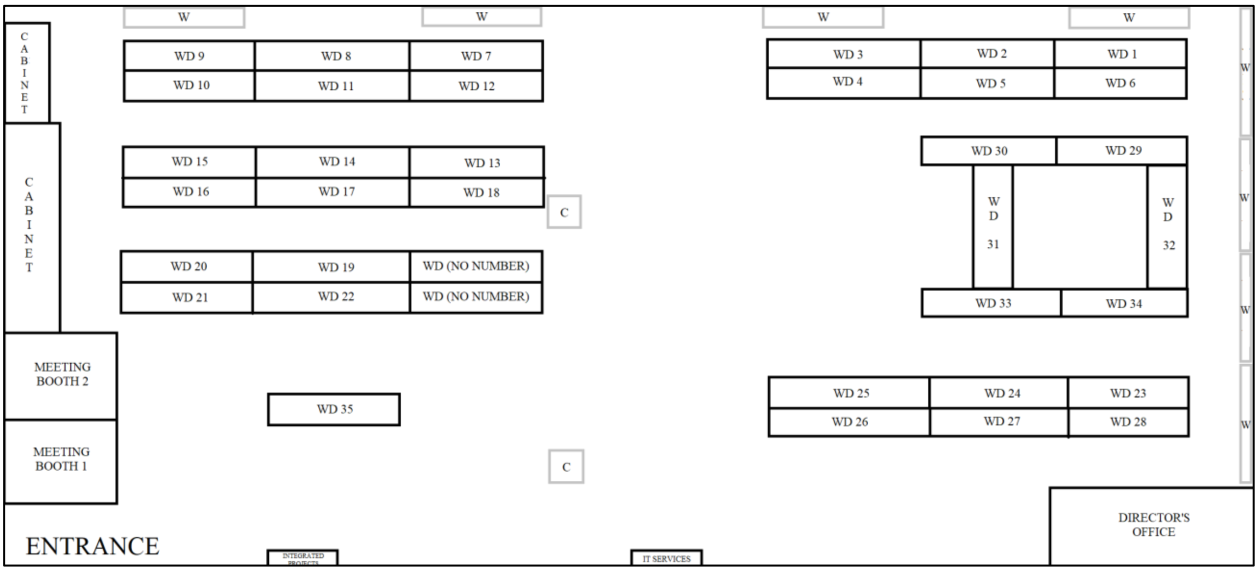


Figure 6 – Open Space Layout (not to scale); Legend: C – Column; WD – Work Desk; W – Window.

4.2 Workstation Characteristics

As stated before, and as presented in Figure 6, the work environment is in an open space, and all workstations have the same characteristics, amounting to 35 workstations. The workstation consists in:

- Work desk – with the dimensions presented in Figure 7;

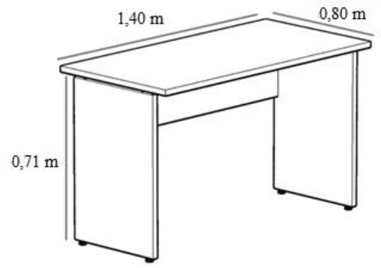


Figure 7 – Dimensions of the office desk.

- Chair – with the dimensions presented in Figure 8;

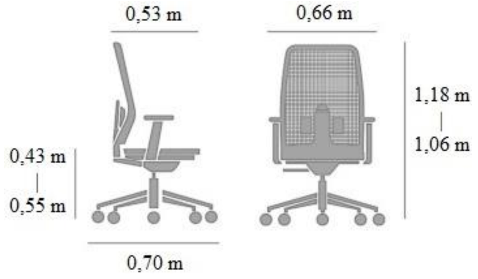


Figure 8 – Dimensions of the office chair.

- Monitor – 0,61 m x 0,17 m x 0,51 m (length x width x height) or 0,62 m x (0,38 to 0,53 m) x 0,23 m (width x height x length);
- Keyboard – 0,43 m x 0,15 m (length x width) or 0,43 m x 0,12 m (length x width);
- Mouse – 0,11 m x 0,06 m (length x width) or 0,11 m x 0,04 m (length x width);
- Small cabinet with three drawers under the left side of the desk – 0,57 m x 0,40 m x 0,54 m (length x width x height).

Nonetheless, some workstations have two or three monitors, and some also have a laptop on the desk. For each desk island, there is a landline phone. Desk 35, referred to as WD 35, has a landline of its own, a small cabinet with three drawers on the right edge and a cabinet with four drawers and open storage space on the left edge.

4.3 Data Collection Methods

To accomplish the proposed in the following dissertation, the following tools and methods were applied, specifically Subjective and Objective Methods.

4.3.1 Sociodemographic Questionnaire

To collect the sociodemographic data of the participants, a Google Forms questionnaire was distributed to facilitate the data treatment, as it is possible to characterise the sample population [45, 48, 54, 59, 66]. Information regarding gender, age, height, weight, marital status, education level, work experience, the average hours spent seated, personal perception of chair comfort, history of musculoskeletal disorders, and involvement in weekly physical activities were collected. This questionnaire included information regarding the Informed Consent and the study's objectives, purposes, and stages. Intelligence regarding the participants' first and last names, heights, and weights was also collected. This questionnaire was developed in Portuguese and English. It consists of 14 questions with a given answer:

1. “Do you accept the Informed Consent?” – “Yes” or “No”;
2. “First and last name” – Open answer;
3. “Date” – Calendar;
4. “Sex” – “Female”, “Male” or “Other”;
5. “Age” – Open answer;
6. “Height (cm)” – Open answer;
7. “Weight (Kg)” – Open answer;
8. “Marital status” – “Single, “Married”, “Divorced”, or “Widow”;
9. “Education level” – “12th Grade”, “Bachelor's Degree”, “Master's Degree”, or “PhD”;
10. “How long have you worked in an Office?” – “Less than 1 year”, “1 to 3 years”, “3 to 5 years”, “5 to 10 years”, or “More than 10 years”;
11. “On average, how many hours a day do you spend seated in your office?” – “Less than 1 hour”, “1 to 3 hours”, “3 to 5 hours”, “5 to 7 hours”, or “More than 7 hours”;
12. “Do you consider your chair comfortable?” – “Yes” or “No”
13. “Do you have any diagnosed musculoskeletal disease?”;
    13.1. “If you answered "yes" in the previous question, please state which.” – Open answer;
14. “On average, how many hours a week do you enrol in physical activities?” – “None”, “1 to 3 hours”, “3 to 5 hours”, “5 to 10 hours”, or “More than 10 hours”.

4.3.2 The Nordic Musculoskeletal Questionnaire

To assess the musculoskeletal complaints of the participants, validated by Mesquita et al. (2010), the Portuguese version of The Nordic Questionnaire paper was filled [110]. Therefore, it was possible to understand if participants felt any pain or discomfort in any region of the body at different moments in time (last 12 months and last 7 days) and if, in the previous 12 months, they needed to cease any habitual activity due to pain or discomfort. It inquires about the history of the experience of musculoskeletal diseases or disorders felt in twelve body sites (neck, shoulders, elbows, wrists, hands, upper back, lower back, hips, thighs, knees, ankles and feet).

This is a questionnaire in which the answer consists of a “yes” or “no” hypothesis. If participants answer “yes” in any of the moments, they should rate the intensity of the pain on a scale between 0 (nothing) and 10 (incapacitating pain) [49, 89]. The questionnaire instructions were given in advance.

4.3.3 Rapid Office Strain Assessment (ROSA)

Through the ROSA method, it is possible to quantify risks related to office work. Following the given checklist, different levels of intervention can be defined, considering the equipment involved in office work (chair, monitor, telephone, keyboard, and mouse) and awarding a score to each of them. It is composed of Section A (seat pan height and depth scores combined with the armrest and back support scores), Section B (phone score combined with monitor score), Section C (mouse score combined with keyboard score), Monitor and Peripherals Score (Section B combined with Section C), and the Grand Score (Section A combined with Monitor and Peripherals Score). The Grand Score range goes from 1 to 10, in which scores of 1 to 3 are considered acceptable and there is no need for intervention, 4 to 5 represent a moderate risk, and 6 to 10 need immediate intervention. Therefore, it is possible to establish priorities and a hierarchical intervention of office work conditions [17, 53, 94].

This analysis was conducted using a Canon PowerShot SX30 IS placed on a tripod set to 0,64 m from the floor at 1,02 m to the participant chair. Two photographs (on the left and right side of the chair) were taken at four different moments for each participant, at a random hour of the workday, so they weren't aware of the time it would be taken. The method was applied by analysing the photos taken at four different moments. After collecting the necessary data for each participant and applying the method, the postures adopted were classified considering two parameters: the most damaging postures and the most adopted postures.

4.3.4 ISO 11226:2000

The ISO 11226:2000 is related to the field of ergonomics and provides guidelines for the evaluation of static working postures, helping to assess ergonomic risk factors related to prolonged or repetitive tasks that involve maintaining a fixed body posture, outlining methodologies that contemplate the measurement of joint angles, body part distances, and other relevant ergonomic parameters. The goal is to evaluate and minimise the risk of awkward or uncomfortable postures in work environments maintained for extended periods of time without variations [111]. It is a checklist that allows the investigator to assess trunk, head, upper extremity, and lower extremity postures [52]. The assessment process examines various body segments and joints separately, either in a single or a dual-phase approach. In the initial phase, the analysis predominantly relies on body angles, with the suggestions primarily concentrated on the potential hazards related to overloading passive body structures such as ligaments, cartilage, and intervertebral disks. The assessment can yield one of three conclusions: "acceptable" when the working posture is satisfactory, and there are variations of posture, "proceed to step 2" when the duration of the working posture also needs to be considered, or "not recommended" when there are extreme positions of the joints. It has a posture assessment section for 1) the trunk, 2) the head, 3) the upper extremity, divided in 3.1) the shoulder and upper arm, 3.2) the forearm and hand, and 4) the lower extremity. Different movements are analysed depending on the body part. The moment contemplated for the trunk region is presented in Figure 9, for the head in Figure 10, for the shoulder and upper arm in Figure 11, for the forearm and wrist in Figure 12, and for the lower extremity in Figure 13 [52].

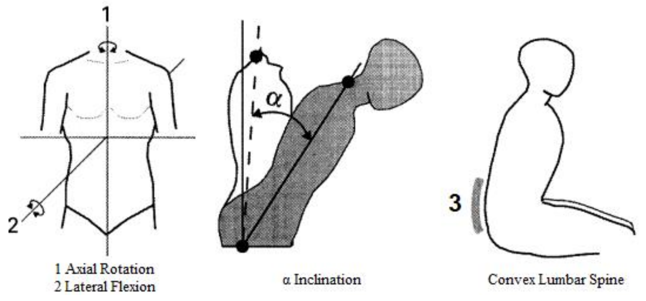


Figure 9 – Trunk Movement.

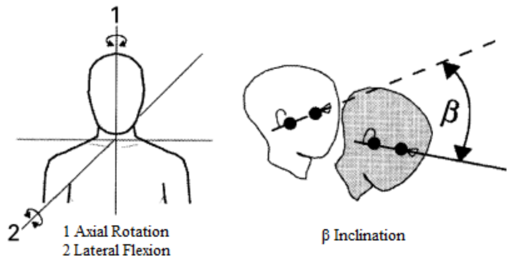


Figure 10 – Head Movement.

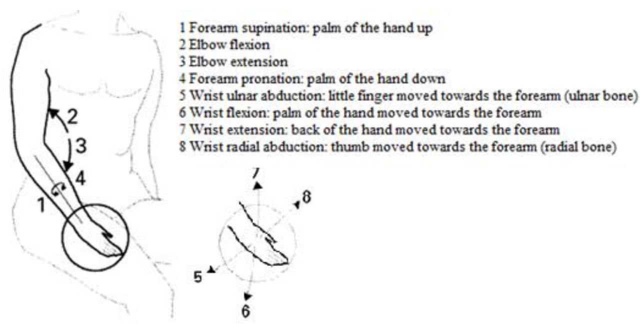


Figure 11 – Forearm and wrist movement.

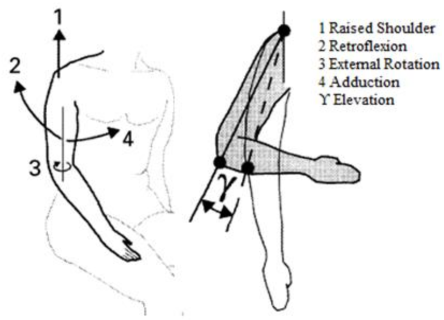


Figure 12 – Shoulder and upper arm movement.

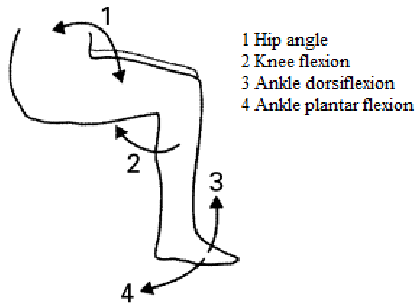


Figure 13 –Lower extremity movement.

4.3.5 Selected Postures

Through the analysis of the information gathered from the literature review presented in subchapter 2.5, the postures to be performed by the study sample were chosen, as presented in Table 4, as they are the most common postures to be adopted by office workers [45, 56, 57, 59, 62, 64, 65, 67, 68]. These kinds of postures, when adopted, may represent an ergonomic risk for the workers, in which different body regions may be affected. This happens as, except for posture 1, all postures represent awkward sitting postures, as in some cases, the user needs full back support or an appropriate back angle. In others, it has an asymmetric trunk posture, and in others, it is performing movements that can cause a cut of the blood flow, particularly in the leg region.

Table 4 – Postures performed by participants.

Number	Postures Defined
1	Upright posture, back supported by the chair's backrest, and buttocks placed at the rear of the seat [45, 56, 57, 62, 65, 67, 68]
2	Reclined position, upper back resting on the chair's back, and buttocks on the front part of the seat [45, 64, 68]
3	Torso bent forward, lower back in the chair's back [45, 57, 64, 68]
4	Torso bent forward, back completely detached from the backrest [45, 62, 64, 65, 67]
5	Torso inclined laterally to the right, armrest providing partial support of the weight [45, 56, 57, 67, 68]
6	Torso inclined laterally to the left, armrest providing partial support of the weight [45, 56, 57, 68]
7	Upright posture, with right leg crossed over left [45, 59, 64, 68]
8	Upright posture, with left leg crossed over right [45, 59, 64, 68]
9	Sitting on the middle of the seat [45, 65]
10	Sitting on the front edge with elbows resting on the table [45, 65]

The setup was assembled in one of the work desks of the open space, composed of one desk, a laptop, one, two or three monitors (that might or might not be used, depending on the participant), and the setup chair in order to be as close to the office reality as possible. In the case of participant identified as WD 20, WD 23, WD 28, and WD 35, the monitoring was performed at their one desk, assuring the conditions were equivalent and maintained even though the setup was different. The assessment of pressure and the angles registered in each position were collected using other equipment, but the retrieval of the data generated by each one was recorded simultaneously. Prior to the monitoring, the instructions and the procedure were explained. The participant was instructed to sit in the setup chair and adapt its height, and the height of the armrests and positions were described. While performing the postures, I was asked to maintain a right angle between the thigh and shin connection. Each one was maintained for 2 minutes to allow participants to decompress and adopt a relaxed position of the muscles. In between postures, there was a 30-second rest period. The postures performed are presented in Figure 14 and the experiment setup.

Figure 14 – Example of a participant performing the different postures and the experiment setup.

Three risk categories were established to characterise the postures adopted based on the ergonomic risk they present: Acceptable, Acceptable depending on the time, and Not recommended, with colour code shown in Table 5. After compiling all the results of the present study, the postures were classified into one of the risk levels mentioned. Although the time factor is also essential and not contemplated in this study, an appreciation regarding the MHT for each posture will also be considered, incorporating the risk associated with prolonged sitting.

Table 5 – Posture risk classification levels.

Posture Risk Classification	Colour Code
Acceptable	
Acceptable depending on the time	
Not Recommended	

4.3.6 Motion Capture System

To capture the different angles and to fully assess the postures presented in Table 4, the Xsens was used as it provides a full-body motion capture system (Xsens Technologies B.V., Enschede, Netherlands) with inertial measurement units held tightly to the body with rubberised straps [112-114]. Therefore, it is used to capture and analyse the movements and postures of individuals during various tasks, assessing workstations, tools, or products. This technology provides detailed data on joint angles, body movements, and the timing of movements. It is also applied in virtual reality (VR) and augmented reality (AR) environments to simulate and assess ergonomic conditions, useful for designing and testing products and workspaces virtually before physical prototypes are built, enabling designers to analyse how different setups affect body movements and identify improvements to minimise strain and discomfort. This means that the data is treated to assess the biomechanical aspects of work-related aspects, movements or postures that may lead to discomfort or injury by evaluating how they affect body segments and postures. It offers various motion capture solutions, including wearable sensors and full-body motion capture systems. These systems are versatile and adaptable for various ergonomic assessments and research applications [115-118]. This equipment is directed by a coordinated system composed of Z, X, and Y, which are the origins of the human body. The Z (blue) vector represents a vector pointing up, the X (red) points to the local magnetic north, and the Y (green) points west (according to the right-handed coordinate system), as presented in Figure 15.

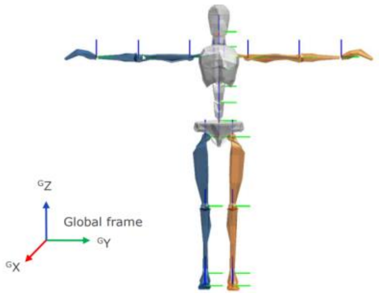


Figure 15 – Xsens coordinate system [119].

Using Velcro stripes and an Xsens-specific t-shirt, seventeen sensors were attached to the participants, as represented in Figure 16. As such, the sensors are placed: one in the head, one in the stern, one in each shoulder, one in each upper arm, one in each lower arm, one in each hand, one in the pelvis, one in each tight, one in each shin, and one in each foot. Before starting the monitoring, each participant's shoe length and height were introduced into Xsens MVN 2023.2 software and saved on the computer. After the connection was established, participants were asked to perform the calibration process: 1) find the start position; 2) hold the pose for 4 seconds (looking straight ahead, arms parallel to the trunk, legs slightly separated and feet forward); 3) walk around for 15 seconds; 4) wait for processing for a maximum of 60 seconds; and 5) stand still for a maximum of 8 seconds. As referenced above, the postures were maintained for 2 minutes, and in this case, the last 15 to 30 seconds (240 frames per second) were recorded using the "recording button" of the software toolbar to start and end it. Before extraction, all trials were reprocessed in the Xsens software. Each participant exported An Excel file per posture, making ten files each.

Figure 16 – Xsens setup and location of the dots.

4.3.7 Pressure Sensor

To assess the pressure produced by each posture adopted by the participants, the Tactilus matrix-based tactile surface sensor (Tactilus®, New York, NY, USA) was used. It is an "electronic skin" that records and interprets pressure distribution and magnitude between two contacting or mating surfaces and assimilates the collected data into a Windows® tool kit [120, 121]. Tactilus systems use an array of tiny pressure-sensing points to measure and visualise pressure distribution on a surface, used to study pressure points, forces, and contact areas. The sensors can be placed on seats, mattresses, or other surfaces to create pressure maps, which help assess how body weight is distributed when individuals are seated. This information can enhance comfort and prevent pressure sores, reducing pressure on key areas of the body and minimising the risk of musculoskeletal discomfort [122-124].

The pressure mat was placed in a chair, as presented in Figure 17. It was placed in the chair pan and taped using specific adhesive tape to ensure the mat did not move in the chair between subjects or postures. The mat was 0,45 m x 0,45 m. It has 32 x 32 sensors distributed equally through the mat. The total area of the mat was 0,20 $m^{2,}$ and each sensor had 0,0019 m^2.

Figure 17 – Setup of the Pressure Mat on the office chair.

It is necessary to connect a USB cable to a computer to establish the connection between the pressure mat and the computer. Using Tactilus 8.1 software, the pressure and the dimension units were defined to Pascal (Pa) and centimetres (cm), respectively. The number of frames per second (FPS) was defined as 1, which means it records one frame per second. The recording started by pressing the “recording button” in the toolbar and ended by pressing the same button after 2 minutes. A .txt file was exported per participant performing the given posture, selected to compile the recorded frames into 15-second segments and the option to extract the values of the average pressure registered, as well as the maximum and minimum value, the centre of pressure in X and Y, and the contact area (cm^2) was also selected. The last 15-second segment of the posture performed by the attendee was later converted and introduced into an Excel file.

4.4 Data Analysis Methods

The following procedures were adopted to examine the data collected by the above methods, considering the Subjective and Objective Methods stated in the previous subchapter.

4.4.1 Sociodemographic Questionnaire

The data exported from the Google Forms questionnaire, in list form, was prepared considering the answers given by each participant to each of the 14 questions. An Excel file was programmed to quantify each response mentioned in subchapter 3.4.1.

Different calculations were applied to the variables, including age, height, and weight. Descriptive statistics were applied, and the average (A), standard deviation (SD), maximum (Max), and minimum (Min) were calculated. For the remaining answers, data was counted considering the number of participants that selected each option, and the percentage of each one was determined.

4.4.2 The Nordic Musculoskeletal Questionnaire

The data of each participant, initially on paper, was introduced in an Excel sheet identifying the participant and the sex. The results were organised by counting the number of participants that answered “yes” or “no” on the different moments contemplated for each body part. The percentage of participants who reported no pain, discomfort, or numbness or did not reply to a question was calculated. In the case of participants with a “yes” answer in one of the moments, the average pain, the standard deviation, the maximum, and the minimum value were also determined.

4.4.3 Rapid Office Strain Assessment (ROSA)

When the photos were taken, the subjects' postures matched the postures selected to test, presented in Table 4, in subchapter 4.3.5. Afterwards, each position's mean range, standard deviation, and maximum and minimum values of ROSA final score were calculated. The raw value was classified qualitatively in one of the three existing risk levels: Acceptable, Moderate and Immediate Intervention. This way, it was possible to establish the most damaging and adopted posture when considering the interaction between the user and the office equipment.

