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Towards human-centered design of supermarket checkout counter

Tânia Micaela Teixeira Silva

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Autor

Tânia Micaela Teixeira Silva

Orientador(es)

Doutora Matilde Alexandra Rodrigues/ Escola Superior de Saúde do Instituto Politécnico do Porto

Doutora Ana Sofia Pinho Colim/Escola de Engenharia da Universidade do Minho

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Resumo

As lesões musculoesqueléticas relacionadas com o trabalho (LMERT) representam uma preocupação significativa para operadores de caixa de supermercado e, muitas vezes, decorrem da adoção de posturas desconfortáveis e da realização de movimentos repetitivos e tarefas que envolvem a movimentação manual de cargas. Este estudo teve como objetivo avaliar o risco de LMERT em operadores de caixa de supermercado e contribuir para o desenvolvimento de novos designs de balcões de checkout. Para atingir esse objetivo, dois estudos distintos foram realizados.

Na primeira investigação, o risco de LMERT foi avaliado através da observação de todas as tarefas realizadas em dois balcões de checkout distintos, utilizando um sistema de captura de movimento inercial – Xsens. O estudo envolveu 5 operadoras de caixa de um supermercado, situado no Norte de Portugal, com idades compreendidas entre os 19 e os 61 anos. Os resultados revelaram que várias tarefas apresentavam risco de LMERT, sublinhando a necessidade de uma reformulação das configurações dos balcões de *checkout* de supermercado de modo a aliviar o esforço físico experienciado pelos trabalhadores. No segundo estudo, foram recolhidos dados antropométricos de 155 funcionários que trabalhavam no mesmo supermercado. A amostra era composta por 117 mulheres e 38 homens, com idades entre 18 e 64 anos. O extenso conjunto de dados abrangeu 28 medidas antropométricas estáticas para cada participante, bem como dados antropométricos adicionais considerados pertinentes para caracterizar esta população, como gordura corporal, massa óssea, água corporal total, gordura visceral, massa corporal (MC) e índice de massa corporal (IMC). O estudo revelou uma tendência notável de crescimento da população. Estes resultados sublinham a necessidade urgente de uma revisão dos dados antropométricos portugueses e da adoção de práticas eficazes de conceção ergonómica do local de trabalho. No futuro, os dados recolhidos serão utilizados para desenvolver diretrizes para o novo design de balcões de *checkout*.

Palavras-chave: Base de dados antropométrica; Ergonomia; Lesões musculoesqueléticas relacionadas com o trabalho; Operador de caixa; Retalho alimentar.

Abstract

Work-related musculoskeletal disorders (WMSD) pose a significant concern for supermarket cashiers, often stemming from the adoption of uncomfortable postures and the performance of repetitive motions and manual material handling tasks. This study aimed to evaluate the risk of WMSD in supermarket cashiers and contribute to the development of new checkout counter designs. To achieve this goal, two separate studies were conducted. In the first study, the risk of WMSD was assessed by observing all tasks performed at two distinct checkout counters, using an inertial motion capture system – Xsens. The study involved 5 female cashiers from a supermarket situated in Northern Portugal, with ages ranging from 19 to 61 years old. The results revealed that various tasks carried a risk of WMSD, underscoring the necessity for a redesign of supermarket checkout setups to ease the physical strain experienced by cashiers. In the second study, anthropometric data was gathered from 155 employees working at the same supermarket. This group comprised 117 women and 38 men, with ages spanning from 18 to 64 years. The extensive dataset encompassed 28 static anthropometric measurements for each participant, as well as additional anthropometric data deemed pertinent for characterizing this population, such as body fat, bone mass, total body water, visceral fat, body mass (BM) and body mass index (BMI). The study unveiled a noticeable trend of growth within the population. These results emphasize the urgent need for a review of Portuguese anthropometric data and the adoption of effective ergonomic workplace design practices. In the future, collected data will be used to develop guidelines for new checkout designs.

Keywords: Anthropometry database; Cashier; Ergonomics; Food Retail; Work-related musculoskeletal disorders.

Contents

Introduction

According to the International Labour Organization (ILO, 2021), approximately two million people die each year due to occupational accidents and diseases. The global statistics reveal that worldwide 340 million occupational accidents and 160 million cases of occupational diseases are reported annually (ILO, 2021). At the European level, the third Survey of Enterprises on New and Emerging Risks (ESENER 3) conducted by the European Agency for Safety and Health at Work (EU-OSHA) in 2019 examines how health and safety risks are identified and managed in European workplaces and aims to assist workplaces to deal more effectively with health and safety and to promote the health and well-being of employees. According to the survey, the most frequently identified risk factors were related to physical and ergonomic issues. These included repetitive hand or arm movements, prolonged sitting posture, and lifting or moving people or heavy loads (EU-OSHA, 2019a). These risk factors contribute to the occurrence of work-related musculoskeletal disorders (WMSD), which are one of the most common occupational diseases (EU-OSHA, 2019a).

These injuries affect millions of workers across Europe and cost employers billions of euros. Given their status as the most prevalent work-related health issue in the EU, workers across all sectors and occupations are affected (EU-OSHA, 2019b). The occurrence of these injuries has been highlighted in some sectors of activity, such as construction, water supply, agriculture, forestry, and fishing. WMSD prevalence is also above average among workers in human health and social work activities (EU-OSHA, 2019b).

Regarding the food retail industry, there is a notably high prevalence of WMSD, conditions that primarily result from tasks that involve manual handling of loads (MHL), the adoption of awkward postures, and repetitive and monotonous upper limb movements (Kihlstedt and Hägg, 2011; Rodacki et al., 2006).

The daily responsibilities of supermarket cashiers are known to pose a significant risk for developing WMSD, as they are among the top 10 occupations with a high susceptibility to these disorders (Lehman, 2001