4.4.4 Motion Capture System

Each participant’s data was selected considering angle values calculated by the Xsens algorithm. The Euler representation of the joint angles chosen was the Euler sequence ZXY, which starts the calculation of the angle with a rotation around the Z-axis, followed by a rotation around the X-axis and finishes with a rotation around the Y-axis. The selected data considered the angles formed between body segments to compare the values registered while performing the postures and the angles recommended in ISO 11226:2000. Therefore, the information presented in Table 6 represents the relation between the ISO parameters and the Xsens data. In the case of the body segments contemplated by the Xsens, the Pelvis_T8 value represents the sum of all trunk angles until the T8, about the pelvis. In T8_Head, the value represents the sum of all registered angles between the T8 and the head. In T8_Left/Right Upper Arm, all angles between these two body regions are being summed. The angles registered by the motion capture system were then compared to the recommended angles of ISO 11226:2000.

Table 6 – Relation between the body parts mentioned in ISO 11226:2000 and the Xsens data**.**

Body Segment	ISO 11226:2000	Xsens
Trunk		
	Axial Rotation	Pelvis_T8 Axial Bending
	Lateral Flexion	Pelvis_T8 Lateral Bending
	Inclination	Vertical_T8 Flexion / Extension
	Convex Lumbar Spine	Pelvis_T8 Flexion / Extension
Head		
	Axial Rotation	T8_Head Axial Bending
	Lateral Flexion	T8_Head Lateral Bending
	Inclination	T8_Head Flexion / Extension
Neck		
	Flexion / Extension	C1_Head Flexion / Extension
Upper Arm		
	Retroflexion / Adduction	T8_Left / Right Upper Arm Flexion / Extension
	External Rotation	T8_Left / Right Upper Arm Axial Bending
	Elevation	T8_Left / Right Upper Arm Lateral Bending
Elbow		
	Flexion / Extension	Left / Right Elbow Flexion / Extension
Forearm		
	Supination / Pronation	Left / Right Wrist Pronation / Supination
Wrist		
	Ulnar abduction / Radial abduction	Left / Right Wrist Ulnar Deviation / Radial Deviation
	Flexion / Extension	Left / Right Wrist Flexion / Extension
Knee		
	Flexion	Left / Right Knee Flexion / Extension

In this way, data regarding the last 15 seconds (3600 frames) of each participant performing the different postures were extracted to an excel file compiling the information of all participants performing the given posture. Then the average of the 3600 frames of each participant was calculated. To compile the 3600 values into one single value, indicative of the angle maintained in that posture, the average and the mean value were calculated for the parameters referred above, for the 10 joint angles presented. through the Xsens it is possible to select the anatomical plane to view the avatar, the interesting ones for the present study, were the anterior, posterior, sagittal left and sagittal right planes. These anatomical planes had a fixed orientation of the three axes as presented in Figure 18. The Z axis was always fixed as it is points up, but the X and Y vectors changed through the different planes as the orientation of the coordinates was shifting, from the anterior to posterior view and from the sagittal left and sagittal right. These anatomical planes allow to fixate the avatar user in the Xsens program.

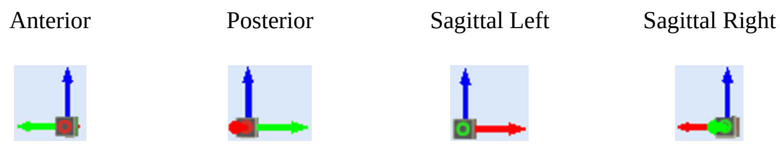


Figure 18 – The Xsens Coordinate System of the different view perspectives.

4.4.5 Pressure Sensor

In order to qualify the pressure level measured by the pressure mat into risk categories, 7 risk levels were defined with a colour code associated, as presented in Table 7, following the same colour code of the Tactilus Software. The colour code was programmed into an Excel sheet, and the data collected was imported and introduced into that Excel sheet, separated by posture.

Table 7 – Pressure risk levels established.

Level	Pressure (Pa)	Risk Level	Colour Code
0	0,0 – 3926,7	None existing	
1	3926,8 – 7853,4	Negligible	
2	7853,5 – 11780,2	Acceptable	
3	11780,3 – 15706,9	Relatively acceptable	
4	15707,0 – 19633,7	Moderate	
5	19633,8 – 23560,5	High	
6	23560,6 – 34663,7	Extremely high	
7	≥ 34663,8	Unacceptable	

The statistical data calculated by the pressure mat software of the postures performed by each subject, were combined by calculating the average of the results, considering all participants performing the posture in question. Therefore, it was possible to obtain the maximum ($\bar{P}_{max}$), minimum ($\bar{P}_{min}$) and average pressure ($\bar{P}$) as well as the center of pressure in X (COP_x) and Y (COP_y) and the contact area ($A_{contact}$), for the ten postures tested combining the twenty participants. The unit measure chosen was accordingly to the International System of Units (SI), therefore pressure is expressed in Pascal (Pa) and distances in meters (m). As the center of pressure was in centimetres, it was necessary to convert the data provided by the Tactilus software in a coordinate value, so through the length and width of the pressure sensor (45 x 45 cm) the size of each pressure cell was calculated and a simple proportion was made as the number of sensors is known (32 x 32 sensors).

In an effort to facilitate the interpretation of the pressure mat results, the gride obtained for the different postures was divided into four Quadrants (Q):

- Quadrant 1 – Front part of the chair pan, left side;
- Quadrant 2 – Front part of the chair pan, right side;
- Quadrant 3 – Rear part of the chair pan, left side;
- Quadrant 4 – Rear part of the chair pan left side.

The average pressure for the quadrant ($\bar{P}_Q$) (1), standard deviation ($SD_{\bar{P}_Q}$) (2), maximum and minimum of each was calculated considering the average pressure level of the cells ($\bar{P}_{cell}$) of each participant.

$$\bar{P}_Q = \sum \bar{P}_{cell} \quad (1)$$

$$SD_{\bar{P}_Q} = \frac{\left|\bar{P}_{Q1,Q2,Q3,Q4} - \bar{P}_{mat}\right|}{\bar{P}_{mat}} \quad (2)$$

To determine the contact area of the different quadrants, the presume mat area (A_{mat}) was determined (3) and the area of each cell (A_{cell}) was deduced (4). Based on the minimum pressure level registered, the number of cells activated was estimated. Therefore, it was possible to determine how many cells had pressure (A_{Pcell}) being applied and the contact area of the quadrant was calculated by summing the area of all those cells (5). To estimate the standard deviation, the value obtained was compared with the value given by the Tactilus software, by summing the contact area of each quadrant ($A_{contactQx}$) (6) and then applying the standard deviation formula (7).

$$A_{mat} = 0{,}45 \ x \ 0{,}45 \quad (3)$$

$$A_{cell} = \frac{A_{mat}}{Total \ nº \ of \ cells} \quad (4)$$

$$A_{contactQx} = \sum A_{Pcell} \quad (5)$$

$$A_{contact\sum Q} = \sum A_{contact} \ Q1, Q2, Q3, Q4 \quad (6)$$

$$SD_{A_{contact}} = \frac{\left|A_{contactQx} - A_{mat}\right|}{A_{mat}} \quad (7)$$

Bearing in mind the centre of pressure in X (CP_X) and Y (CP_X), the centroid calculation formula was applied to each quadrant. The position of the centre of pressure of each row (s_{XQ}) and each line (s_{YQ}) was calculated by multiplying the different coordinate of that row (X) or line (Y) with the sum of the average pressure of each cell of the row ($\bar{P}_{row}$) or of the line ($\bar{P}_{line}$) (8). Afterwards, the centre of pressure in X and in Y was determined by dividing the sum of all coordinates in X or Y by the sum of all the average pressure values of the cells of the entire quadrant (9). The final result was a coordinate in X and Y, for each quadrant.

$$s_{XQ} = X \ x \sum \bar{P}_{line}$$
$$s_{YQ} = Y \ x \sum \bar{P}_{row} \quad (8)$$

$$CP_{XQ} = \frac{\sum Coordenates \ in \ X}{\sum \bar{P}_{cell}}$$
$$CP_{YQ} = \frac{\sum Coordenates \ in \ Y}{\sum \bar{P}_{cell}} \quad (9)$$

4.4.6 Interdependence Between Variables

In order to understand the relation between the different variables of the study, some statistical tests were performed. As so, the IBM SPSS Statistics 29.0.1.0 software was used, where the different variables were introduced. All answers were transformed into numeric options, in which:

- 1 – Yes; 2 – No;
- 1 – Female; 2 – Male;
- Education Level: 1 – 12th Grade; 2 – Bachelor’s Degree; 3 – Master's Degree; 4 – PhD;
- Job Experience: 1 – Less than 1 year; 2 – 1 to 3 years; 3 – 3 to 5 years; 4 – 5 to 10 years; 5 – More than 10 years;
- Time spend seated per day: 1 – Less than 1 hour; 2 – 1 to 3 hours; 3 – 3 to 5 hours; 4 – 5 to 7 hours; 5 – More than 7 hours;
- Exercise practice per week: 0 – No answer (NA); 1 – None; 2 – 1 to 3 hours; 3 – 3 to 5 hours; 4 – 5 to 10 hours; 5 – More than 10 hours.

In order to test the normality of the sample, the Shapiro-Wilk normality test was done, where the null hypothesis is that the data follows a normal distribution, therefore if the p-value is less than the chosen significance level (α= 0.05), the null hypothesis is rejected, suggesting non-normality. Afterwards, the Spearman Correlation Matrix was determined, as through the interpretation of the Spearman rank correlation coefficients it is possible to understand the relation between different pairs of variables, and it presents a non-parametric measure of association that assesses the monotonic relationship between two variables, regardless of the linearity of the relationship, from -1 (negative correlation) to 1 (positive correlation). It signals two significance levels, α= 0,01 or α= 0,05. Therefore, the correlation between variables, can be positive, which means that if one increases the other increases as well, null, if one of the variables did not have any results (in these analyses, those variables were deleted to facilitate data interpretation) and negative, which means that the increase of one represents the decrease of the other.

To understand the pattern between the correlated variables, a linear regression line was calculated in which it is possible to obtain the dependent variable (y), the independent variable (x), y-intercept (b), and the slope (m) (10). Through the R^2, it is possible to understand how close the equation is to linear, ranging from 0 (not linear) to 1 (linear). If the $R^2 \geq 0{,}70$ it was assumed that there was a correlation between variables and if the $R^2 \leq 0{,}30$ it was assumed that there was not a correlation between variables.

$$y = m_x + b \qquad (10)$$

PART 2

5 RESULTS

Applying the previously described methods made it possible to obtain the results presented in the present chapter. By applying the subjective methods described in the previous chapter, it was possible to gain information regarding the sample characteristics and characterise and evaluate the workstation and the postures adopted by the participants while performing their tasks.

5.1 Sociodemographic Questionnaire

As it was stated before, a total of 20 individuals completed the study. Regarding the sample characteristics, it is possible to see that it comprises most female individuals since they represent 55% (n= 11), and the males represent the other 45% (n= 9). Considering the total population, the average age is 29,33 years old (SD= 8,22 years), the minimum is 22, and the maximum is 59 years old. The height of the study population is an average of 1,70m (SD= 0,09 m), a minimum of 1,53m, and a maximum height of 1,84m. Considering the weight, on average, the sample population has 68,70kg (SD= 10,40kg), with a minimum of 55kg and a maximum weight of 90kg. This information is portrayed in Table 8.

Table 8 – Sample population Gender, Age, Height, and Weight.

Variable	Total Sample	Female	Male
N	20	11 (55,00%)	9 (45,00%)
Age (years)			
A | SD	29,33 | 8,22	32,33 | 9,68	26,33 | 3,46
Min | Max	22 | 59	25 | 59	22 | 33
Height (m)			
A | SD	1,70 | 0,09	1,64 | 0,05	1,77 | 0,06
Min | Max	153 | 184	153 | 170	164 | 184
Weight (kg)			
A | SD	68,70 | 10,40	62,73 | 6,92	76,00 | 9,38
Min | Max	55 | 90	55 | 75	61 | 90

When inquired about their marital status, 90% (n= 18) of the participants stated that they are single and 10% (2) are married. Regarding the education level, 70% (n= 14) have a Master's Degree, 25% (n= 5) have a PhD, and 5% (n= 1) have the 12th grade. When inquired about job experience, 25% (n= 5) of the sample worked for more than five but less than ten years, another 25% (n= 5) worked less than 1 year, 20% (n= 4) for more than 3 and less than five years, 20% (n= 4) for more than one and less than 3 years, and 10% (n= 2) for more than 10 years. Most individuals spend between 5 to 7 hours seated at their workstation, respectively 55% (n= 11), others 40% (n= 8) spend more than 7 hours, and 5% (n= 1) spends between 3 to 5 hours seated. Taking into consideration the time spent per week enrolling in some physical activity, 50% (n= 10) of the survey participants dedicate 1 to 3 hours weekly, 30% (n= 6) between 3 to 5 hours a week, 10% (n= 2) does not enrol in any activity, and 5% (n= 1) practices some kind of physical activity more than 10 hours per week. The information can be consulted in Table 9, presented below. Considering the total sample, 75% (n= 15) does not have any diagnose of MSDs and 25% (n= 5) does. From these 25% (n= 5) of individual that have a MSD, 40% (n= 2) have scoliosis, 20% (n=

1) have herniated disc, another 20% (n= 1) underwent a Osteosynthesis with DHS (Dynamic Hip Screw) in Hip Fracture, and the final 20% (n= 1) have wear and tear of the intervertebral discs. Since, in some cases, work experience and time spend seated can have a relation to the diagnosis of MSDs the participants may have, when considering the total amount of diagnosis of musculoskeletal ailment, 40% (n= 2) of them happened in individuals with 1 to 3 years of work experience, 20% (n= 1) occur in participants with less than 1 year, 20% (n= 1) have worked for more than 3 and less than 5 years, and another 20% (n= 1) worked for more than 5 years and less than 10 in an office. Regarding the time spent seated per day in relation to MSDs diagnosis, 60% (n= 3) of the positive diagnosis occur in individuals that spend 5 to 7 hours seated at their workstation and the other 40% (n= 2) spend more than 7 hours at their desk, seated. The information can be consulted in Table 9, where the percentage of participants with MSDs are accounted and from those, the disease diagnosed are specified and there is the relation between MSDs and work experience.

Table 9 – Participant information regarding Marital Status, Education level, Work experience, seated time duration, and exercise enrolment per week.

Variable	% (n)
Marital Status	(20)
Single	90% (18)
Married	10% (2)
Divorced	-
Widow	-
Education Level	(20)
12th Grade	5% (1)
Bachelor's Degree	-
Master's Degree	70% (14)
PhD	25% (5)
Work Experience	(20)
Less than 1 year	25% (5)
1 to 3 years	20% (4)
3 to 5 years	20% (4)
5 to 10 years	25% (5)
More than 10 years	10% (2)
Seated time duration	(20)
Less than 1 hour	-
1 to 3 hours	-
3 to 5 hours	5% (1)
5 to 7 hours	55% (11)
More than 7 hours	40% (8)
Seated time duration	(20)
Less than 1 hour	-
1 to 3 hours	-
3 to 5 hours	5% (1)
5 to 7 hours	55% (11)
More than 7 hours	40% (8)
Exercise enrolment per week	(20)
None	10% (2)
1 to 3 hours	50% (10)
3 to 5 hours	30% (6)
5 to 10 hours	-
More than 10 hours	5% (1)
MSDs Diagnose	(20)
No	75% (15)
Yes	25% (5)
Disease	(5)

Variable	% (n)
Marital Status	(20)
Scoliosis	40% (2)
Herniated disc	20% (1)
Osteosynthesis with DHS in Hip Fracture	20% (1)
Wear and tear of the intervertebral discs	20% (1)
Work Experience	(5)
Less than 1 year	20% (1)
1 to 3 years	40% (2)
3 to 5 years	20% (1)
5 to 10 years	20% (1)
More than 10 years	-

- Represents a question that was not identified by participants

As so the study sample is composed of adults (individuals between 18 and 65 years old), mostly females (55%), with a height and weight within the normal values for the Portuguese population. The Portuguese average female has 1,61m and weights 65,80kg and the average male has 1,74m and weights 79,50kg. In the literature the standard value for the height and weight of men is 1,74m and 79,50kg and 1,61m and 68,80kg for the woman. In the present sample, males were taller (1,76m) but weighted less (76kg) than the reference, and females were also taller (1,64m) and weighted less (62,73kg). There is a high number of subjects with a college degree, such as Master’s (75%) and PhD (25%), a lot of whom have started to work in an office less than one year (25%) and for more than 5 and less than 10 (25%). As expected, participants spend 5 to 7 hours seated (55%) or more than 7 hours (40%). Most participants practice some kind of physical activity for more than 1 hour and a half. Considering participants with MSD diagnosed, they represent 5% of the study sample, and most of them have 1 to 3 years of work experience.

5.2 The Nordic Musculoskeletal Questionnaire

Considering the Nordic Questionnaire, a total of 20 participants answered the questions. Considering the responses given by them when inquired about the regions of the body where they might feel pain, discomfort or numbness in the last 12 months, present in Table 10: 70% (n= 10) identified the neck and the lumbar region, 20% (n= 4) both shoulders; 15% the right shoulder, right wrist/hand, hips/thighs, and the ankle/feet; 10% (n= 2) the thoracic region and knees; and 5% the left elbow. No one reported feeling anything on the left shoulder, right or both elbows and on the left or both wrists/hands. When separated into groups considering the work experience, those who work for:

- Less than 1 year (25% of the total sample) – 20% (n= 4) reported symptoms on the lumbar region; 15% (n= 3) on the neck; 10% (n= 2) on both shoulders and right wrist/hand; 5% (n= 1) on the thoracic region, hips/thighs, knees and ankle/feet; and the other body segments were not identified.
- 1 to 3 years (20% of the total sample) – all 20% (n= 3), identify the neck and lumbar region; 5% (n= 1) both shoulders and the right wrist/hand; and the other body parts are not referenced.
- 3 to 5 years (20% of the total sample) – 15% (n= 3) indicate the neck and lumbar region; 5% (n= 1) the hips/thighs; and the other body parts are not mentioned.

- 5 to 10 years (25% of the total sample) – 15% (n= 3) signals the neck and the thoracic regions; 10% the right shoulder and ankle/feet; 5% (n= 1) both shoulders, hips/thighs and knees; and the other body parts are not.
- More than 10 years (10% of the total sample) – 5% (n= 1) pinpoint the neck, right shoulder, left elbow, and thoracic region; and the other body parts are not identified.

Table 10 – The Nordic Questionnaire answers, for "Considering the last 12 months, have you experienced any issue (such as pain, discomfort, or numbness)?".

Considering the last 12 months, have you experienced any issue (such as pain, discomfort, or numbness)?						
	Total % (n)	Less than 1 year % (n)	1 to 3 years % (n)	3 to 5 years % (n)	5 to 10 years % (n)	More than 10 years % (n)
Total Answers	100% (20)	25% (5)	20% (4)	20% (4)	25% (5)	10% (2)
Body Parts*						
Neck	70% (14)	15% (3)	20% (4)	15% (3)	15% (3)	5% (1)
Right shoulder	15% (3)	-	-	-	10% (2)	5% (1)
Left shoulder	-	-	-	-	-	-
Both shoulders	20% (4)	10% (2)	5% (1)	0% (0)	5% (1)	0% (0)
Right elbow	-	-	-	-	-	0% (0)
Left elbow	5% (1)	-	-	-	-	5% (1)
Both elbows	-	-	-	-	-	-
Right wrist/hand	15% (3)	10% (2)	5% (1)	-	-	-
Left wrist/hand	-	-	-	-	-	-
Both wrists/hands	-	-	-	-	-	-
Thoracic region	10% (2)	5% (1)	-	-	-	5% (1)
Lumbar region	70% (14)	20% (4)	20% (4)	15% (3)	15% (3)	-
Hips/Thighs	15% (3)	5% (1)	-	5% (1)	5% (1)	-
Knees	10% (2)	5% (1)	-	-	5% (1)	-
Ankle/Feet	15% (3)	5% (1)	-	-	10% (2)	-

*The values presented represent the individuals thar answered “Yes”.

- Represents a question that all participants answer “No”.

When inquired about the last 7 days information present in Table 11, 50% (n= 10) also felt pain, discomfort or numbness in the neck area, 30% (n= 6) continued to identify the lumbar region, 20% (n= 4) both shoulders, 10% (n= 2) the right shoulder, the thoracic region and the knees, and 5% (n= 1) reported symptoms in the right wrist/hand, on hips/thighs and on the ankle/feet. Considering this period, participants did not report pain, discomfort or numbness on the left shoulder, none of the elbows, and on the left or both wrists/hands. When separated into groups considering the work experience, those who work for:

- Less than 1 year (25% of the total sample) – 15% (n= 3) identify the lumbar region, 10% (n= 2) the neck and both shoulders; 5% (n= 1) the thoracic region, hips/thighs, and the ankle/feet; and the other body parts are not mentioned.
- 1 to 3 years (20% of the total sample) – 15% (n= 3) reference the neck; 5% (n= 1) the right wrist/hand and the lumbar region; and the other body parts are not signalled.
- 3 to 5 years (20% of the total sample) – 5% (n=1) indicate the neck and lumbar region; and the other body parts are not identified.
- 5 to 10 years (25% of the total sample) – 15% (n= 3) mention the neck; 5% (n= 1) the right or both shoulders, the lumbar region, the knees and the ankle feet; and the other body parts are not pinpoint.

- More than 10 years (10% of the total sample) – 5% (n= 1) refer the neck, right shoulder, and the thoracic region; and the other body parts are nor signalled.

Table 11 – The Nordic Questionnaire answers, for "Considering the last 7 days, have you experienced any issue (such as pain, discomfort, or numbness)?".

Considering the last 7 days, have you experienced any issue (such as pain, discomfort, or numbness)?						
	Total Participants % (n)	Less than 1 year % (n)	1 to 3 years % (n)	3 to 5 years % (n)	5 to 10 years % (n)	More than 10 years % (n)
Total Answers	100% (20)	25% (5)	20% (4)	20% (4)	25% (5)	10% (2)
Body Parts*						
Neck	50% (10)	10% (2)	15% (3)	5% (1)	15% (3)	5% (1)
Right shoulder	10% (2)	-	-	-	5% (1)	5% (1)
Left shoulder	-	-	-	-	-	-
Both shoulders	20% (4)	10% (2)	-	-	5% (1)	-
Right elbow	-	-	-	-	-	-
Left elbow	-	-	-	-	-	-
Both elbows	-	-	-	-	-	-
Right wrist/hand	5% (1)	-	5% (1)	-	-	-
Left wrist/hand	-	-	-	-	-	-
Both wrists/hands	-	-	-	-	-	-
Thoracic region	10% (2)	5% (1)	-	-	-	5% (1)
Lumbar region	30% (6)	15% (3)	5% (1)	5% (1)	5% (1)	-
Hips/Thighs	5% (1)	5% (1)	-	-	-	-
Knees	10% (2)	5% (1)	-	-	5% (1)	-
Ankle/Feet	5% (1)	-	-	-	5% (1)	-

*The values presented represent the individuals thar answered “Yes”.

- Represents a question that all participants answer “No”.

When asked if the pain, discomfort or numbness felt in the last 12 months were in anyway incapacitating, present in Table 12, 10% (n= 2) answer “yes” considering the lumbar region, and 5% (n= 1) identified both shoulders, the left elbow, the thoracic region, the hips/thighs, the knees and the ankle/feet. When separated into groups considering the work experience, those who work for:

- Less than 1 year (25% of the total sample) – 10% (n= 2) reference both shoulders; 5% (n=1) the thoracic and lumbar region, the hips/thighs, knees and the ankle/feet; and the other body parts are not identified.
- 1 to 3 years (20% of the total sample) – 5% refer the lumbar region; and the other body parts are not pointed.
- 3 to 5 years (20% of the total sample) – Did not had to interrupt any activity due MSDs.
- 5 to 10 years (25% of the total sample) – 5% (n= 1) signals both shoulders; and none of the other body parts.
- More than 10 years (10% of the total sample) – 5% (n= 1) identify the left elbow; and no other body part is mentioned.

Table 12 – The Nordic Questionnaire answers, for "During the last 12 months, have you had to avoid your normal activities (work, household chores, or hobbies)?".

During the last 12 months, have you had to avoid your normal activities (work, household chores, or hobbies)?						
	Total Participants % (n)	Less than 1 year % (n)	1 to 3 years % (n)	3 to 5 years % (n)	5 to 10 years % (n)	More than 10 years % (n)
Total Answers	100% (20)	25% (5)	20% (4)	20% (4)	25% (5)	10% (2)
Body Parts*						
Neck	-	-	-	-	-	-
Right shoulder	-	-	-	-	-	-
Left shoulder	-	-	-	-	-	-
Both shoulders	5% (1)	10% (2)	-	-	5% (1)	-
Right elbow	-	-	-	-	-	-
Left elbow	5% (1)	-	-	-	-	5% (1)
Both elbows	-	-	-	-	-	-
Right wrist/hand	-	-	-	-	-	-
Left wrist/hand	-	-	-	-	-	-
Both wrists/hands	-	-	-	-	-	-
Thoracic region	5% (1)	5% (1)	-	-	-	-
Lumbar region	10% (2)	5% (1)	5% (1)	-	-	-
Hips/Thighs	5% (1)	5% (1)	-	-	-	-
Knees	5% (1)	5% (1)	-	-	-	-
Ankle/Feet	5% (1)	5% (1)	-	-	-	-

*The values presented represent the individuals that answered "Yes".

- Represents a question that all participants answer "No".

The results obtained in the present study revel that the sample of office workers analysed reported musculoskeletal symptoms mostly in the neck, lumbar region and in both shoulders considering the last 7 days and 12 moths. An overwhelming number of individuals report symptoms in this body parts, independently of job experience. Which means that the musculoskeletal symptoms reported by individuals might not be related to the years on the job. Although, it is important to mentioned that, even though ¼ of the sample individuals have less than 1 year of job experience, all have a college degree, which means that a portion of their past time was spend in a classroom environment. This environment sometimes portrait ergonomic challenges and. Since no participant had to interrupt their normal activity due to symptoms in the neck in the past 12 months, it is possible to say that, for this sample population, neck pain or discomfort was not debilitating, but lumbar region symptoms were, as a small number of participants ceased activities because of it. Therefore, this is a population within the normal society metrics and adapted to the job preformed.

5.3 Rapid Office Strain Assessment (ROSA)

The postures participants were adopting the moment the ROSA method was applied were matched with the postures selected through the state of the art performed. As so, the postures were classified considering the most damaging and most adopted ones. Therefore, the top 3 postures were classified according to these parameters, considering the 80 moments analysed.

Taking into account the most adopted postures, the first was Posture 1 (upright posture, back supported by the chair's backrest, and buttocks placed at the rear of the seat) registered in 41,25%

(n= 33) of the situations, followed by Posture 3 (torso bent forward, lower back in the chair's back) in 15,00% (n= 12) and, in third place, registered in 12,50% (n= 12) of the analysis. Considering the other postures, Posture 7 (upright posture, with right leg crossed over left) was adopted in 10,00% (n= 8) of the moments, Posture 4 (torso bent forward, back completely detached from the backrest) and 8 (upright posture, with left leg crossed over right) in 6,25% (n= 5), Posture 6 (torso inclined laterally to the left, armrest providing partial support of the weight) in 2,50% (n= 2), Posture 9 (sitting on the middle of the seat) and 10 (sitting on the front edge with elbows resting on the table) in 1,25% (n= 1), Posture 5 (torso inclined laterally to the right, armrest providing partial support of the weight) was not verified, and in 3,75% (n= 3) the posture adopted by the participants did not match the postures defined (NA). The information is resumed in Figure 19.

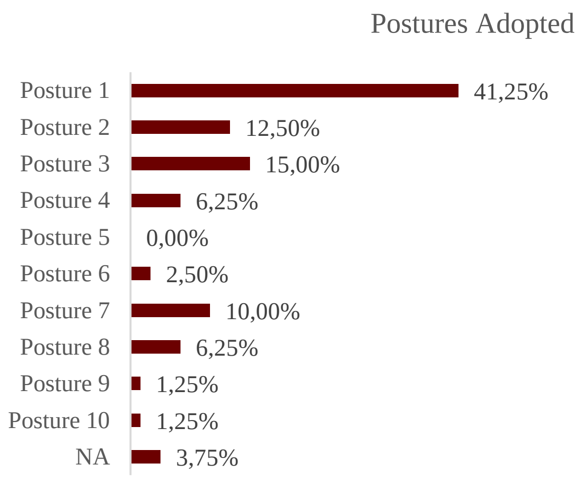


Figure 19 – Percentage occurrence of the postures tested in the 4 moments the photographs were taken.

Considering the most damaging postures adopted, the same comparison was made, and the three postures with the highest Score were identified and can be consulted in Table 13, where the score of the different ROSA sections, respectively, ROSA A (chair score), ROSA B (monitor and telephone), ROSA C (keyboard and mouse), ROSA D (monitor and telephone combine with keyboard and mouse), and the Grand Score. When analysing the section score individually, different postures had a score level of 5,00, which, in the majority of the situations, was related to the positioning of the trunk in relation to the back support and with the height of the chair. ROSA B combines the monitor and telephone score into one value in which both have the same weight in the calculation, and the telephone was rarely used with the exception of WD35, so the null results of this parameter conceal the results of the monitor, which in some situations was too low, some participants had 2 or 3 monitors which imply head axial bending and neck flexion-extension. Focusing on the ROSA C score, there were acceptable risks associated with the monitor and mouse, related to the fact that in some situations, participants did not have the need to resort to this equipment, although, in almost every observation, participants using the mouse had a pinch grip on the mouse and wrist deviation while typing. The risk level was also acceptable when combining the B and C scores into ROSA D. As so, Posture 9 was the one with the higher Grand Score (risk level 5,00, acceptable), followed by 2 (risk level 4,10, acceptable) and third place Posture 4 and 10 had the same grand score (risk level 4,00), and because both represent ergonomic risk related to an unsupported trunk both enter to the top of most damaging postures. Taking into account the other postures, Posture 3 had a risk level of 3,83, Posture 1 of 3,58, Posture 7 of 3,50, Posture 8 of 3,20, Posture 6 of 3,00, and it was mentioned that Posture 5 had a risk level of 0,00 since it was not adopted by any of the participants. If considering the posture classified as NA, it had a risk level of 6,00, but it is not a common position to adopt while working at an office.

Table 13 – ROSA section and Grand scores, considering each posture.

Posture	ROSA A	ROSA B	ROSA C	ROSA D	Grand Score
1					
A | SD	3,61 | 0,79	1,73 | 0,72	2,82 | 0,88	2,94 | 0,83	3,58 | 0,83
Min | Max	3,00 | 5,00	1,00 | 3,00	1,00 | 5,00	1,00 | 5,00	3,00 | 5,00
2					
A | SD	4,20 | 0,92	1,80 | 0,79	3,00 | 1,63	3,30 | 1,34	4,10 | 0,99
Min | Max	3,00 | 5,00	1,00 | 3,00	1,00 | 5,00	1,00 | 5,00	3,00 | 5,00
3					
A | SD	3,75 | 0,75	1,50 | 0,52	3,00 | 0,85	3,33 | 0,78	3,83 | 0,83
Min | Max	3,00 | 5,00	1,00 | 2,00	1,00 | 5,00	1,00 | 5,00	3,00 | 5,00
4					
A | SD	4,00 | 0,71	2,80 | 0,84	2,80 | 0,45	3,20 | 0,45	4,00 | 0,71
Min | Max	3,00 | 5,00	2,00 | 4,00	2,00 | 3,00	3,00 | 4,00	3,00 | 5,00
5					
A | SD	NA	NA	NA	NA	NA
Min | Max	NA	NA	NA	NA	NA
6					
A | SD	3,00 | 0,00	2,00 | 1,41	2,00 | 0,00	2,50 | 0,71	3,00 | 0,00
Min | Max	3,00 | 3,00	1,00 | 3,00	2,00 | 2,00	2,00 | 3,00	3,00 | 3,00
7					
A | SD	3,50 | 0,53	1,75 | 0,46	2,88 | 0,35	2,88 | 0,35	3,50 | 0,53
Min | Max	3,00 | 4,00	1,00 | 2,00	2,00 | 3,00	2,00 | 3,00	3,00 | 4,00
8					
A | SD	3,20 | 0,45	1,80 | 0,45	2,40 | 0,89	2,80 | 0,84	3,20 | 0,45
Min | Max	3,00 | 4,00	1,00 | 2,00	1,00 | 3,00	2,00 | 4,00	3,00 | 4,00
9					
A | SD	5,00 | NA	2,00 | NA	1,00 | NA	2,00 | NA	5,00 | NA
Min | Max	5,00 | 5,00	2,00 | 2,00	1,00 | 1,00	2,00 | 2,00	5,00 | 5,00
10					
A | SD	5,00 | NA	1,00 | NA	2,00 | NA	2,00 | NA	4,00 | NA
Min | Max	5,00 | 2,00	1,00 | 1,00	2,00 | 2,00	2,00 | 2,00	4,00 | 2,00

Accordingly, if preceding to the risk qualification according to this method, 50,00% (n= 5) represent a Moderate Risk, 40,00% (n= 4) Acceptable, and 10,00% (n= 1) did not had classification since it did not occur. No posture needed immediate intervention, as presented in Figure 20. Although when analysing the maximum value of ROSA final score, some postures had a higher risk level, particularly, the posture defined as NA (not a common office posture and excluded from the analysis) with a ROSA final score of 6, implying immediate intervention, and posture 1, 2, 3, 4, and 9 representing a moderate risk (maximum 5).

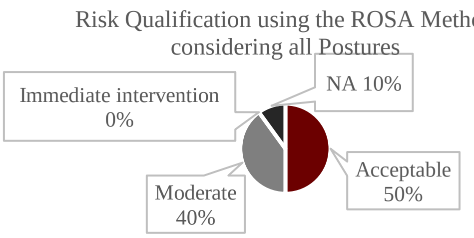


Figure 20 – Risk Qualification by the application of the ROSA method.

5.4 Motion Caption System

Considering the results of the Motion Caption System used, the Xsens, it is possible to see a participant's avatar performing the 10 postures in Figure 21. In the different postures, the top figure on the left represents the anterior view and, on the right, the posterior view. The bottom posture on the left is the left view, and on the right is the right view. As this is a view cut done by the Xsens, the angle is fixed in every view, and the coordinate system is the one presented in Figure 18, Chapter 4.4.5. This way, it was possible to capture the angles maintained by participants in real time and associate them with the pressure values registered in the different positions. In the different postures were asked to maintain a right angle between the upper and lower leg and, as instructed, vary the way they were seated.

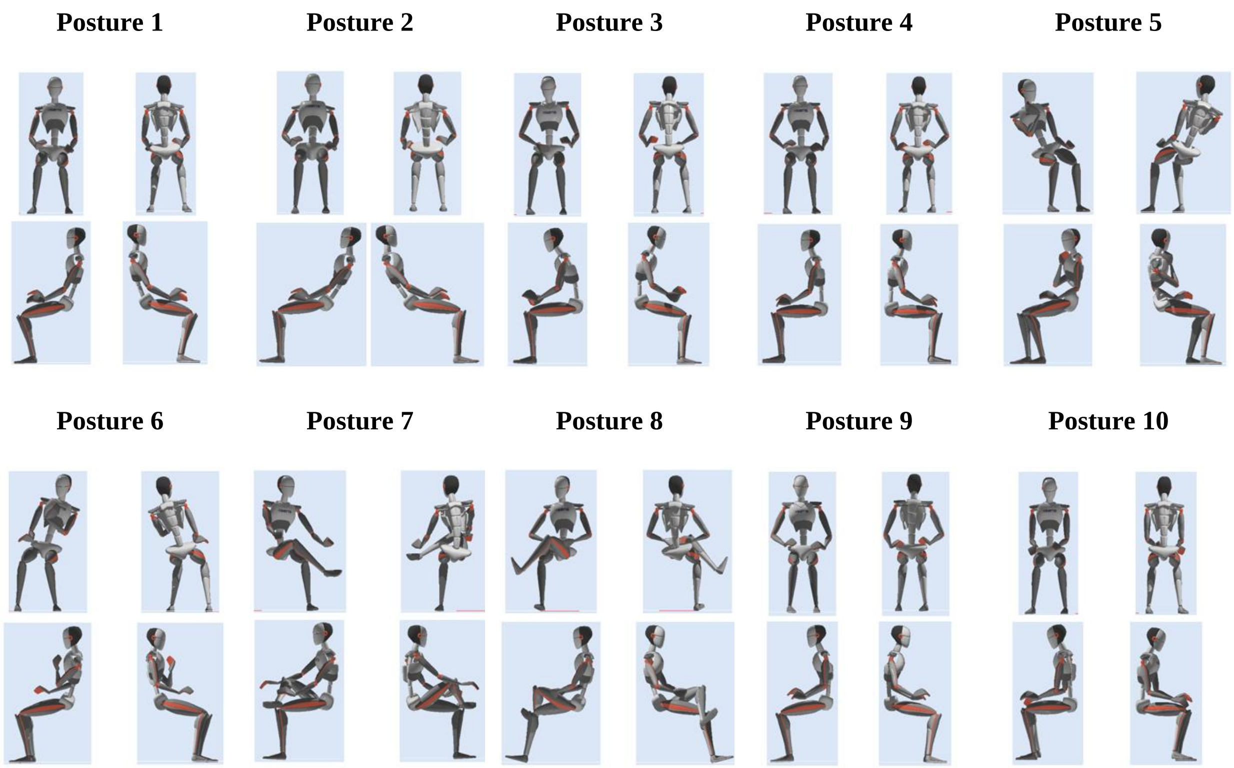


Figure 21 - Xsens Avatar of a Participant Performing the 10 postures (anterior, posterior, left and right view).

The values of the angles extracted from the Xsens are presented in Table 2, present in Appendix I, considering the different body parts analysed and the postures tested. As so, observing the values makes it possible to see that the postures are static as the values vary between each other few angles. As stated before, participants were only asked to maintain a right angle between the thigh and shin and free movement in all other body segments. To characterise the risk associated with the postures based on the angles, the average value obtained for the different body parts was compared with the values presented in ISO 11226:2000.

By analysing the results of the application of ISO 11226:2000, present in Table 14, considering posture 1, all parameters are acceptable, except for the trunk and head symmetry, the neck flexion/extension angles were negative, and the knee angle was less than 90°. For posture 2, there is asymmetrical trunk and head posture. The trunk inclination was negative since participants were without full back support, as the lumbar region was not in contact with the chair back, and the neck flexion/extension angle was also negative. For posture 3, there is also asymmetric trunk and neck posture, the lumbar spine is convex, the head angle is smaller than 0° with no support, the neck flexion/extension angle is smaller than 0°, and, as in the case the other postures, the knee angle is smaller than 90°. Considering posture 4, the trunk and head posture is also asymmetric. The head inclination angle is smaller than 0° without full support, the neck flexion/extension angle is also smaller than 0°, and the knee angle is smaller than 90°. In posture 5, as in the others, there is no symmetry in the trunk and head angle, there is a convex lumbar spine, the head inclination angle is smaller than 0° without full support, the neck flexion/extension angle is smaller than 0°, and the knee angle is smaller than 90°. Posture 6 also has asymmetrical trunk and head postures, the neck flexion/extension angle is smaller than 0°, and the knee angle is smaller than 90°. Regarding posture 7, the results were the same as in posture 6. In posture 8, participants had an asymmetrical trunk and head posture, the lumbar spine was in a convex position, the neck flexion/extension angle was smaller than 0°, and the knee angle was smaller than 90°. Taking into consideration posture 9, there is also the asymmetric trunk and head posture; the head inclination angle was smaller than 0 without support, the flexion/extension neck angle was smaller than 0°, and the knee angle was smaller than 90°. In posture 10, the same situation as in posture 9 was verified.

Table 14 – Posture Risk analysis according to ISO 11226:2000.

Body Segment	**Postures**																			
	1		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**		**10**	
	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N
Symmetrical trunk posture																				
No	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X
Yes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trunk inclination																				
> 60 °	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20 ° to 60 ° without full Trunk support	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
20 ° to 60 ° with full Trunk support	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0 ° to 20 °	-	-	-	-	X	-	X	-	X	-	X	-	-	-	-	-	-	-	X	-
< 0 ° without full trunk support	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
< 0 ° with full trunk support	X	-	-	-	-	-	-	-	-	-	-	-	X	-	X	-	-	-	-	-
For sitting: convex lumbar spine posture																				
No	X	-	X	-	-	-	X	-	X	-	X	-	-	-	-	-	X	-	-	-
Yes	-	-	-	-	-	X	-	-	-	-	-	-	-	X	-	X	-	-	-	X
Symmetrical head posture																				
No	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X

Body Segment	Postures																			
	1		2		3		4		5		6		7		8		9		10	
	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N
Yes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Head inclination																				
> 85 °	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25 ° to 85 ° without full head support	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25 ° to 85 ° with full head support	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0 ° to 25 °	-	-	X	-	-	-	-	-	-	-	X	-	-	-	X	-	-	-	-	-
< 0 ° without full head support	-	X	-	-	-	X	-	X	-	X	-	-	-	X	-	-	-	X		X
< 0 ° with full head support	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Neck flexion / extension																				
> 25 °	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0 ° to 25 °	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
< 0 °	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X
Awkward upper arm posture																				
No	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-
Yes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Upper arm elevation																				
> 60 °	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20 ° to 60 ° without full arm support	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20 ° to 60 ° with full arm support	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-
20 ° to 20 °	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Raised shoulder																				
No	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-
Yes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Extreme elbow flexion/extension																				
No	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-
Yes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Extreme forearm pronation / supination																				
No	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-
Yes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Body Segment	Postures																			
	1		2		3		4		5		6		7		8		9		10	
	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N
Extreme wrist posture																				
No	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-
Yes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Extreme knee flexion																				
No	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-
Yes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
For sitting knee angle																				
> 135 °	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90 ° to 135 °	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
< 90 °	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X	-	X

A – Acceptable; N – Not recommended; X – Answer

When comparing the obtained values with the referenced in ISO 11226:2000, all postures presented asymmetric trunk and head postures because to have a symmetric posture, there is “neither axial rotation nor lateral flexion”, which was not verified. The convex lumbar spine was defined considering the value registered in posture 1 and values above that were considered as convex, and postures 3, 7, 8 and 10 registered a value superior to the one of posture 1. The trunk inclination angle had diverse variations when comparing the different postures, with postures within the acceptable limit (postures 1, 3, 4, 5, 6, 8, 9 and 10) and others not recommended (posture 2). Bearing in mind the head inclination angle, there are also diverse variations through the postures, and in most cases, the posture adopted is not recommended (Postures 1, 3, 4, 5, 7, 9 and 10). Contemplating the neck inclination angle, all postures registered a value within the not recommended. Considering the upper extremity postures, all the positions tested were within acceptable values. Although participants were instructed to maintain a 90° angle in the knee, it was verified that this angle is smaller, which is related to the miscalibration of the feet sensor, which sometimes caused participants to have the feet in awkward positions or the illusion that participants had a right knee angle and in reality, the angle is slightly lower. In the present study, the duration variable of the posture was not contemplated as the protocol established that participants performed it for 2 minutes, a duration that is not recommended if the body angle is too extreme, which did not occur in the present situation. None the less it is important to refer that it is always important to consider the duration of the position adopted, as no matter how correct the posture might be, it should not be performed for more than a specific period without carrying ergonomic risk, as more and shorter holding time represents a higher endurance surplus, also referred as remaining endurance capacity (REC).

5.5 Pressure Sensor

After the application of the data method analysis on the pressure mat results, the information was compiled in Table 15, considering the Average, Max and Min Pressure, the centre of pressure in X and Y, the average contact area for the total area as well as the contact area, average pressure and X and Y coordinates of the different quadrants. The results of the pressure mat indicate that the posture with the higher average pressure are the postures with the lower contact area, with a inverse proportionality relationship. Taking into consideration the centre of pressure values, as mentioned above, the results were extrapolated from centimetres to a coordinate value. Exploring the values obtained in this parameter, it is possible to identify a pattern, as posture 1 and posture 3 present almost the same coordinates, as well as posture 2 and posture 4, that might be related to the way the user utilises the seat pan to adopt the given posture. In postures 5 and 6, it is possible to distinguish the side to which participants are inclined as the X coordinate is further apart. In the case of postures 7 and 8, the leg position is symmetric, so the centre of pressure is similar in both, and the overall pressure applied is homogeneous. Considering postures 9 and 10, it is possible to observe that the Y coordinate decreases, indicating that the pressure points are moving towards the front part of the seat.

Table 15 – Results of the sensor pressure.

Variable	1	2	3	4	5	6	7	8	9	10
$\bar{P}_{max}$	17231,00	17806,54	18926,10	20765,20	21665,64	20458,08	23578,46	22383,96	23823,03	30962,52
$\bar{P}_{min}$	9,72	41,67	11,89	11,35	11,16	15,01	13,62	15,38	19,12	23,85
$\bar{P}$	4166,48	4521,07	4187,73	4863,11	4619,71	4859,12	5622,50	5534,65	6053,81	7468,38
$A_{contact}$	1500,80	1440,59	1508,09	1460,68	1517,80	1513,68	1286,59	1263,45	1247,32	931,02
X (cm)	21,88	21,87	21,72	22,02	24,73	20,03	20,78	22,46	21,79	21,59
Y (cm)	27,05	24,00	26,95	25,11	25,66	25,91	27,06	26,92	19,43	13,29

Considering the average pressure registered in the different quadrants, it is possible to see in which part of the seat pan the subjects need to apply pressure to perform the different postures present in Table 16. For instance, in posture number 1, where the subject maintains an upright posture with the back completely supported by the chair back, the pressure in both back quadrants (Q_3 and Q_4) is almost the same, as well as the pressure registered in the front quadrants (Q_1 and Q_2), a phenomenon that can be explained since this posture has no asymmetry and participants have back and feet support. The same happens in postures 2, 3 and 4, where in this present ergonomic risk due to trunk inclination angle and/or back support, the quadrants where pressure was mainly applied were Q_3 and Q_4, but the body assumed a symmetric posture. For instance, between postures 5 and 6, symmetric in relation to one another, it is possible to see that the front and back quadrants with more pressure changed from one side to the other when changing the lateral inclination angle. These postures represent ergonomic risk due to the asymmetric trunk posture, in which the user is inclined to the right or to the left. The results indicate that the average pressure changes from Q_1 to Q_2 and from Q_3 to Q_4 when changing from posture 5 (right side) to 6 (left side). In the case of posture 5, the quadrants with a higher value were Q_4, Q_2, Q_3 and Q_1, in decrescent order, and in the case of posture 6, the quadrants were Q_3, Q_1, Q_4 and Q_2. In postures 7 and 8, the same happened as they were also symmetric with each other, but this time the highest value was registered in the back part of the seat pan. In the case of posture 7, the value was higher in Q_4 because participants crossed their right leg over the left, applied more pressure in the right buttock, and used the other leg to help support the body. In Posture 8, the symmetric situation happens, as the left leg is crossed over the right, meaning that the left buttock supports most of the pressure, located in Q_3, and the right leg supports the rest. In postures 9 and 10, since participants were asked to move forward in the seat pan, the quadrants with the higher values were in the front of the chair pan. In posture 9, the values registered in the front quadrants, Q_1 and Q_2, start to increase in comparison with the postures described so far, related to the fact that participants are seated in the middle of the seat pan without back support. In posture 10, is possible to observe the differences between the front and back quadrants, as the front quadrants registered the highest value of average pressure of the 10 postures, and on the other hand, also registered the lowest in the back quadrants. In this posture, participants are seated on the front edge of the seat to simulate the moments when the duration of the time spent seated is relatively short.

Table 16 – Results of average pressure in the different quadrants, for the postures tested.

Variable	1	2	3	4	5	6	7	8	9	10
$\bar{P}_{Q1}$	1995,73	2440,65	2071,37	2478,78	1994,41	2902,14	2953,68	1417,96	4445,86	6076,11
$\bar{P}_{Q2}$	2169,69	2698,10	2240,94	2902,65	3116,51	2264,93	1249,27	2727,24	4558,38	5756,45
$\bar{P}_{Q3}$	3738,19	3575,40	3730,92	3831,15	3057,19	4977,29	4412,92	4803,39	2552,10	470,45
$\bar{P}_{Q4}$	3797,83	3382,54	3706,90	3946,98	4891,16	3450,93	4749,79	3994,20	2427,36	422,54

Considering the contact area registered by each posture, presented in Table 17, it is possible to observe that postures have particular characteristics. As such, postures 1 and 3 present similar values as the higher value in Q3, meaning participants tend to put more pressure on the left buttock area, distributing the rest through the other quadrants. In postures 2 and 4, a similar situation is possible to observe, as the four quadrants have similar values of contact area, as a slumped or completely detached back position is adopted, implying the migration of the buttock slightly forward. In Posture 5 (body supported by right armrest), the contact area of each quadrant is relatively homogeneous, but in Posture 6 (body supported by left armrest), the symmetric posture of number 5, it is possible to see that the higher value was in Q_3, correspondent to the left buttock. Postures 7 and 8, as mentioned, are also symmetric, as Q2 registered the lowest value in posture 7 and Q1 the lowest in posture 8, since in one of the cases, the right leg is crossed over the left and in the other, the left over the right, explaining the shift in quadrants. Posture 9 had a higher value on the front quadrants, concordant with the postural shift towards the front part of the seat. As posture 10 is the most extreme of positions, the front quadrants registered a high level of contact area in comparison to the back quadrants, which had an extremely low value.

Table 17 – Contact area results of the different quadrants.

Variable	1	2	3	4	5	6	7	8	9	10
$A_{contactQ1}$	310,47	346,07	308,20	330,15	323,43	343,89	311,86	214,86	387,80	408,36
$A_{contactQ2}$	297,82	328,37	302,27	318,78	327,48	300,29	168,59	263,31	347,06	348,15
$A_{contactQ3}$	429,03	368,32	432,29	390,27	381,37	436,05	397,78	389,38	235,52	59,72
$A_{contactQ4}$	368,22	306,02	369,60	328,67	376,52	337,37	326,69	315,71	197,75	55,77

The value of the centre of pressure in X and Y in the different quadrants allows an understanding of the epicentre of the pressure applied in the front and back of the seat in each posture, presented in Table 18. As so, in posture 1, in the back quadrants, the centre of pressure was in the ischium, and in the front quadrants, is close to the back limit, which means there is no risk of cut-off circulation caused by an excess pressure applied in the thighs. In Posture 2, the Q_3 and Q_4 coordinates moved towards the front limit. Posture 3 had results equal to posture 1 in all quadrants, except number 4, with a minimal difference, related to the similarity postures, also verified in the average pressure values. In Posture 4, the pressure is almost equally distributed through the quadrants, the same as in Posture 2, as the positions adopted by participants in the seat are similar, but the back support is different. In postures 5 and 6, the centre of pressure was identical, as they represent the same posture, but in one case with trunk lateral bend to the right and the other to the left. The same happened for postures 7 and 8, as both are symmetric to each other. In posture 9, the back coordinates shifted forward, in the direction of the front limit, as participants were in the middle of the chair. In the case of posture 10, the back coordinates have shifted even further than in posture 9, as participants are seated at the edge of the pan.

Table 18 – Results regarding the average, standard deviation, minimum and maximum pressure, as well as centre of pressure and contact area of the total pressure mat.

Variable	1	2	3	4	5	6	7	8	9	10
CP_X1	7	8	7	7	8	7	9	10	9	10
CP_Y1	11	11	11	11	11	11	11	12	11	9
CP_X2	23	23	23	23	23	23	22	21	22	21
CP_Y2	11	11	11	11	11	11	13	11	11	9
CP_X3	9	10	9	10	10	9	10	10	10	10
CP_Y3	24	22	24	22	23	23	23	23	20	15
CP_X4	22	22	22	22	22	22	21	21	21	24
CP_Y4	23	22	23	22	22	23	22	22	20	20

To allow easier visualisation of the data, a dispersion chart of the centre of pressure distribution of the different postures was calculated, and the information is presented in Figure 22. To do so, the centre of pressure coordinates of the different participants in each posture was considered. Through this visual analysis, it is possible to identify the pattern of each posture, allowing the identification of differences and similarities between them. As previously mentioned, there are great similarities between postures 1 and 3, 2 and 4, and 7 and 8, as the interaction with the seat is similar. In postures 5 and 6, it is possible to observe the symmetry between them, as one has most participants with values in the right side and in other shifts to the left. In postures 9 and 10 is possible to observe the position of participants in the chair, as in the case of posture 9, it is concentrated in the middle of the grid and in posture 10, in the part that represents the edge of the seat.

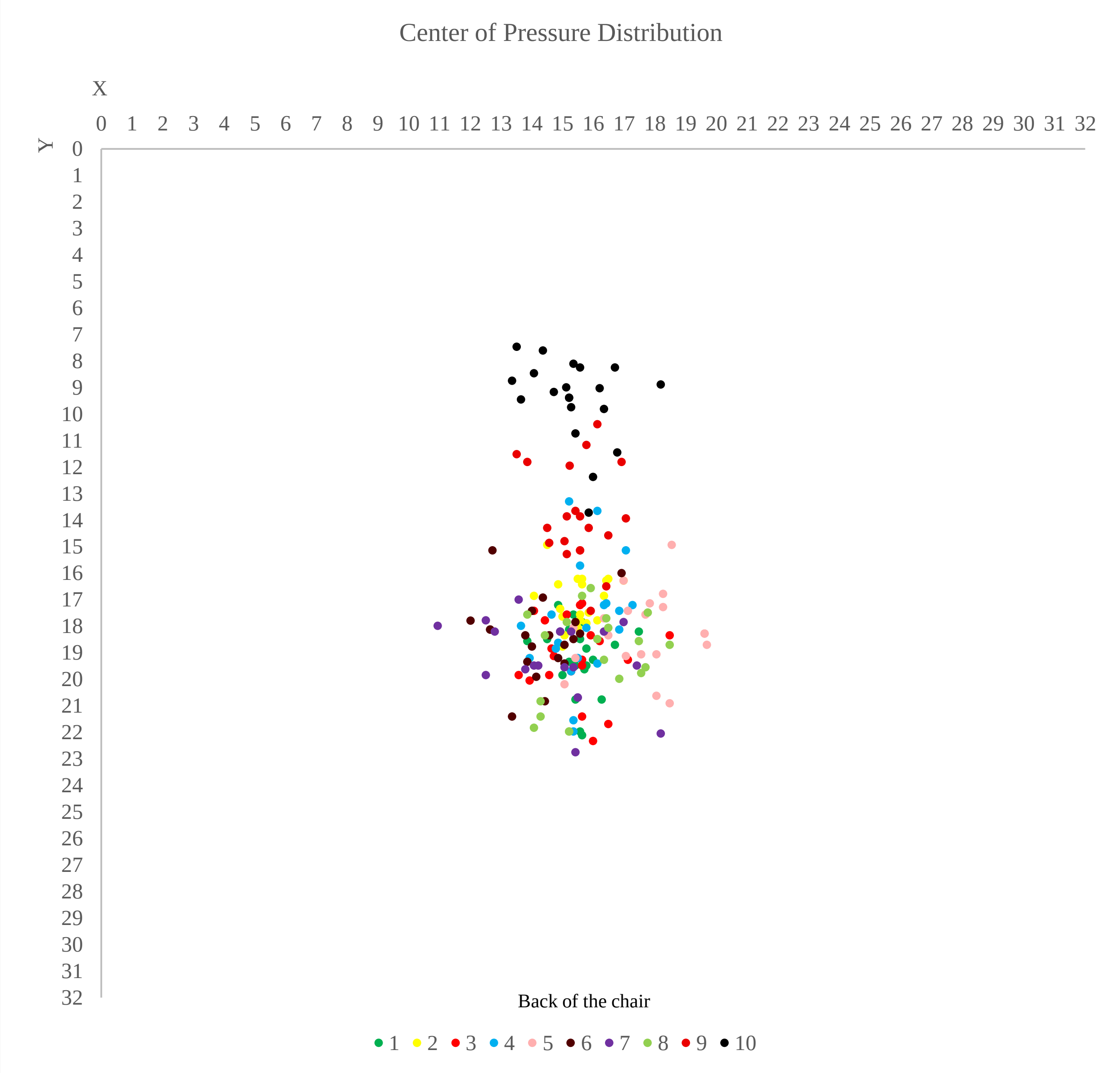


Figure 22 – Center of pressure distribution of the different postures.

Analysing the scatter plot of the different postures when the quadrant division is made, present in Figure 23, it is possible to observe that in the back quadrants the location is similar for a lot of postures, as there exists a big agglomerate of postures in each one, except in the case of posture 9 and 10, that because of the way users where seated the coordinates decreased. In the front quadrants, the postures that stand out in comparison with the other are posture 7 and 8, due to the leg position adopted.

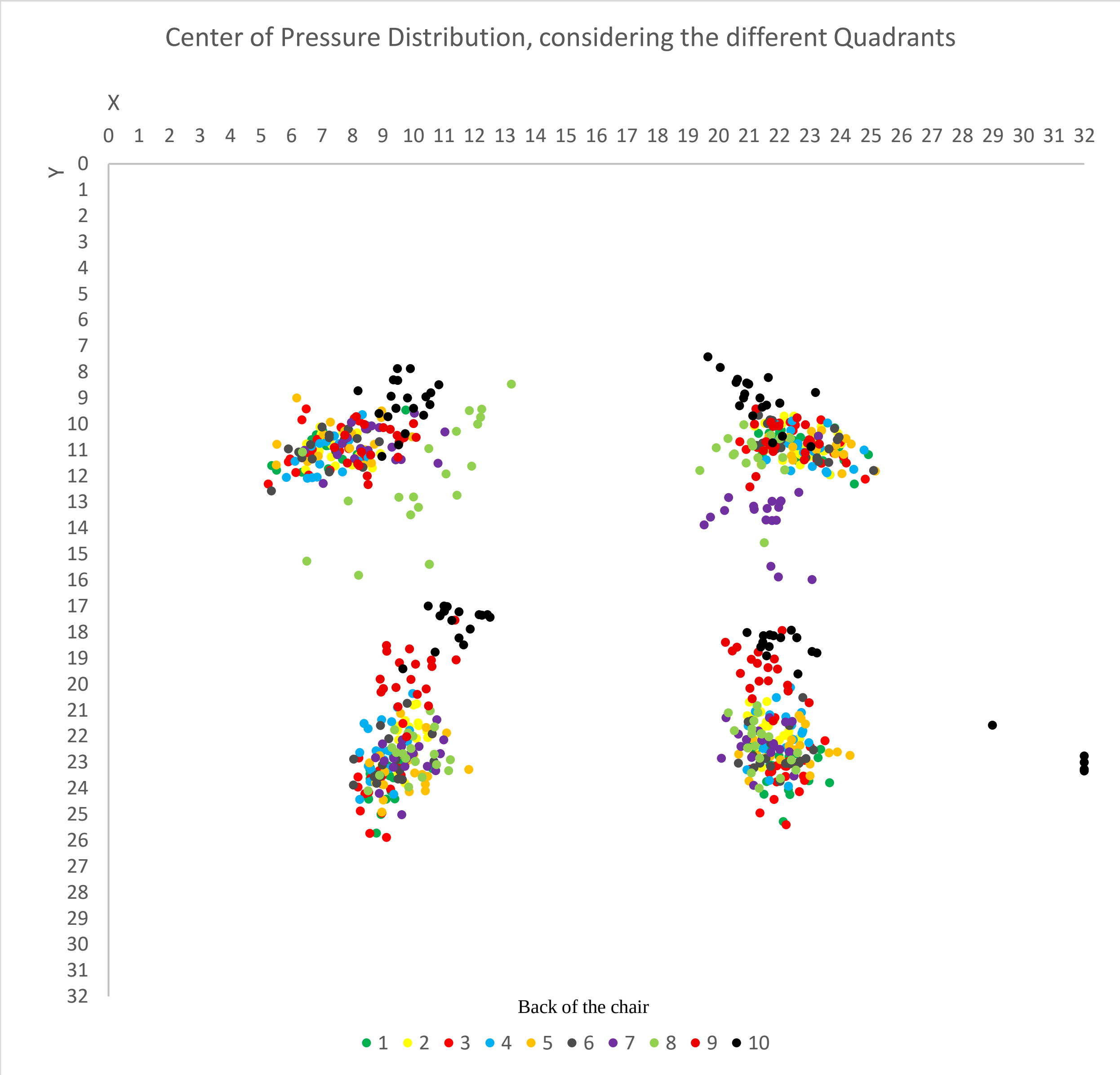
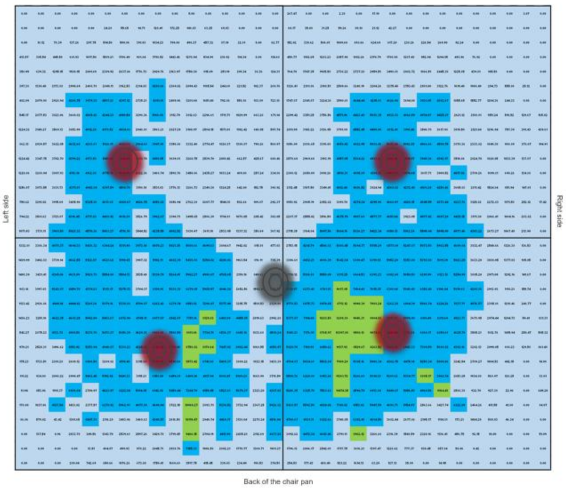


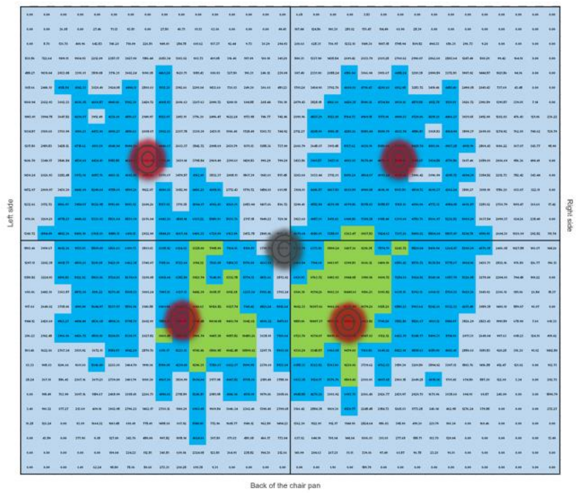
Figure 23 – Center of Pressure Distribution, considering the Posture.

The results were analysed considering the pressure risk qualification, proposed in Table 6. As so the postures risk classification based on the average pressure was performed, for each posture, contemplating the four quadrants. The following analysis is depicted from Figure 24, in which the black circle represents the center of pressure of the posture without considering the quadrants, and the red circle the center of pressure when considering the quadrants. Analysing the visual representation of the different postures, it is possible to clearly observe the leg and lower trunk position in relation to the seat pan. Through the pressure maps capture, it is viable to assume user position, based on the average pressure applied in the seat, the contact area between the legs and the chair, as well as observe the distribution of pressure in the different situations. As it was mentioned, the pressure mat proved to depict a reliable solution in identifying leg and trunk position on the chair, but postures that have those same characteristics but differences in terms of upper back position are difficult to distinguish. As so, using the pressure mat alone it was not possible to distinguish posture 1 from posture 3, as the difference is that in posture 3 users assume the same leg and lower back position as in posture 1, but the upper back is not supported by the back of the chair. It is also not possible to differentiate posture 2 from posture 4, because in both postures users do not have lower back support, but in posture 4 the upper back is also not supported. Through the pressure mat results it was also possible to detect situation in which the user has an asymmetric trunk posture due to trunk lateral bending, as one side of the sensors register higher values than the other.

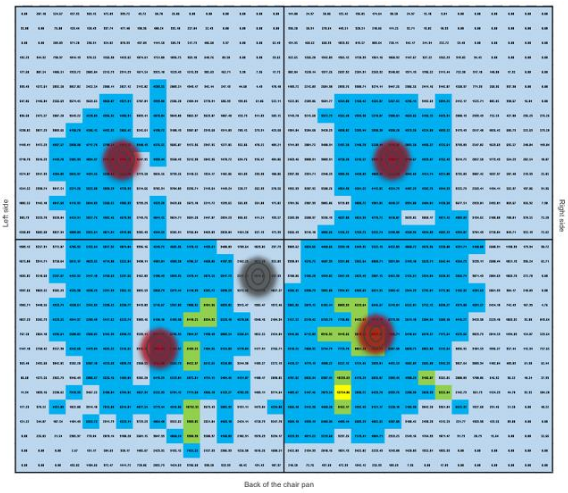
Posture 1



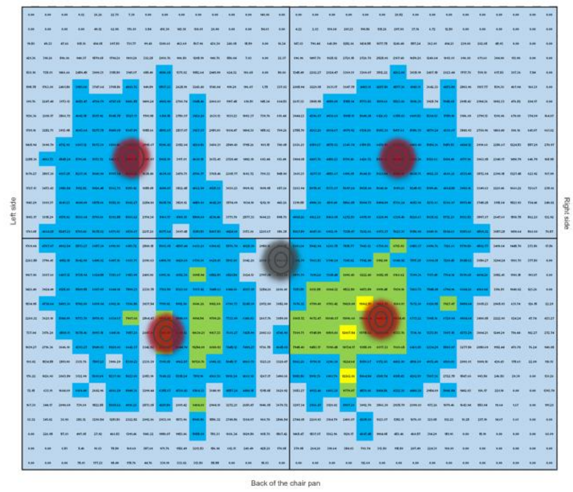
Posture 2



Posture 3

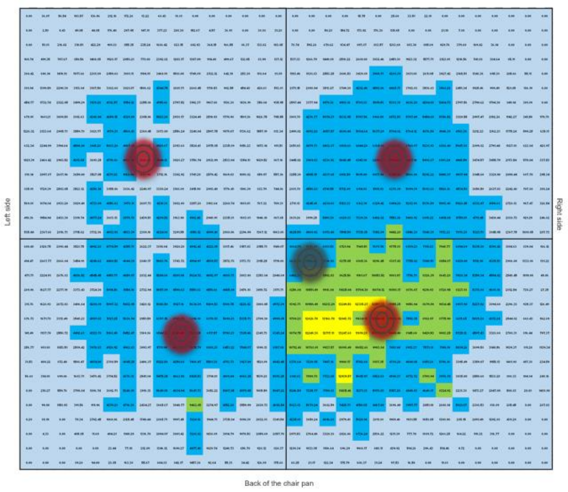


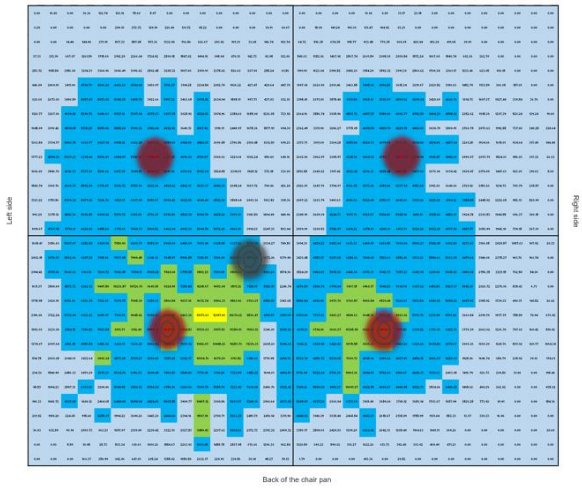
Posture 4



Posture 5

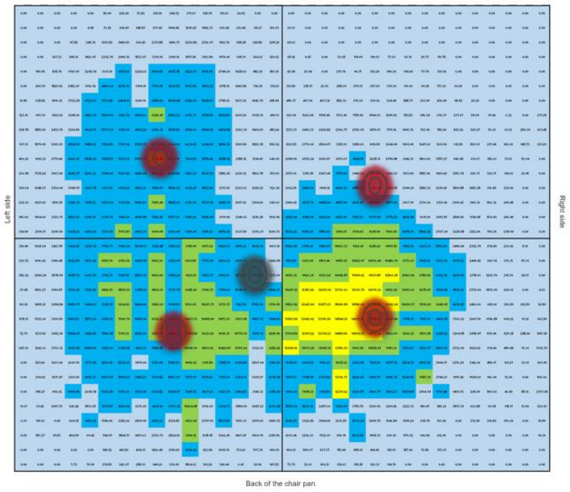
Posture 6

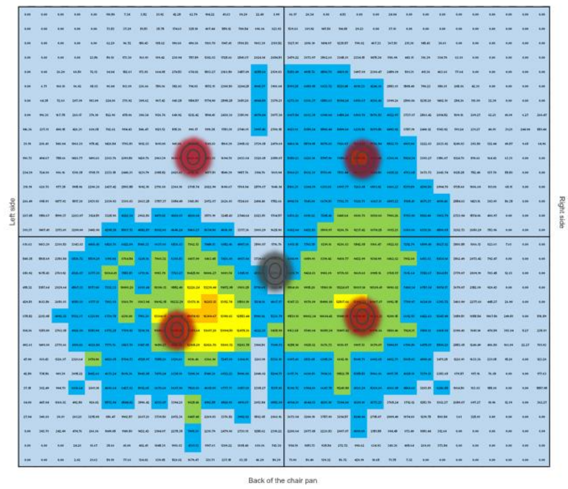




Posture 7

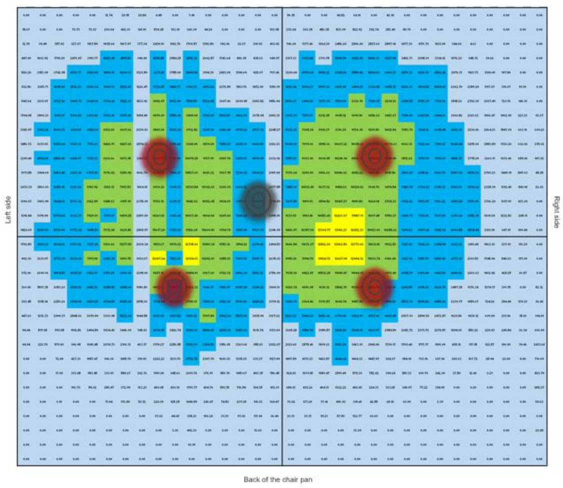
Posture 8





Posture 9

Posture 10



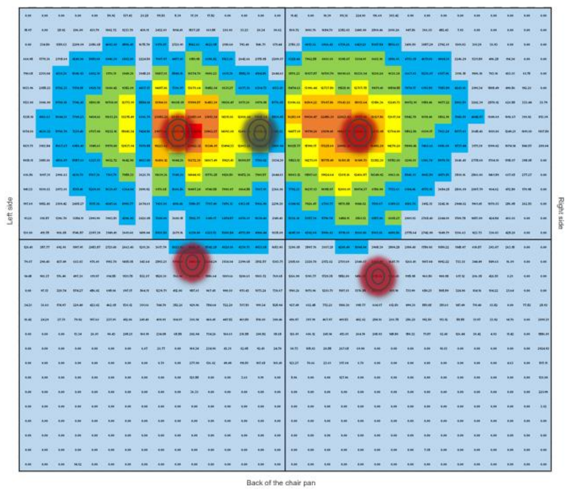


Figure 24 – Pressure sensor visual representation of the results.

5.6 Interdependency Between Variables

After obtaining the values and organising the information, the Shapiro-Wilk normality test was conducted, as presented in Table 2, Appendix I. Since not all the variables to be compared follow a normal distribution, the Spearman Correlation Matrix was applied to relate the answers given on the questionnaires with one another and the relation between the values obtained with the pressure sensor and the angles measured by the Xsens.

Therefore, in Table 3, Appendix I, it is possible to observe the values of the Spearman rank correlation coefficient of the questionnaire results with each other. The variables deleted from this correlation matrix were answers from the NMQ inquiring about pain or discomfort in the left shoulder, right or both elbows left or both wrists/hands in the last seven months and left shoulder, right, left or both shoulders, left or both wrists/hands over the previous 12 months, as no participant identified these body regions. Focusing on the **positive correlation**, participants' age was connected to the period of job experience, as older individuals have worked longer. The more time participants spend seated, the higher the probability of reporting pain or discomfort in both shoulders in the last 7 and 12 months. Participants who reported their chair as uncomfortable were the ones who also reported symptoms over the previous 7 and 12 months in the right wrist/hand and the last 12 months for the hips/thighs, as individuals who considered their chair uncomfortable tend to have symptoms in these body regions. Pain or discomfort felt in the last seven months in the lumbar region and on both shoulders in the last 12 months was associated with the hours of weekly exercise, as individuals who practice more exercise over the week report more symptoms in these areas than the others. On the other hand, considering the **negative correlations**, age was connected to the number of hours of weekly exercise practice, as older individuals tend to dedicate fewer hours to this practice. Participants with a higher weight tend to report more symptoms in the right wrist/hand in the last 7 months. Participants with more years of work experience considered their chair more comfortable, practised fewer hours of exercise daily and reported fewer symptoms of pain or discomfort in the right wrist/hand.

Considering the Spearman correlation matrix, starting on the positive correlations obtained between the pressure mat and the Xsens, shown in Table 4, Appendix I, as the postures tested advance, from 1 to 10, the angle of flexion/extension of the right wrist increased. The average pressure will increase as the right upper arm external rotation increases. The trunk convex position influences the Y coordinate, which means that the higher the convex angle, the higher the Y coordinate. This can indicate that as participants curve, the spine tends to increase the pressure on the Y side of the mat. The average contact area of Q_1 increases due to an increase in the left knee flexion angle and Q_2 due to the right knee. The X coordinate of Q_1 is influenced by the right wrist flexion/extension angle; therefore, the angle increases as the coordinate goes closer to the Q_2 limit. In $Q_{2,}$ the coordinate will be closer to the mat limit as the left forearm pronation/supination angle increases, and in $Q_{3,}$ the coordinate shifts toward the Q_4 limit as the right upper arm external rotation angle increases. Regarding the negative correlations, the pressure applied in Q_3 is going to be smaller as the right upper arm external rotation and the forearm pronation/supination increases, and in Q_4, the value also decreases as the left knee flexion angle increases. The average contact area in Q_1 decreases as the trunk lateral flexion angle increases as well as with the angle formed in the lumbar region. In Q_3, it decreases as the right upper arm external rotation angle increases. The X coordinate of the centre of pressure in Q_1 is closer to the left mat limit as the left forearm pronation/supination angle increases. In Q_3, the same happens but is also influenced by the increase of the right wrist ulnar/radial deviation angle. The Y coordinate of Q_2 is closer to the left mat limit as the right knee flexion angle increases. In Q_3 and Q_4, the right upper arm external rotation angle increase.

As stated before, the variables that had a Spearman Correlation Rank with a significant correlation between them were analysed through a linear regression model to understand if the increase in the variable x, the dependent variable, represents an increase or decrease (dependent on the slope signal, in which positive represents increase and negative decrease) of m in y. So, depending on the R^2 (≥ 0,70; ≤ 0,30), it is possible to understand if the dependent variable is being explained by the regression line. In Table 19, it is possible to consult the linear regression equation values for each of the variable pairs. This model proved to be reliable in understanding the pattern of the variation of the $\mathrm{CP_x}$ and the trunk axial rotation angle, as the increase of the $\mathrm{CP_x}$ causes a variation of -1,07 of the trunk axial rotation angle, which means that every time the $\mathrm{CP_x}$ increases, the angle has the opposite response and decreases, and will contribute to an asymmetric trunk posture, verified in all postures tested ($R^2 = 0{,}83$). Every time the $\mathrm{A_{contactQ1}}$ increases 1 cm^2, the left knee flexion/extension angle increases by 0,085 degrees, which means that while participants extend their left leg and the knee angle augments, the part of the leg closer to the knee is going to occupy a larger area ($R^2 = 0{,}76$). The same happens considering Q_2, as every time the $\mathrm{A_{contactQ2}}$ increases 1 cm^2, in this case, the right knee flexion/extension angle increases 0,10 degrees, and in this situation, the right leg knee joint activates more cells meaning a larger contact area ($R^2 = 0{,}88$). Although the right knee flexion/extension angle decreases -5,25 degrees with the increase of the $\mathrm{CP_{YQ2}}$, the increase in the y coordinate of Q_2 is going to be influenced by a decrease of the right knee flexion/extension angle ($R^2 = 0{,}74$). The external rotation angle of the right upper arm will be influenced in -2.03 degrees due to the increase of the $\mathrm{CP_{Y4}}$, so the increase of the y coordinates in Q_4 might represent an extreme external rotation angle of the right upper arm, used particularly and with a lot of frequency by the worker to control the mouse and typewrite ($R^2 = 0{,}73$). The model tested proved not to be appropriate to assess certain variables, and for example, the variation of the head inclination angle is not related to the variation of the $\mathrm{CP_x}$ ($R^2 = 0{,}0020$). Another situation is that the right arm pronation/supination angle does not depend on the $\overline{\mathrm{P}}_{\mathrm{Q3}}$ ($R^2 = 0{,}30$) and the left wrist flexion/extension angle is not influenced by the increase or the decrease of the $\overline{\mathrm{P}}_{\mathrm{Q4}}$ ($R^2 = 0{,}20$). These two results indicate that the increase of the average pressure registered in Q_3 and Q_4 (left and right buttock, respectively), do not have any influence on some of the upper arm movement, right forearm and left wrist). Through the increase or decrease of the Q_1 contact area the chair user is activated the angle formed by a convex lumbar spine is not going to be influenced, so the register of $\mathrm{A_{contactQ1}}$is not reliable to understand if participants have this unrecommended lumbar angle ($R^2 = 0{,}080$). The center of pressure variation of the X coordinate in Q_1 and in Q_3, is not going to influence by the right wrist ulnar / radial deviation angle, therefore as the coordinate oscillates the angles remains similar ($R^2 = 0{,}022;\ R^2 = 0{,}13$, respectively), this wrist movement is not moulded by the oscillations of centre of pressure of the left quadrants. The contact area of the front quadrants is helpful to understand the knee angle of participants and avoid extreme angles. To help to assess the knee angle, the y coordinate of the front quadrants, particularly, the right, also proven to be reliable. To understand part of the arm movement the model has also proven to be consistent considering the right buttock centre of pressure.

Table 19 – Linear regression values for the different variables.

Independent Variable	Dependent Variable	m	b	R^2
$\overline{P}$	Right Upper Arm External Rotation	0,0023	7,63	0,50
CP_y	Lumbar Convex Spine	-0,12	22,57	**0,073**
$\overline{\mathrm{P}}_{\mathrm{Q2}}$	Right Knee Flexion / Extension	0,0031	61,47	0,50
$\overline{\mathrm{P}}_{\mathrm{Q2}}$	Right Elbow Flexion / Extension	0,0040	47,33	0,33
$\overline{\mathrm{P}}_{\mathrm{Q3}}$	Right Knee Flexion / Extension	-0,0025	79,59	0,34
$\overline{\mathrm{P}}_{\mathrm{Q3}}$	Right Upper Arm External Rotation	-0,0019	26,45	0,58
$\overline{\mathrm{P}}_{\mathrm{Q3}}$	Right Forearm Pronation / Supination	-0,0027	13,11	**0,30**
$\overline{\mathrm{P}}_{\mathrm{Q4}}$	Left Wrist Flexion / Extension	0,0021	-26,40	**0,20**
$\overline{\mathrm{P}}_{\mathrm{Q4}}$	Left Knee Flexion / Extension	-0,0019	77,49	**0,22**
$\mathrm{A}_{\mathrm{contactQ1}}$	Lumbar Convex Spine	-0,0019	29,06	**0,080**
$\mathrm{A}_{\mathrm{contactQ1}}$	Left Knee Flexion / Extension	0,085	43,011	**0,76**
$\mathrm{A}_{\mathrm{contactQ2}}$	Right Knee Flexion / Extension	0,10	40,70	**0,88**
$\mathrm{A}_{\mathrm{contactQ3}}$	Right Upper Arm External Rotation	-0,023	27,64	0,65
$\mathrm{CP}_{\mathrm{X1}}$	Forearm Left Pronation / Supination	-3,75	38,90	0,46
$\mathrm{CP}_{\mathrm{X1}}$	Right Wrist Flexion / Extension	3,95	-47,13	0,52
$\mathrm{CP}_{\mathrm{X1}}$	Right Wrist Ulnar / Radial Deviation	-0,84	20,46	**0,022**
$\mathrm{CP}_{\mathrm{X2}}$	Forearm Left Pronation / Supination	5,68	-119,23	0,39
$\mathrm{CP}_{\mathrm{Y2}}$	Right Knee Flexion / Extension	-5,25	127,72	**0,77**
$\mathrm{CP}_{\mathrm{X3}}$	Right Upper Arm External Rotation	3,90	-17,89	0,45
$\mathrm{CP}_{\mathrm{X3}}$	Forearm Left Pronation / Supination	-8,30	87,76	0,52
$\mathrm{CP}_{\mathrm{X3}}$	Right Wrist Ulnar / Radial Deviation	-4,31	54,97	**0,13**
$\mathrm{CP}_{\mathrm{Y3}}$	Right Upper Arm External Rotation	-1,61	55,35	0,64
$\mathrm{CP}_{\mathrm{Y4}}$	Right Upper Arm External Rotation	-2,03	64,04	**0,72**

5.7 Posture Risk Classification

The focus of the angle risk classification was made on the recommendations suggested in ISO 11226:2000 for the trunk region, although attention was paid to considering if the posture had pressure symmetry between the right and left side and if the trunk was or was not supported. Therefore, as expected, posture 1 fulfils the requirements imposed and was considered acceptable. The other postures tested were all considered not recommended as the criteria referred to in the justification field were not met.

Considering the results of the initial risk classification of postures using the pressure mat and the Xsens, a deeper analysis of the postures was made contemplating the results, presented in Figures 24. The goal was to create categories of posture classification based on the results of the pressure evaluation to clearly identify each of the 10 postures tested. As so, the information was organized considering the posture, the body segment, the position of the different body regions, the risk level (acceptable or not recommended), and the analysis tool, as presented in Table 6, Appendix I. The selected body regions were the trunk, neck, arms and legs. Considering the neck and arms, the position adopted was considered to be acceptable in all postures, although they are angle-duration dependent. This way considering these two body regions, the risk classification must be made considering the criteria present in Figure 25. In order to do so, with the information of the pressure sensor in the seat alone, it is not possible to fully determine the angles performed. Therefore, supplementary information would be needed to make a conscious risk classification. The leg posture was also considered acceptable in all postures, except 7 and 8, as long as the flexion/extension angle is within 90º and 135º.

Focusing on posture 1, this was classified with an acceptable risk level as no pressure or extreme angles were verified on the trunk, neck, arms and legs, and the user had back and feet support. Based on the information collected using the pressure sensor, it was possible to assess trunk and leg position, establishing specific criteria that would be verified while this posture is being performed. On posture 2, there was no lumbar support, and therefore, the posture was considered not recommended. Using the pressure sensor, it was also possible to assess trunk and leg position by the lack of pressure application in the seat pan closest to the back of the chair. On posture 3, participants were seated without upper back support, so the posture was classified as not recommended. Because Posture 1 and Posture 3 are similar in how the legs are positioned, using the information collected with the pressure sensor alone, it is impossible to assess the trunk position, so supplementary information would be needed to determine the trunk inclination. On posture 4, participants were seated without back support, so the posture was classified as not recommended. Because posture 2 and posture 4 are similar in how the legs are positioned, using the information collected with the pressure sensor alone, it is impossible to assess the trunk position, so supplementary information would be needed to determine the trunk inclination. In posture 5, the trunk was inclined to the right side, which classifies this posture as asymmetric and hence not recommended. Using the pressure sensor results, it is possible to observe this asymmetry. In posture 6, the trunk was inclined to the left side, which classifies this posture as asymmetric and hence not recommended. Using the pressure sensor results, it is possible to observe this asymmetry. In posture 7, participants had the right leg crossed over the left, which can implicate a blood circulation cut on the right shin, which classifies the posture as not recommended. Participants had back support, and the leg position could be observed with the pressure sensor results. In posture 8, participants had the left leg crossed over the right, which can implicate blood circulation cut on the left shin, classifying the posture as not recommended. Participants had back support, and the leg position could be observed with the pressure sensor results. In posture 9, participants were seated in the middle of the seat, without back support, a posture not recommended while seated. The pressure sensor results made it possible to assess both trunk and legs position. Finally, on posture 10, participants were sitting in the front of the seat pan without back support, which is not recommended either. The results obtained with the pressure sensor enable the posture classification of the trunk and leg position. Therefore, body parts classification criteria were established considering the values of the contact area, average pressure and the X and Y coordinates, for the whole pressure mat and for the four quadrants, as presented in Figure 25.

Trunk			Neck	Arm	Legs	
Recommended	Not Recommended		Recommended depending on the duration	Recommended depending on the duration	Recommended	Not Recommended
Posture 1, 7 and 8	Posture 2, 3*, 4*, 9 and 10	Posture 5 and 6	All postures	All postures	Posture 1, 2, 3, 4, 5, 6, 9 and 10	Posture 7 and 8
Supported	Unsupported	Asymmetric	Supplementary information required	Supplementary information required	Supported	Leg crossed
$A_{contact\ Q3} = A_{contact\ Q4}$; $P_{Q3} = P_{Q4}$	$A_{contact\ Q3}$ and $A_{contact\ Q4}$ <; COP <; P >	$A_{contact\ Q1}$ and $A_{contact\ Q3}$ < $A_{contact\ Q2}$ and $A_{contact\ Q4}$; P_{Q1} and $P_{Q3} < P_{Q2}$ and P_{Q4} (vice-versa)	Not possible to identify	Not possible to identify	$A_{contact\ Q1} = A_{contact\ Q2}$; $P_{Q1} = P_{Q2}$	$A_{contact\ Q1} > A_{contact\ Q2}$; $P_{Q1} > P_{Q2}$ (vice-versa)

Figure 25 – Body segment pressure criteria.

Afterwards the posture classification criteria were established considering the values of the contact area, average pressure and the X and Y coordinates, for the whole pressure mat and for the four quadrants. This way, every time the specific criteria established for each posture is verified, it is indicative that the posture is being performed. Therefore, through the analysis of the pressure mat results, for a posture to be performed by a participant the conditions identified in the list below the posture identification in Figure 26.

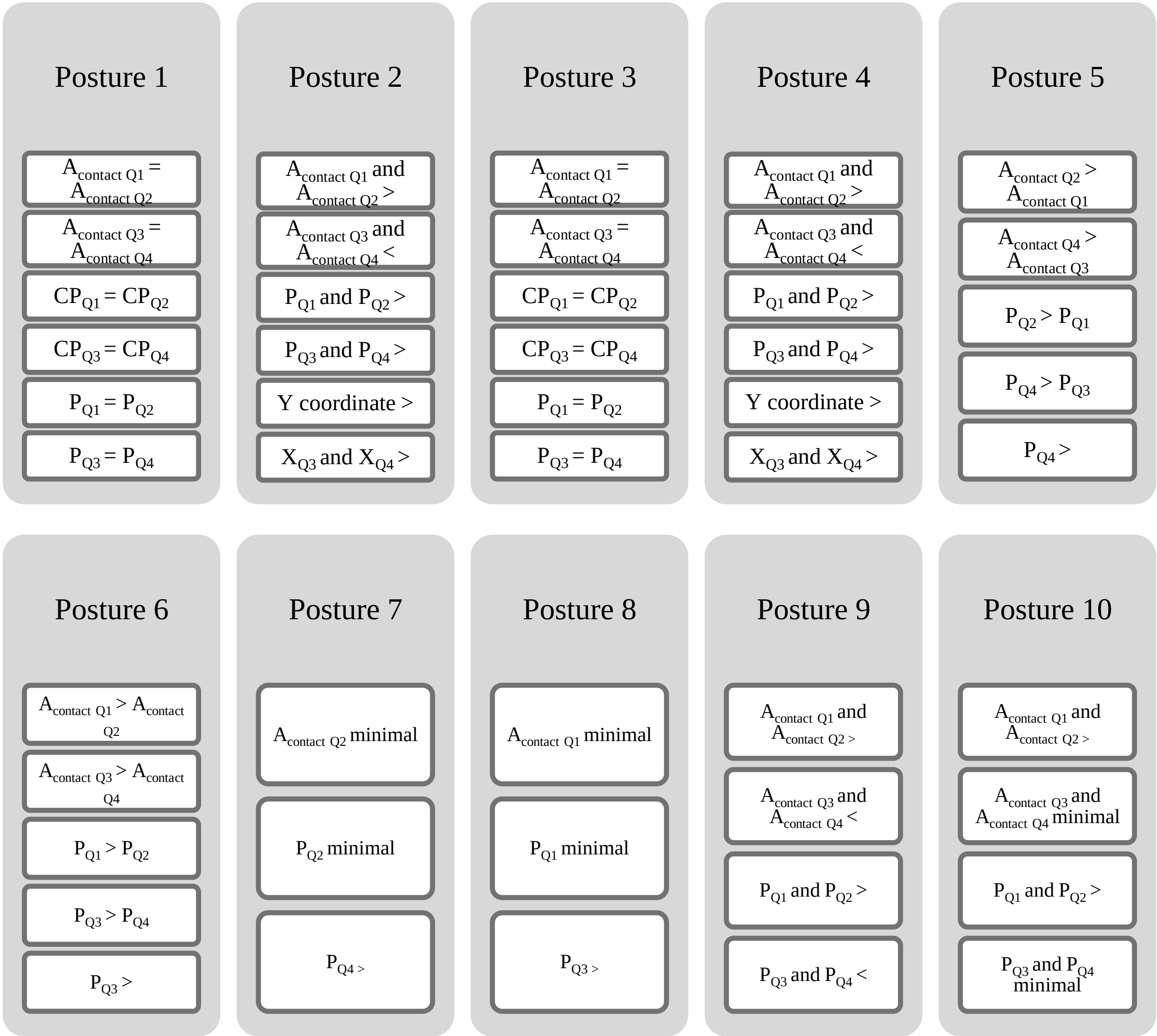


Figure 26 – Posture pressure criteria.

As it was mentioned above, the MHT was not considered in the present study as the duration in which each posture was maintained was previously defined. Although, even the most correct posture presents risks if maintained for too long. Therefore, the trunk and head inclination and the upper arm elevation angle must meet some duration requirements, as presented in Table 20, as every posture is considered acceptable if the MHT requirements are fellfield. So, extreme angles must be maintained for less than 1-minute, intermediate angles must be maintained for a maximum of 4 (trunk and upper arm) or 8 minutes (neck), but as the angle value increases the MHT decreases. The trunk and head inclination and the upper arm elevation angle within the normal range, can be maintained for a longer period, although it should have postural shifts, because of the ergonomic risk associated with prologue sitting. Based on the results of Table 20, the risk classification level for the neck and trunk inclination angle must consider the angle preformed and the time. Every time the angle increases the MHT decreases.

Table 20 – Angle-duration relation for trunk and head inclination.

Body Segment	Angle (°)	MHT
Trunk Inclination	0° to 20°	≥ 4 minutes
	20° to 60°	From 4 to 1 minute (as the angle increases)*
	> 60°	≤ 1 minute
Head Inclination	0° to 25°	≥ 8 minutes
	25° to 85°	From 8 to 1 minute (as the angle increases)*
	> 85°	≤ 1 minute

*If the body part is not supported, the situation is considered Not recommended, independently of the angle

This way, following the proposed analysis methods it is possible to assess segment position that may represent ergonomic risk to users. As so, the summary of results of the present study are:

- Postures with similar leg and lower back position with similar average pressure, contact area and center of pressure;
- Posture 5 and 6 symmetric variables;
- Q_1 and Q_2 center of pressure distribution similar in all postures except posture 7 and 8;
- Big agglomerate of center of pressure of postures in Q_3 and Q_4 (except posture 9 and 10)
- Relation between leg flexion angle and contact area of Q_1 and Q_2;
- Using a pressure sensor covering the entirety of the chair seat, it is possible to assume user leg and lower back position on the chair based on the value of average pressure, contact area and centre of pressure;
- Using a pressure sensor alone it is not possible to distinguish postures in which users have the same leg and lower trunk position.

6 DISCUSSION

This study proved to be different from the ones developed so far, as intends to understand the relation between the pressure applied in the chair seat and the joint angle between body segments in awkward postures adopted in offices and see if it is possible to make a connection between the two to assess the risk and prevent MSDs and discomfort or pain. The main goal was to try to comprehend if is feasible to identify a pattern amongst average pressure values registered in different office postures and the angles registered in the different body segments. Another study objective was to characterise the WRMSDs symptoms in this office population and characterise the study sample. The ROSA method was also applied to understand the risk level of each posture in real life context.

The sample population had the characteristics of a standard office population, as the average age is between 25 to 49 years old, with an average age of 29,33 years old (± 8,22), corresponding to the statistical data provided by CEDEFOP in 2021. Another typical characteristic of this population is that workers spend more than 80,00% of their time seated at their workstations. It is documented by Arippa, Nguyen [63] that time will contribute to the augment of the feeling of discomfort by workers, and prolonged sitting must be avoided. According to the World Health Organization (WHO), a healthy adult must engage in 02h30min to 05h00min or more of moderate-intensity aerobic physical activity weakly, or 01h15min to 02h30min or more of vigorous-intensity, or a combination of both, creating a balance through the week. The majority of the population of the present study enrol in the practice of some physical activity, from one to five hours weekly. However, the negative correlation between job experience and weekly hours of exercise per week, demonstrates that over time, the time dedicated to exercise will diminish, and this population may enrol in a sedentary behaviour, as some do not reach the recommended number of weakly hours and the trend is to decrease for unrecommended levels. By avoiding this type of behaviour and enrolling in the weekly practice of physical activities, it is possible to avoid and prevent some health problems, such as cardiovascular disease, type-2 diabetes, colon and breast cancer, adiposity, and improve mental health, cognition and sleep. As stated by WHO, "there is high certainty evidence that higher levels of physical activity are associated with lower risk of all-cause mortality, cardiovascular disease mortality, cancer mortality, cardiovascular disease incidence, and incidence of hypertension and type-2 diabetes, with no increased risk of harms". As such, for an individual to be considered active should walk at least 10.000 steps a day, according to the National Institutes of Health (NIH). While working, because the time spent seated represents most of the workday, it is important to stand up over time, walk around the office and occasionally stretch in the chair, avoiding extended periods in the same position or without standing up. In this way, participants should be aware of the benefits of practising regular physical activity and an active lifestyle perspective [125].

When analysing the MSDs complains of participants, most of the symptoms are reported on the neck, shoulders and lower back region. These results are similar to the ones obtain in the study conducted by Mohammadipour, Pourranjbar [49], as 55,2%, 51,60% and 72,4 % reported symptoms on the neck, shoulders and lower back, respectively. As the nature of the job preformed is the same, Singh and Singh [47] studied a sample of insurance office employees and found that the body region where workers reported symptoms was the neck followed by the lower back and shoulders, and therefore identifying the same body parts as in the present study. As a matter of fact, different studies conducted in the office world environment have reached the conclusion that the body regions more affected by the tasks and movements required to perform the necessary tasks to fulfil job demands will be the neck, trunk and shoulders [16, 17, 47-49, 51, 53, 71]. As the pain in this body regions are a consequence of the setup of the workstation and the postures preformed, users should be given instructions regarding the most correct ergonomic office practices. Since the education level of office workers have been increasing, as is possible to see in the present study sample, where the majority of the individuals have a high level of academic degree, one of the first steps toward an ergonomic work environment is through the training of workers about the correct context for their own workplace settings. This way, employers should give the tools and the means for employees to be able to set the workstation characteristics to their individual needs. As so, employees must have chairs with the proper ergonomic characteristics, as well as a table with sufficient space to accommodate the office equipment within the reaching zone and enough leg space under the table, monitor with a mechanism to regulate the height, keyboard with angle regulation mechanism, as so as information regarding the best ergonomic attitudes [48, 49, 53].

Another way to identify the ergonomic risk of offices is through Ergonomic Risk Assessment Methods. Accordingly, in the present study the ROSA checklist was applied to classify the postures adopted depending on the most damaging and most adopted among study participants. The posture selection was made considering the state-of-the-art review, presented in chapter 2.1, that aimed to collect information about common office postures. In this way, except for three of the eighty observations completed, the postures participants were adopting in the moment the ROSA method was applied were consistent with the postures selected. Posture 5 was not verified in any moment, because it is more common for workers to adopt this king of sitting position while reading documents or while attending a meeting, and in most of the observations, participants were using the VDU, the keyboard and mouse. None the less, posture 6, the symmetric of posture 5, was verified in 2 occasions. As it is possible to observe in the results of the present study, the ROSA section with the higher impact on the Grand Score, was related to the chair. In the study conducted by Mohammadipour, Pourranjbar [49], the results suggest a positive correlation between ROSA chair score and the Grand Score, and with the monitor and telephone score as well. In the present study, the monitor and telephone score might have been influenced by the inexistent telephone use by participants, which disguised situations where the monitor features have ergonomic risk. The study conducted by Motamedzadeh, Jalali [48] also found an association between the chair and grand score after ergonomic intervention of office workers at a bank. Although Motamedzadeh, Jalali [48], results show that with the proper ergonomic intervention, it is possible to upgrade ergonomic characteristics of workstations and behaviours, as the ROSA section and Grand Score decreased after educational and/or physical intervention. Mianehsaz, Tabatabaei [17] also found that the majority of participants had a moderate risk level associated with the chair. This reinforced the idea that office workers must be instructed and sensibilized about the correct equipment set-up and about the postures they usually adopt. By providing information about the equipment setup and postures, avoiding extreme and awkward joint angles, such as asymmetric head and trunk posture, trunk unsupported or in lateral bending, neck extension, and legs and arms position, is possible to improve workers health.

Regarding office ergonomic behaviour and setup, different studies have found that ergonomic intervention in workplaces positively reduces risk factors. For example, in the study conducted by Motamedzadeh, Jalali [48], the results indicate that after workers received educational intervention or educational and physical intervention, the ROSA section scores lowered significantly as well as musculoskeletal symptoms, in which the group how received both educational and physical intervention had even less symptoms than the one who received only educational intervention. The study conducted by Alshehre, Pakkir Mohamed [126], tried to assess the differences between two groups, one who had ergonomic modifications made in the workstation and also received physical training (experimental group) and another that only had ergonomic modifications made in the workstation (control group), regarding the effectiveness of the introduction of physical exercise on different work parameters, with 4 and 8 months follow up. The results indicate that in both groups, that pain intensity and neck functional disability decreased in both groups after 4 and 8 months, but the experimental results of the experimental group were even lower than in the control. The article published by Akkarakittichoke, Waongenngarm [54] and Waongenngarm, van der Beek [66], that aimed to assess the effect of the promotion of rest breaks and postural shifts on new onset of neck and low-back pain during 6-month follow-up by placing a device in the seat pan. The results obtained show that active breaks and postural shifts during work hours can reduce the symptoms associated with neck and back pain. As so, it is possible to understand the advantages of ergonomic interventions in workplaces, such as basic body awareness (instructions to focus on sustaining proper posture, equilibrium, continuous breathing, heightened awareness, and reduced unnecessary muscle tension during the execution of each activity), neck training exercises (stretching and strengthening exercises and endurance training), workstation modifications (adjust chair, monitor and desk height, mouse and keyboard placement and sitting postures), as well as the promotion of more breaks, diminishing the time spend seated daily. It is well documented that ergonomic office conditions have been increasing since this job became more popular, so over the next few years, more ergonomic office analysis must be conducted to improve workers' health continually.

Regarding the results obtained for the present study, considering the angles registered by the Motion Capture System, it is possible to observe that participants had an asymmetric trunk posture. Although the values are similar to each other and might be related to a normal body deviation, except for the asymmetric postures, that, as expected, registered higher values of axial rotation and lateral flexion because in these postures (5, 6, 7 and 8) the trunk movement tends to shift away or rotate in relation to the vertical axis. All postures have asymmetric trunk posture because ISO considers that for a posture to be symmetric, there can neither exist axial rotation nor lateral flexion of the thorax with respect to the pelvis, which is not verified in this analysis and, therefore, can present ergonomic risk. As mentioned, the postures participants were instructed to perform gave them free movement of the head and arms, and in any of the postures, symmetric head posture was verified. This result is extremely important as most participants have already reported pain or discomfort symptoms in this body region, which means that the neck deviation from the vertical axis might be related to the reported symptoms. The chair in which the analysis was conducted did not have neck support, implicating a neck posture that is not recommended if the angle formed is smaller than 0. Based on this result, it is recommended that the chairs available in offices must have neck support to help workers. The results of the arms suggest that no awkward angles were performed, nor did the workers have ergonomic risk associated with the postures tested. Nonetheless, it is recommended that all workers have arm support. Through the ROSA analysis, it was possible to verify that participants have arm support, provided mainly by the table. Still, different participants needed to have the correct setup of the chair armrest, as this was too low. This reinforces the need for an ergonomic sensitisation of workers. Participants were instructed to maintain a 90 angle in relation to the knee angle, and the requirement was fulfilled visually. Examining the results makes it possible to observe that this requirement was not reached, as the angle value was smaller than expected. This can be related to the fact that when the participants place their feet in the group, although the angle seems to be at 90°, it is slightly smaller. It also could be influenced by the miscalibration of the Xsens feet sensors, which frequently misalign and did not record the correct values and could affect the shin position. The correct knee angle is defined in ISO as between 90° and 135°, but it is important to guarantee that there is no blood cut [52].

As it was referred, this study tries to close the gap between ergonomic assessment tools to evaluate office work, and the possibility to identify harmful behaviours of users in real time, respectively user seated position. Through the pressure map result analysis, it was possible to assume user position in terms of leg and lower trunk. The results obtained are identical to the study conducted by Pereira and Plácido da Silva [57] that used pressure sensors to predicted user position in terms of leg and lower trunk. In this study, posture number 1, 2, 4, 5, 6, 7 and 8 correspond to postures 1, 3, 2, 5, 6, 7 and 8 of the present dissertation, and by analysing the center of pressure allocation it is possible to observe body movement in the different postures. The center of pressure in this situation was near the back of the chair, and the difference might be related to the fact that only three pressure sensors were utilized instead of multiple sensors in the seat pan. In the present study, as expected, a connection was found between average pressure and contact area, as the contact area decreases as pressure increase. Postures, where symmetry was maintained had a similar average pressure registered between the back quadrants and between the front quadrants. In asymmetric postures, the average pressure was higher in one of the back quadrants over the other (depending on the side) and in one of the front quadrants over the other. As so, it was possible to presume seated asymmetry by analysing the results obtained. In the study conducted by Anwary, Cetinkaya [67] the goal was to assess postures with lateral trunk bending with sensors in the pan and the back of the chair and see how it would be registered by the sensors. As in the present study, when testing postures with a mild asymmetry (posture 5 and 6) the pressure is mainly being applied in the side to which user is leaning, and the more extreme the lateral bending angle is the more the pressure is going to be in that side.

The linear regression model applied is reliable in assessing the knee flexion angle through the front quadrants' contact area and the right upper arm external rotation through the centre of pressure Y coordinate in quadrant four. This model is valid for the ten postures tested and in the angle range measured. Accordingly, the model may not be valid if the user seated position is different from the one referred and if the angle range is different. Nonetheless, the postures tested comprise almost every posture adopted in offices, which means that almost every office seating position is covered in this analysis. Studies conducted by other authors using a pressure sensor show that it is possible to predict postures based on the pressure users apply on the seat pan. The research conducted by Tavares, Silva [56] demonstrates that by using pressure sensors placed on the seat and back of the chair, it is possible to predict six office seating postures with 100% confidence, considering the location of the sensors. The study conducted by Pereira and Plácido da Silva [57], Luna-Perejon, Montes-Sanchez [68], Jeong and Park [65], proved that using machine learning tools it is also possible to predict user seated postures with a high confidence and accuracy rate. This way, using different analysis methods makes it possible to assess user postures, although these methods require a considerable amount of input data and specific knowledge.

Considering the risk level classification of each posture, the results indicate that the postures tested, except posture 1, were considered not recommended and present ergonomic risk for workers. Posture 1 was classified as a risk-free position as prestigious institutions identify it as the correct posture to adopt [52]. All the other postures had one or more risk factors, which condemns them as not recommended. For instance, participants did not have proper back support in postures 2, 3, 4, 9 and 10. In one of the situations, there was no lumbar support; in the other, there was no upper back support; and in the others, there was no back support. Therefore, proper back support is extremely important and can be provided by an ergonomic chair that has appropriate lumbar support and helps to maintain a neutral spine position, reducing back pain or discomfort symptoms, preventing poor spinal alignment, minimising musculoskeletal risk factors [127]. Focusing on postures 5 and 6, the trunk had an asymmetric position, which goes against the principle of maintaining a neutral spine position and increases the risk of spinal muscular spasm and spinal imbalance [67]. In postures 7 and 8, the knee angle is lower than the acceptable angle range; therefore, the postures are also not recommended. This knee flexion is associated with the fact that the posterior part of the thigh is under pressure. The other thigh domed this posture, as the user can have a numb shin in minutes due to a blood circulation cut [128]. The analysis proved that it is possible to partially and fully identify user postures by analysing pressure maps, as it proved to be reliable in assessing leg and lower back positions. This way, it was possible to establish specific criteria that would only be verified if users performed one of the different postures. The use of a pressure mat in the seat pan proved insufficient in assessing postures with similar leg and lower back positions, as posture 1 was mistaken with posture 3, posture 2 with posture 4, and vice versa. Hence, to assess the postures with higher precision, in addition to the sensors in the seat, there also should be sensors in the back. An interesting sensor solution is distance sensors, as they can estimate the distance between the user's back and chair back support, incorporating the range of values presented in ISO for trunk and head inclination with the MHT for each angle [56]. This was also raised by Pereira and Plácido da Silva [57] and Luna-Perejon, Montes-Sanchez [68].

7 CONCLUSION AND PROSPECTS

In the present chapter, final inferences and the prospects for the research conducted will be presented.

7.1 Conclusion

In conclusion, this master's thesis has undertaken a comprehensive exploration into the integration of pressure-based assessments in evaluating sitting postures, aiming to provide valuable insights into the dynamic interplay between body pressure distribution and musculoskeletal health. The research objectives set out to address the limitations of traditional ergonomic assessments and contribute to advancing user-centric interventions and designs for sitting environments.

The research successfully demonstrated the effectiveness in capturing real-time pressure during various sitting postures. Through rigorous investigation, the research has identified sitting postures based on pressure metrics. It proves that the analysis of pressure patterns applied in the seat of the chair is reliable in identifying leg and trunk position. These findings contribute to a nuanced understanding of pressure distribution maps in relation to postures, and posture in relation to MSDs. By understanding user posture and the ergonomic risk associate to those postures it is possible to formulate an action plan bearing in mind the prevention of WRMSDs. This way, the identification of bad office behaviours, such as posture and prolonged sitting, it is achievable using pressure sensors. This contributes valuable insights to the broader field of ergonomics, shedding light on the specific pressure dynamics associated with awkward sitting postures.

In summary, this master's thesis has made notable progress in propelling the ergonomic assessment field forward by introducing a pressure-based approach to assess sitting postures. The discoveries and suggestions outlined here provide a foundation for subsequent research and pragmatic implementations focused on enhancing the welfare of individuals who enrol in office work. As our comprehension of pressure dynamics and their effects undergoes further refinement, there is considerable potential for inventive and precise interventions to play a transformative role in redesigning sitting environments for improved comfort and well-being.

7.2 Prospects

Considering the research developed in the present study, it would be interesting to incorporate more individuals or collect a higher volume of data for each participant. It would be interesting to do the analysis with a pressure sensor placed in the seat and a distance sensor in the back and see if the identification of posture with similar leg and lower back posture would be easier. The possibility of applying nonlinear modelling analysis tools should be considered in trying to assess the validity of the system for predicting the postures using a specific algorithm. If this possibility presents as possible, the system developed can be applied in a real office chair, and ergonomic risk factors can be addressed. The possibility of analysing the time spend seated should also be considered, to try to evaluate postural shifts and sedentary behaviour of workers. In order to allow a proper workstation setup, it will also be interesting to use participant anthropometric information to allow a personalize setup of the work elements to the user.

8 LIMITATIONS

Using the protocol defined in the present study it is possible to predict user posture considering the pressure applied in the seat pan and understand data collection and data treatment methods. Even so, the present study presented limitations.

As so, the sample population was composed by a relatively small number of individuals, which can compromise the representativity of the data obtained, that none the less proved to be promising in posture classification tools. In the ROSA checklist a chair value often represented a high Grand score and as the phone was not used, the overall results might be influenced. The model chosen to analyse the relation between the dependent and independent variables proved to be inappropriate, and other models should be tested. The lack of sensors in the chair back complicated the identification of identical postures, considering lower back and leg position in the chair.

9 BIBLIOGRAPHY

1. Cardoso, M.R., A.K. Cardenas, and W.J. Albert, *A biomechanical analysis of active vs static office chair designs.* Applied Ergonomics, 2021. **96**.

2. Mistarihi, M.Z., A.A. Al-Omari, and A.F. Al-Dwairi *Designing and Simulation Assessment of a Chair Attachment Air Blowing Methods to Enhance the Safety of Prolonged Sitting*. Biomimetics, 2023. **8**, DOI: 10.3390/biomimetics8020194.

3. Kar, G. and A. Hedge, *Effect of workstation configuration on musculoskeletal discomfort, productivity, postural risks, and perceived fatigue in a sit-stand-walk intervention for computer-based work.* Applied Ergonomics, 2021. **90**.

4. Shahwan, B.S., M. D'Emeh W, and M.I. Yacoub, *Evaluation of computer workstations ergonomics and its relationship with reported musculoskeletal and visual symptoms among university employees in Jordan.* Int J Occup Med Environ Health, 2022. **35**(2): p. 141-156.

5. Fewster, K.M., G. Mayberry, and J.P. Callaghan, *Office Chair Backrest Height Affects Physiological Responses to Sitting.* Iise Transactions on Occupational Ergonomics & Human Factors, 2020. **8**(1): p. 50-59.

6. Clemes, S.A., S.E. O'Connell, and C.L. Edwardson, *Office workers' objectively measured sedentary behavior and physical activity during and outside working hours.* J Occup Environ Med, 2014. **56**(3): p. 298-303.

7. Tremblay, M.S., et al., *Sedentary Behavior Research Network (SBRN) – Terminology Consensus Project process and outcome.* International Journal of Behavioral Nutrition and Physical Activity, 2017. **14**(1): p. 75.

8. O'Donoghue, G., et al., *A systematic review of correlates of sedentary behaviour in adults aged 18-65 years: a socio-ecological approach.* BMC Public Health, 2016. **16**: p. 163.

9. Parry, S. and L. Straker, *The contribution of office work to sedentary behaviour associated risk.* BMC Public Health, 2013. **13**(1): p. 296.

10. Clemes, S.A., S.E. O'Connell, and C.L. Edwardson, *Office Workers' Objectively Measured Sedentary Behavior and Physical Activity During and Outside Working Hours.* Journal of Occupational and Environmental Medicine, 2014. **56**(3): p. 298-303.

11. Morton, S., et al., *What works to reduce sedentary behavior in the office, and could these intervention components transfer to the home working environment?: A rapid review and transferability appraisal.* Front Sports Act Living, 2022. **4**: p. 954639.

12. Shahwan, B.S., W.M. D'Emeh, and M.I. Yacoub, *EVALUATION OF COMPUTER WORKSTATIONS ERGONOMICS AND ITS RELATIONSHIP WITH REPORTED MUSCULOSKELETAL AND VISUAL SYMPTOMS AMONG UNIVERSITY EMPLOYEES IN JORDAN.* International Journal of Occupational Medicine and Environmental Health, 2022. **35**(2): p. 141-156.

13. Ozdemir, F. and S. Toy, *Evaluation of scapular dyskinesis and ergonomic risk level in office workers.* International Journal of Occupational Safety and Ergonomics, 2021. **27**(4): p. 1193-1198.

14. National Academies of Sciences, E., et al., in *Selected Health Conditions and Likelihood of Improvement with Treatment*. 2020, National Academies Press (US)

Copyright 2020 by the National Academy of Sciences. All rights reserved.: Washington (DC).

15. Organization, W.H. *Musculoskeletal health*. 2022; Available from: https://www.who.int/news-room/fact-sheets/detail/musculoskeletal-conditions.

16. Chowdhury, N., F. Aghazadeh, and M. Amini, *Ergonomic assessment of working postures for the design of university computer workstations.* Occupational Ergonomics, 2018. **13**(S1): p. S37-S46.

17. Mianehsaz, E., et al., *Evaluating Musculoskeletal Disorders and Their Ergonomic Risk Factors among Office Workers of a Large Public Hospital in Iran.* International Archives of Health Sciences, 2022. **9**(1): p. 35-40.

18. Okezue, O.C., et al., *Work-Related Musculoskeletal Disorders among Office Workers in Higher Education Institutions: A Cross-Sectional Study.* Ethiopian journal of health sciences, 2020. **30**(5): p. 715-724.

19. Kwon, Y.J., et al., *A Work-Related Musculoskeletal Disorders (WMSDs) Risk-Assessment System Using a Single-View Pose Estimation Model.* Int J Environ Res Public Health, 2022. **19**(16).

20. Chandra, A., et al., *Ergonomics in the Office Environment: A Review*. 2009.

21. O'Neill, M., *Holistic ergonomics for the evolving nature of work.* Topic Brief, 2011: p. 1-8.

22. Koningsveld, E., *History of the International Ergonomics Association*, ed. I. Press. 2019.

23. Organization, W.H., *Introduction to Ergonomics*. 1972.

24. Adler, M.H., *The Writing Machine: A History of the Typewriter*. 1973.

25. Anton, K., *History of the Office*. 2015.

26. Björkman, T., *The rationalisation movement in perspective and some ergonomic implications.* Applied Ergonomics, 1996. **27**(2): p. 111-117.

27. Sznelwar, L.I., et al., *Ergonomics and Work Organization: The Relationship Between Tayloristic Design and Workers' Health in Banks and Credit Cards Companies.* International Journal of Occupational Safety and Ergonomics, 1999. **5**(2): p. 291-301.

28. Edwards, R.J., *"Machines and People" - The evolution of industrial ergonomics in the midtwentieth century*. 2017, University of Manchester.

29. Abrahão, J.I., et al., *Introdução à ergonomia: da prática à teoria.* 2009.

30. Safety, E.o.O.H. *The Nature and Aims of Ergonomics*. 2011 [cited 2023; Available from: https://www.iloencyclopaedia.org/part-iv-66769/ergonomics-52353/goals-principles-and-methods-91538/item/478-the-nature-and-aims-of-ergonomics.

31. Hevner, A.R. and D.J. Berndt, *Eras of business computing*, in *Advances in Computers*, M.V. Zelkowitz, Editor. 2000, Elsevier. p. 1-90.

32. Parsons, K.C., B. Shackel, and B. Metz, *Ergonomics and international standards: History, organizational structure and method of development.* Applied Ergonomics, 1995. **26**(4): p. 249-258.

33. Madhwani, K.P. and P.K. Nag, *Effective Office Ergonomics Awareness: Experiences from Global Corporates.* Indian J Occup Environ Med, 2017. **21**(2): p. 77-83.

34. Zerguine, H., et al., *Online office ergonomics training programs: A scoping review examining design and user-related outcomes.* Safety Science, 2023. **158**: p. 106000.

35. McKeown, C.l., *Office ergonomics and human factors : practical applications*. Second edition. ed. 2019, Boca Raton: Taylor & Francis. pages cm.

36. Martin, C. and D.M. Andrew-Tuthill, *Office ergonomics: Measurements for success.* AAOHN Journal, 1999. **47**(10): p. 479-493.

37. McKeown, C., *Ergonomics in Action.* 2016.

38. Punnett, L., U.O.V. Bergqvist, and Arbetslivsinstitutet, *Visual display unit work and upper extremity musculoskeletal disorders : a review of epidemiological findings*. National Institute for Working Life, Ergonomic Expert Committee Document no.1. 1997, Solna: Arbetslivsinstitutet. 161p. : ill.

39. Gerr, F., C.P. Monteilh, and M. Marcus, *Keyboard use and musculoskeletal outcomes among computer users.* J Occup Rehabil, 2006. **16**(3): p. 265-77.

40. van Vledder, N. and Q. Louw, *The effect of a workstation chair and computer screen height adjustment on neck and upper back musculoskeletal pain and sitting comfort in office workers.* S Afr J Physiother, 2015. **71**(1): p. 279.

41. *ISO 9241-3:1992: Ergonomic requirements for office work with visual display terminals (VDTs). Part 3. Visual display requirements*. 1993, London: BSI.

42. Psihogios, J.P., et al., *A field evaluation of monitor placement effects in VDT users.* Applied Ergonomics, 2001. **32**(4): p. 313-325.

43. OSHA, *Easy Ergonomics for Desktop Computer Users*. 2022.

44. Waersted, M., T.N. Hanvold, and K.B. Veiersted, *Computer work and musculoskeletal disorders of the neck and upper extremity: a systematic review.* BMC Musculoskelet Disord, 2010. **11**: p. 79.

45. Tahernejad, S., et al., *Recommended maximum holding time of common static sitting postures of office workers.* International Journal of Occupational Safety and Ergonomics, 2023. **29**(2): p. 847-854.

46. Peereboom;, K., N.d. Langen;, and A. Bortkiewicz, *Prolonged static sitting at work*, in *Health effects and good practice advice*, S. Copsey, Editor. 2021, EU-OSHA: Luxembourg: Publications Office of the European Union.

47. Singh, H. and L.P. Singh, *Musculoskeletal disorders among insurance office employees: A case study.* Work, 2019. **64**(1): p. 153-160.

48. Motamedzadeh, M., et al., *Ergonomic risk factors and musculoskeletal disorders in bank staff: an interventional follow-up study in Iran.* Journal of the Egyptian Public Health Association, 2021. **96**(1).

49. Mohammadipour, F., et al., *Work-related Musculoskeletal Disorders in Iranian Office Workers: Prevalence and Risk Factors.* Journal of medicine and life, 2018. **11**(4): p. 328-333.

50. Mohan, V., et al., *Prevalence of complaints of arm, neck, and shoulders among computer professionals in Bangalore: A cross-sectional study.* J Family Med Prim Care, 2019. **8**(1): p. 171-177.

51. Iram, H., et al., *Ergonomic risk factors among computer office workers for complaints of arm, neck and shoulder and workstation evaluation.* Work, 2022. **73**(1): p. 321-326.

52. *ISO 11226:2000: Ergonomics — Evaluation of static working postures*. 2000.

53. Redivo, V.S. and B. Olivier, *Time to re-think our strategy with musculoskeletal disorders and workstation ergonomics.* South African Journal of Physiotherapy, 2021. **77**(1).

54. Akkarakittichoke, N., P. Waongenngarm, and P. Janwantanakul, *The effects of active break and postural shift interventions on recovery from and recurrence of neck and low back*

pain in office workers: A 3-arm cluster-randomized controlled trial. Musculoskeletal Science and Practice, 2021. **56**.

55. Shamseer, L., et al., *Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation.* BMJ : British Medical Journal, 2015. **349**: p. g7647.

56. Tavares, C., et al., *Smart Office Chair for Working Conditions Optimization.* IEEE Access, 2023. **11**: p. 50497-50509.

57. Pereira, L. and H. Plácido da Silva, *A Novel Smart Chair System for Posture Classification and Invisible ECG Monitoring.* Sensors, 2023. **23**(2).

58. Holzgreve, F., et al., *Home office versus ergonomic workstation - is the ergonomic risk increased when working at the dining table? An inertial motion capture based pilot study.* BMC Musculoskeletal Disorders, 2022. **23**(1).

59. Tahernejad, S., et al., *Investigation of office workers' sitting behaviors in an ergonomically adjusted workstation.* International Journal of Occupational Safety and Ergonomics, 2022. **28**(4): p. 2346-2354.

60. Graf, M., U. Guggenbühl, and H. Krueger, *An assessment of seated activity and postures at five workplaces.* International Journal of Industrial Ergonomics, 1995. **15**(2): p. 81-90.

61. Ordean, M.N., et al., *Analysis of Available Solutions for the Improvement of Body Posture in Chairs.* Applied Sciences (Switzerland), 2022. **12**(13).

62. Tavares, C., et al., *Instrumented Office Chair With Low-Cost Plastic Optical Fiber Sensors for Posture Control and Work Conditions Optimization.* IEEE Access, 2022. **10**: p. 69063-69071.

63. Arippa, F., et al., *Postural strategies among office workers during a prolonged sitting bout.* Applied Ergonomics, 2022. **102**.

64. Naumova, K.A., et al., *AN ORTHOPEDIC CHAIR WITH THE ACTIVE SITTING FUNCTION (A PROSPECTIVE PROJECT).* Human Sport Medicine, 2022. **22**: p. 85-90.

65. Jeong, H. and W. Park, *Developing and Evaluating a Mixed Sensor Smart Chair System for Real-Time Posture Classification: Combining Pressure and Distance Sensors.* IEEE Journal of Biomedical and Health Informatics, 2021. **25**(5): p. 1805-1813.

66. Waongenngarm, P., et al., *Effects of an active break and postural shift intervention on preventing neck and low-back pain among high-risk office workers: A 3-arm cluster-randomized controlled trial.* Scandinavian Journal of Work, Environment and Health, 2021. **47**(4): p. 306-317.

67. Anwary, A.R., et al., *Smart-Cover: A real time sitting posture monitoring system.* Sensors and Actuators, A: Physical, 2021. **317**.

68. Luna-Perejon, F., et al., *IoT Device for Sitting Posture Classification Using Artificial Neural Networks.* Electronics, 2021. **10**(15).

69. Waongenngarm, P., et al., *Perceived musculoskeletal discomfort and its association with postural shifts during 4-h prolonged sitting in office workers.* Applied Ergonomics, 2020. **89**.

70. Jun, D., et al., *Are Measures of Postural Behavior Using Motion Sensors in Seated Office Workers Reliable?* Hum Factors, 2019. **61**(7): p. 1141-1161.

71. Depreli, Ö. and E. Angin, *Review of scapular movement disorders among office workers having ergonomic risk.* Journal of Back and Musculoskeletal Rehabilitation, 2018. **31**(2): p. 371-380.

72. Rhén, I.-M., *Ergonomics risk assessment methods for creating healthy work environments*. 2023, KTH Royal Institute of Technology. p. 121.

73. EU-OSHA, *Musculoskeletal disorders: association with psychosocial risk factors at work - Literature review*. 2021.

74. Burdorf, A. and A. van der Beek, *Exposure assessment strategies for work-related risk factors for musculoskeletal disorders.* Scand J Work Environ Health, 1999. **25 Suppl 4**: p. 25-30.

75. Kuorinka, I. and L. Patry, *Participation as a means of promoting occupational health.* International Journal of Industrial Ergonomics, 1995. **15**(5): p. 365-370.

76. David, G.C., *Ergonomic methods for assessing exposure to risk factors for work-related musculoskeletal disorders.* Occup Med (Lond), 2005. **55**(3): p. 190-9.

77. *Lei nº 7/2009, de 12 de fevereiro*. 2009.

78. *Lei n.º 102/2009, de 10 de Setembro*. 2009.

79. *Decreto-Lei n.º 243/86, de 20 de agosto*. 1986.

80. *Decreto-Lei n.º 347/93, de 1 de outubro*. 1993.

81. *Lei n.º 113/99, de 3 de agosto*. 1999.

82. *Portaria n.º 987/93, de 6 de outubro*. 1993.

83. *Decreto-Lei n.º 50/2005, de 25 de fevereiro*. 2005.

84. *Decreto-Lei n.º 349/93, de 1 de outubro*. 1993.

85. *Portaria n.º 989/93, de 6 de outubro*. 1993.

86. Eppes, S., *Washington State Ergonomics Tool*. 2004.

87. CUErgo. *Cornell University Ergonomics Web*. 2023; Available from: https://ergo.human.cornell.edu/.

88. Executive, H.a.S., *Display screen equipment (DSE) workstation checklist.* 2023.

89. Kuorinka, I., et al., *Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms.* Appl Ergon, 1987. **18**(3): p. 233-7.

90. Hedge, A., S. Morimoto, and D. McCrobie, *Effects of keyboard tray geometry on upper body posture and comfort.* Ergonomics, 1999. **42**(10): p. 1333-49.

91. Borg, G.A., *Psychophysical bases of perceived exertion.* Med Sci Sports Exerc, 1982. **14**(5): p. 377-81.

92. Hignett, S. and L. McAtamney, *Rapid entire body assessment (REBA).* Appl Ergon, 2000. **31**(2): p. 201-5.

93. McAtamney, L. and E. Nigel Corlett, *RULA: a survey method for the investigation of work-related upper limb disorders.* Appl Ergon, 1993. **24**(2): p. 91-9.

94. Sonne, M., D.L. Villalta, and D.M. Andrews, *Development and evaluation of an office ergonomic risk checklist: ROSA--rapid office strain assessment.* Appl Ergon, 2012. **43**(1): p. 98-108.

95. Moore, J.S. and A. Garg, *The Strain Index: a proposed method to analyze jobs for risk of distal upper extremity disorders.* Am Ind Hyg Assoc J, 1995. **56**(5): p. 443-58.

96. Rhén, I.M. and M. Forsman, *Inter- and intra-rater reliability of the OCRA checklist method in video-recorded manual work tasks.* Appl Ergon, 2020. **84**: p. 103025.

97. Colombini, D., *An observational method for classifying exposure to repetitive movements of the upper limbs.* Ergonomics, 1998. **41**(9): p. 1261-89.

98. Iriondo Pascual, A., et al., *Implementation of Ergonomics Evaluation Methods in a Multi-Objective Optimization Framework.* Proceedings of the 6th International Digital Human Modeling Symposium (Dhm2020), 2020. **11**: p. 361-371.

99. Dempsey, P.G., R.W. McGorry, and W.S. Maynard, *A survey of tools and methods used by certified professional ergonomists.* Applied Ergonomics, 2005. **36**(4): p. 489-503.

100. Lee, W., et al., *Methods for measuring physical workload among commercial cleaners: A scoping review.* International Journal of Industrial Ergonomics, 2022. **90**: p. 103319.

101. Van Der Beek, A.J. and M.H. Frings-Dresen, *Assessment of mechanical exposure in ergonomic epidemiology.* Occupational and Environmental Medicine, 1998. **55**(5): p. 291-299.

102. Casadei, K. and J. Kiel, *Anthropometric Measurement*, in *StatPearls*. 2023, StatPearls Publishing

Copyright © 2023, StatPearls Publishing LLC.: Treasure Island (FL) ineligible companies. Disclosure: John Kiel declares no relevant financial relationships with ineligible companies.

103. Karwowski, W. and W.S. Marras, *The occupational ergonomics handbook*. 1998: Crc Press.

104. Romano, E., et al., *The use of pressure mapping to assess the comfort of agricultural machinery seats.* International Journal of Industrial Ergonomics, 2020. **77**: p. 102835.

105. Salisu, S., et al., *Motion Capture Technologies for Ergonomics: A Systematic Literature Review.* Diagnostics (Basel), 2023. **13**(15).

106. Maurya, C.M., S. Karmakar, and A.K. Das, *Digital human modeling (DHM) for improving work environment for specially-abled and elderly.* SN Applied Sciences, 2019. **1**(11).

107. Ji, X., et al., *Using Digital Human Modelling to Evaluate the Risk of Musculoskeletal Injury for Workers in the Healthcare Industry.* Sensors, 2023. **23**(5): p. 2781.

108. Paul, G., X. Wang, and J. Yang, *An Introduction to the Special Issue on Digital Human Modeling (DHM) in Ergonomics 4.0.* IISE Transactions on Occupational Ergonomics and Human Factors, 2021. **9**(3-4): p. 107-110.

109. Schall, M.C., Jr., N.B. Fethke, and V. Roemig, *Digital Human Modeling in the Occupational Safety and Health Process: An Application in Manufacturing.* IISE Trans Occup Ergon Hum Factors, 2018. **6**(2): p. 64-75.

110. Mesquita, C.C., J.C. Ribeiro, and P. Moreira, *Portuguese version of the standardized Nordic musculoskeletal questionnaire: cross cultural and reliability.* Journal of Public Health, 2010. **18**(5): p. 461-466.

111. *NPR 2739:1995, Human physical load — Characteristics and measuring methods*. 1995: Delft, The Netherlands.

112. Bennett, T., P. Kumar, and V.R. Garate, *A Machine Learning Model for Predicting Sit-to-Stand Trajectories of People with and without Stroke: Towards Adaptive Robotic Assistance.* Sensors, 2022. **22**(13): p. 4789.

113. Khamis, N.K., et al., *Pattern of Pressure Distribution on the Car Seat Under Static Condition and Its Relationship with Driving Posture.* International Journal of Innovative Technology and Exploring Engineering, 2019.

114. Benjaminse, A., et al. *A VALIDITY STUDY COMPARING XSENS WITH VICON*. 2020.

115. Schepers, M., M. Giuberti, and G. Bellusci, *Xsens MVN: Consistent Tracking of Human Motion Using Inertial Sensing*. 2018.

116. Kim, S. and M.A. Nussbaum, *Performance evaluation of a wearable inertial motion capture system for capturing physical exposures during manual material handling tasks.* Ergonomics, 2013. **56**(2): p. 314-326.

117. Bandouch, J., F. Engstler, and M. Beetz, *Accurate Human Motion Capture Using an Ergonomics-Based Anthropometric Human Model*. Springer Berlin Heidelberg. p. 248-258.

118. Huang, C., et al., *Development and Validation of a Wearable Inertial Sensors-Based Automated System for Assessing Work-Related Musculoskeletal Disorders in the Workspace.* Int J Environ Res Public Health, 2020. **17**(17).

119. PHA, *MVN User Manual*. 2021.

120. Martínez-Estrada, M., et al., *A Smart Chair to Monitor Sitting Posture by Capacitive Textile Sensors.* Materials, 2023. **16**(13): p. 4838.

121. Lu, C., et al., *Hole Matrix Mapping Model for Partitioned Sitting Surface Based on Human Body Pressure Distribution Matrix.* Healthcare, 2023. **11**(6): p. 895.

122. Hudák, R., V. Rajťúková, and J. Živčák, *Automatization of Contact Pressure Measurement between Trunk Orthosis and Patient's Body Using a Matrix Tactile Sensor.* Acta Mechanica et Automatica, 2015. **9**(1): p. 38-43.

123. Zhou, G., M.-L. Lu, and D. Yu, *Investigating gripping force during lifting tasks using a pressure sensing glove system.* Applied Ergonomics, 2023. **107**: p. 103917.

124. Maksimović, N., et al., *Challenging Ergonomics Risks with Smart Wearable Extension Sensors.* Electronics, 2022. **11**(20): p. 3395.

125. Organization, W.H., *WHO guidelines on physical activity and sedentary behaviour*. 2020.

126. Alshehre, Y.M., et al., *Effectiveness of Physical Exercise on Pain, Disability, Job Stress, and Quality of Life in Office Workers with Chronic Non-Specific Neck Pain: A Randomized Controlled Trial.* Healthcare (Basel), 2023. **11**(16).

127. Wang, X., et al., *The effects of using a footrest during computer tasks varying in complexity and temporal demands: A postural and electromyographic analysis.* Applied Ergonomics, 2022. **98**: p. 103550.

128. Adiyaman, A., et al., *The effect of crossing legs on blood pressure.* Blood Press Monit, 2007. **12**(3): p. 189-93.

APENDICES

APENDIX I

Table 1 – Resume of research results considering the inclusion criteria.

Keyword Combination	Research Data base	Keywords	Date	Document	Source	Language	On Topic
1	SCOPUS	29	16	11	11	11	5
2	SCOPUS	28	11	9	9	9	1
3	SCOPUS	13	4	4	4	4	2
4	SCOPUS	192	56	39	39	38	4
5	SCOPUS	111	26	19	19	19	4
6	SCOPUS	66	24	15	15	15	7
7	SCOPUS	65	42	30	29	28	4
1	Web of Science	21	15	11	11	11	5
2	Web of Science	15	3	3	3	3	0
3	Web of Science	3	1	1	1	1	0
4	Web of Science	498	178	127	127	122	4
5	Web of Science	214	76	53	53	52	4
6	Web of Science	202	79	75	75	75	9
7	Web of Science	54	37	31	31	31	3

Table 2 – Body Angles value considering the postures tested, in degree (º).

Body Region	Posture									
	1	2	3	4	5	6	7	8	9	10
Trunk										
Axial Rotation	0,99	0,75	0,18	-0,02	-2,38	3,43	1,15	1,09	0,52	0,99
Lateral Flexion	0,40	-1,34	0,95	0,41	-2,03	0,18	-6,54	4,54	0,25	0,58
Inclination	-3,99	-11,53	15,07	19,20	2,04	2,79	-0,92	-3,91	16,46	16,38
Convex Lumbar Spine	25,60	25,48	30,47	25,20	23,24	24,96	25,62	25,70	23,12	25,51
Head										
Axial Rotation	5,50	1,58	2,39	-0,34	10,69	-4,59	5,60	1,89	3,19	4,76
Lateral Flexion	13,97	18,92	1,54	-3,75	7,82	11,36	10,24	14,94	2,81	1,46
Inclination	-0,22	0,36	-1,14	-2,05	-6,95	6,96	-0,22	0,35	-1,46	-1,85
Neck										
Flexion / Extension	-3,51	-0,25	-11,46	-14,75	-7,23	-5,03	-5,93	-2,77	-10,73	-11,59
Upper Arm										
Left External Rotation	8,78	8,97	15,24	18,96	12,73	19,71	11,91	15,53	16,42	17,32
Right External Rotation	15,99	20,29	17,43	18,41	21,32	15,82	21,36	16,74	24,77	24,53
Left Retroflexion / Adduction	21,75	21,11	29,64	35,01	17,82	23,80	26,23	24,68	28,64	31,16
Right Retroflexion / Adduction	26,38	24,77	29,82	29,25	20,90	16,66	23,59	23,28	30,34	29,14
Left Elevation	6,22	10,77	10,55	11,59	4,33	6,76	10,34	9,11	7,82	7,99
Right Elevation	13,04	12,34	18,31	17,71	6,83	5,40	6,34	12,93	13,02	13,24
Elbow										
Left Flexion	49,13	48,65	62,51	74,50	54,49	63,35	51,23	55,72	67,68	71,14
Right Flexion	45,47	43,84	64,64	65,68	64,58	57,01	55,08	60,69	67,19	69,97
Forearm										
Left Pronation / Supination	9,87	6,43	17,05	15,75	4,28	15,83	-2,49	1,45	7,16	5,17
Right Pronation / Supination	3,95	-1,21	1,76	-2,88	18,85	1,99	-1,25	-0,89	5,58	9,33
Wrist										
Left Flexion / Extension	-24,97	-20,01	-22,57	-19,47	-15,96	-23,70	-8,58	-9,29	-25,64	-20,09
Right Flexion / Extension	-22,61	-22,11	-17,81	-20,25	-10,39	-12,47	-6,77	-3,17	-16,59	-13,87
Left Ulnar / Radial Deviation	11,25	12,64	14,18	20,63	21,63	5,58	10,95	9,87	19,14	12,04
Right Ulnar / Radial Deviation	18,53	13,42	15,87	19,82	-4,23	16,40	15,10	11,93	15,17	13,36
Knee										
Left Flexion	74,66	73,47	70,54	71,41	71,19	73,52	67,87	58,02	73,14	75,98
Right Flexion	74,19	73,04	68,86	71,90	74,08	68,95	56,45	69,57	73,94	76,36

Table 3 – Shapiro-Wilk normality test results.

Variable	Statistic	df	Sig.
Sex	0,637	20	<,001
Age	0,661	20	<,001
Height	0,956	20	0,475
Weight	0,942	20	0,257
Education Level	0,659	20	<,001
Job Experience	0,897	20	0,036
Time Spend Seated	0,744	20	<,001
Chair Perceived Discomfort	0,495	20	<,001
MSDs	0,544	20	<,001
Exercise Hours/Week	0,865	20	0,01
Neck (7 months)	0,58	20	<,001
Right shoulder (7 months)	0,433	20	<,001
Both shoulders (7 months)	0,495	20	<,001
Left elbow (7 months)	0,236	20	<,001
Right wrist/hand (7 months)	0,433	20	<,001
Thoracic region (7 months)	0,351	20	<,001
Lumbar region (7 months)	0,58	20	<,001
Hips/Thighs (7 months)	0,433	20	<,001
Knees (7 months)	0,351	20	<,001
Ankle/Feet (7 months)	0,433	20	<,001
Neck (12 months)	0,641	20	<,001
Right shoulder (12 months)	0,351	20	<,001
Both shoulders (12 months)	0,433	20	<,001
Right wrist/hand (12 months)	0,236	20	<,001
Thoracic region (12 months)	0,351	20	<,001
Lumbar region (12 months)	0,58	20	<,001
Hips/Thighs (12 months)	0,236	20	<,001
Knees (12 months)	0,351	20	<,001
Ankle/Feet (12 months)	0,236	20	<,001
Average Contact Area	0,799	10	0,014
Coordinate X	0,73	10	0,002
Coordinate Y	0,699	10	<,001
Average Pressure Q1	0,827	10	0,031
Average Contact Area Q2	0,794	10	0,012
Average Contact Area Q3	0,702	10	<,001
Average Contact Area Q4	0,743	10	0,003
Coordinate Y Q1	0,366	10	<,001
Coordinate Y Q2	0,717	10	0,001
Coordinate X Q2	0,658	10	<,001
Coordinate X Q3	0,802	10	0,015
Coordinate Y Q3	0,77	10	0,006
Coordinate X Q4	0,751	10	0,004
Coordinate Y Q4	0,784	10	0,009
Trunk Lateral Flexion	0,758	10	0,004
Trunk Convex Lumbar Spine	0,747	10	0,003
Forearm Right Pronation / Supination	0,844	10	0,049
Wrist Right Ulnar / Radial Deviation	0,713	10	0,001
Knee Left Flexion	0,782	10	0,009
Knee Right Flexion	0,778	10	0,008
ROSA Method	0,872	10	0,106
Average Pressure	0,879	10	0,127
Average Pressure Q2	0,875	10	0,113
Average Pressure Q3	0,881	10	0,134
Average Pressure Q4	0,849	10	0,056
Average Contact Area Q1	0,91	10	0,284
Coordinate X Q1	0,896	10	0,198
Trunk Axial Rotation	0,867	10	0,092

Variable	Statistic	df	Sig.
Sex	0,637	20	<,001
Trunk Inclination	0,901	10	0,226
Head Axial Rotation	0,967	10	0,858
Head Lateral Flexion	0,963	10	0,823
Head Inclination	0,853	10	0,064
Upper Arm Left External Rotation	0,937	10	0,523
Upper Arm Right External Rotation	0,908	10	0,267
Upper Arm Left Retroflexion / Adduction	0,989	10	0,995
Upper Arm Right Retroflexion / Adduction	0,919	10	0,349
Upper Arm Left Elevation	0,952	10	0,694
Upper Arm Right Elevation	0,887	10	0,156
Elbow Left Flexion	0,928	10	0,427
Elbow Right Flexion	0,893	10	0,183
Forearm Left Pronation / Supination	0,939	10	0,542
Wrist Left Flexion / Extension	0,877	10	0,121
Wrist Right Flexion / Extension	0,954	10	0,716
Wrist Left Ulnar / Radial Deviation	0,928	10	0,433

Table 4 - Correlation Matrix between the questionnaire variables.

Variable	Age	Job Experience	Time Spend Seated	Chair Perceived Discomfort	MSDs	Exercise Hours/Week
Age	1,000	,807**	0,185	0,033	-0,101	-,590**
Height	-,446*	-,458*	-,473*	0,022	0,201	0,388
Weight	-0,102	-0,119	-0,103	-0,109	0,070	-0,167
Job Experience	,807**	1,000	0,189	-,466*	0,144	-,603**
Time Spend Seated	0,185	0,189	1,000	-0,111	-0,034	-0,164
Chair Perceived Discomfort	0,033	-,466*	-0,111	1,000	-0,289	0,188
MSDs	-0,101	0,144	-0,034	-0,289	1,000	0,000
Exercise Hours/Week	-,590**	-,603**	-0,164	0,188	0,000	1,000
Neck (7 months)	-0,219	-0,116	-0,032	0,055	-0,126	0,041
Right shoulder (7 months)	,551*	,497*	-0,028	-0,210	0,243	-0,356
Both shoulders (7 months)	-0,218	-0,277	,592**	0,063	-0,289	0,376
Left elbow (7 months)	0,341	0,367	0,272	-0,115	0,132	-0,345
Right wrist/hand (7 months)	-0,110	-,447*	-0,028	,490*	-0,081	0,356
Thoracic region (7 months)	0,058	0,044	0,395	-0,167	0,192	-0,110
Lumbar region (7 months)	-0,343	-0,436	-0,366	0,327	-0,378	,524*
Hips/Thighs (7 months)	-0,061	-0,025	0,235	0,140	-0,081	0,264
Knees (7 months)	0,248	-0,059	0,082	0,250	-0,192	0,125
Ankle/Feet (7 months)	0,024	0,087	-0,028	-0,210	-0,081	-0,013
Neck (12 months)	0,009	0,044	0,247	0,000	0,115	-0,179
Right shoulder (12 months)	0,437	0,429	0,082	-0,167	0,192	-0,361
Both shoulders (12 months)	-0,135	-0,236	,498*	0,140	-0,081	,474*
Right wrist/hand (12 months)	0,160	-0,122	-0,159	,459*	0,132	-0,086
Thoracic region (12 months)	0,058	0,044	0,395	-0,167	0,192	-0,110
Lumbar region (12 months)	-0,086	-0,368	-0,043	0,218	-0,378	0,359
Hips/Thighs (12 months)	0,040	-0,305	0,272	,459*	-0,397	0,259
Knees (12 months)	0,248	-0,059	0,082	0,250	-0,192	0,125
Ankle/Feet (12 months)	0,261	0,224	-0,159	-0,115	-0,397	-0,345

* Significance level α= 0,01

** Significance level α=

Table 5 – Correlation Matrix between the pressure mat and the Xsens results.

Variable	$\bar{P}$	$A_{contact}$	CP_x	CP_y	$\bar{P}_Q$ 1	$\bar{P}_Q$ 2	$\bar{P}_Q$ 3	$\bar{P}_Q$ 4	$A_{contactQ}$ 1	$A_{contactQ}$ 2	$A_{contactQ}$ 3	$A_{contactQ}$ 4	CP_X1	CP_Y1	CP_X2	CP_Y2	CP_X3	CP_Y3	CP_X4	CP_Y4
Trunk Axial Rotation	0,243	-0,261	-0,551	0,219	0,274	-0,432	0,511	-0,164	-0,061	-0,523	0,304	-0,304	0,456	-0,116	-0,4	0,195	0,071	-0,036	-0,052	0,164
Trunk Lateral Flexion	0,042	-0,285	-0,039	0,133	-0,236	0,212	0,018	-0,212	-0,285	0,03	0,006	-0,139	0,044	-0,29	-0,303	-0,545	-0,141	0,143	-0,052	0,02
Trunk Inclination	0,491	-0,152	-0,369	-0,412	0,479	0,43	-0,212	-0,212	0,394	0,442	-0,139	-0,127	-0,062	-0,29	-0,11	-0,311	-0,08	-0,259	0,276	-0,347
Trunk Convex Lumbar Spine	-0,212	-0,127	-0,058	,691*	-0,345	-0,552	0,333	0,236	-,685*	-0,564	0,358	0,091	0,012	-0,058	-0,22	0,156	-0,101	0,493	-0,082	0,334
Head Axial Rotation	0,067	-0,042	0,265	0,146	-0,018	0,103	-0,539	0,321	-0,139	-0,03	-0,248	0,176	0,162	-0,174	-0,22	0,156	0,422	0,065	0,425	-0,229
Head Lateral Flexion	-0,37	0,091	0,22	0,298	-0,406	-0,37	0,345	0,079	-0,285	-0,418	0,139	-0,006	0,181	0,406	0,055	0,311	0,04	0,13	-0,395	0,321
Head Inclination	-0,231	0,012	-0,344	0,273	-0,079	-0,596	0,614	-0,188	-0,17	-0,468	0,413	-0,134	0,128	0,291	0,028	0,273	-0,192	0,127	-0,352	0,454
Neck Flexion / Extension	-0,37	0,091	0,22	0,298	-0,406	-0,37	0,345	0,079	-0,285	-0,418	0,139	-0,006	0,181	0,406	0,055	0,311	0,04	0,13	-0,395	0,321
Upper Arm Left External Rotation	0,527	-0,115	-0,478	-0,405	0,382	0,345	0,2	-0,261	0,382	0,261	-0,006	-0,224	0,181	-0,29	-0,193	-0,389	-0,08	-0,331	-0,037	-0,216
Upper Arm Right External Rotation	,648*	-0,576	-0,039	-0,583	0,552	0,527	-,661*	-0,2	0,564	0,588	-,782**	-0,539	0,443	-0,406	-0,468	-0,078	,744*	-,707*	-0,097	-,859**
Upper Arm Left Retroflexion / Adduction	0,515	-0,479	-0,433	-0,146	0,479	0,176	-0,042	-0,248	0,164	0,176	-0,079	-0,358	0,037	-0,406	-0,358	-0,234	-0,04	-0,169	0,142	-0,321
Upper Arm Right Retroflexion / Adduction	0,127	-0,418	-0,149	-0,234	0,333	0,261	-0,503	-0,442	0,212	0,442	-0,273	-0,297	-0,231	-0,174	-0,083	-0,234	-0,06	-0,13	0,216	-0,282
Upper Arm Left Elevation	0,067	-0,285	-0,039	0,038	0,067	-0,212	0,297	-0,018	-0,03	-0,006	-0,018	-0,297	-0,125	0,058	0	0,156	-0,08	-0,071	-0,5	-0,098
Upper Arm Right Elevation	-0,091	-0,212	0,091	-0,019	-0,03	0,261	-0,382	-0,248	-0,079	0,309	-0,115	-0,042	-0,355	-0,29	0	-0,467	-0,201	0,143	0,231	-0,072
Elbow Left Flexion	0,564	-0,248	-0,381	-0,424	0,442	0,491	-0,091	-0,285	0,382	0,394	-0,152	-0,248	0,087	-0,406	-0,248	-0,467	-0,04	-0,318	0,157	-0,361
Elbow Right Flexion	0,588	-0,345	-0,22	-0,469	0,358	,661*	-0,442	-0,248	0,358	0,564	-0,418	-0,261	0,206	-0,522	-0,385	-0,545	0,241	-0,389	0,157	-0,557
Forearm Left Pronation / Supination	-0,479	0,442	-0,323	-0,019	0,018	-0,188	0,091	-0,358	0,055	0,152	0,503	0,345	-,735*	0,174	,633*	-0,234	-,784**	0,363	0,336	0,557
Forearm Right Pronation / Supination	0,067	0,079	0	-0,386	0,067	0,527	-,673*	-0,273	0,297	0,479	-0,333	0,079	0,181	-0,406	-0,11	-0,545	0,322	-0,214	0,365	-0,203
Wrist Left Flexion / Extension	0,2	-0,042	0,394	0,317	-0,309	-0,139	0,37	,721*	-0,358	-0,382	-0,079	0,042	0,324	0,058	-0,248	0,389	0,342	0,019	-0,455	-0,19
Wrist Right Flexion / Extension	0,539	-0,127	-0,149	0,171	-0,079	-0,006	0,345	0,467	-0,212	-0,333	-0,042	-0,055	,717*	-0,058	-0,578	0,234	0,442	-0,143	-0,276	-0,243
Wrist Left Ulnar / Radial Deviation	-0,091	0,164	0,472	-0,348	-0,079	0,491	-0,588	0,103	0,224	0,6	-0,406	0,188	-0,374	0,058	0,33	-0,156	0,04	-0,117	0,082	-0,308
Wrist Right Ulnar / Radial Deviation	-0,309	0,236	-0,304	0,19	0,224	-0,358	0,261	-0,188	-0,03	-0,2	0,588	0,224	-,698*	0,29	0,495	0,156	-,824**	0,422	0,529	0,505
Knee Left Flexion	-0,042	-0,067	-0,207	-0,596	0,515	0,333	-0,479	-,770**	,673*	0,527	-0,188	-0,248	-0,168	-0,522	0,165	-0,623	0	-0,331	0,365	-0,072
Knee Right Flexion	0,055	-0,2	0,394	-0,564	0,139	,770**	-,818**	-0,43	0,467	,636*	-0,624	-0,224	0,056	-0,522	-0,083	-,701*	0,362	-0,389	0,261	-0,426

* Significance level α= 0,01

** Significance level α=

Table 6 – Posture Risk Classification.

Posture	Body Regions	Position	Risk Factors	Risk Classification	Analysis Tool
1	Trunk	Supported on the chair back	No risk	**Recommended**	Pressure Sensor
	Neck	No neck Support	No risk*	Recommended	Supplementary information required
	Arm	Supported on the chair arm rest / table	No risk*	Recommended	Supplementary information required
	Legs	Closer to 90° and feet supported	No risk	Recommended	Pressure Sensor
2	Trunk	No lumbar support	Risk	Not Recommended	Pressure Sensor
	Neck	No neck Support	No risk*	Recommended	Supplementary information required
	Arm	Supported on the chair arm rest / table	No risk*	Recommended	Supplementary information required
	Legs	Closer to 90° and feet supported	No risk	Recommended	Pressure Sensor
3	Trunk	No upper back support	Risk	Not Recommended	Supplementary information required**
	Neck	No neck Support	No risk*	Recommended	Supplementary information required
	Arm	Supported on the chair arm rest / table	No risk*	Recommended	Supplementary information required
	Legs	Closer to 90° and feet supported	No risk	Recommended	Pressure Sensor
4	Trunk	No back support	Risk	Not Recommended	Supplementary information required***
	Neck	No neck Support	No risk*	Recommended	Supplementary information required
	Arm	Supported on the chair arm rest / table	No risk*	Recommended	Supplementary information required
	Legs	Closer to 90° and feet supported	No risk	Recommended	Pressure Sensor
5	Trunk	Asymmetric trunk posture slope to the right	Risk	Not Recommended	Pressure Sensor
	Neck	No neck Support	No risk*	Recommended	Supplementary information required
	Arm	Supported on the chair arm rest / table	No risk*	Recommended	Supplementary information required
	Legs	Closer to 90° and feet supported	No risk	Recommended	Pressure Sensor
6	Trunk	Asymmetric trunk posture slope to the left	Risk	Not Recommended	Pressure Sensor
	Neck	No neck Support	No risk*	Recommended	Supplementary information required
	Arm	Supported on the chair arm rest / table	No risk*	Recommended	Supplementary information required
	Legs	Closer to 90° and feet supported	No risk	Recommended	Pressure Sensor
7	Trunk	Supported on the chair back	No risk	Recommended	Pressure Sensor
	Neck	No neck Support	No risk*	Recommended	Supplementary information required
	Arm	Supported on the chair arm rest / table	No risk*	Recommended	Supplementary information required
	Legs	Interrupt blood circulation on the right shin	Risk	Not Recommended	Pressure Sensor
8	Trunk	Supported on the chair back	No risk	Recommended	Pressure Sensor

Posture	Body Regions	Position	Risk Factors	Risk Classification	Analysis Tool
1	Trunk	Supported on the chair back	No risk	**Recommended**	Pressure Sensor
	Neck	No neck Support	No risk*	Recommended	Supplementary information required
	Arm	Supported on the chair arm rest / table	No risk*	Recommended	Supplementary information required
	Legs	Interrupt blood circulation on the left shin	Risk	Not Recommended	Pressure Sensor
9	Trunk	No back support	Risk	Not Recommended	Pressure Sensor
	Neck	No neck Support	No risk*	Recommended	Supplementary information required
	Arm	Supported on the chair arm rest / table	No risk*	Recommended	Supplementary information required
	Legs	Closer to 90° and feet supported	No risk	Recommended	Pressure Sensor
10	Trunk	No back support	Risk	Not Recommended	Pressure Sensor
	Neck	No neck Support	No risk*	Recommended	Supplementary information required
	Arm	Supported on the chair arm rest / table	No risk*	Recommended	Supplementary information required
	Legs	Closer to 90° and feet supported	No risk	Recommended	Pressure Sensor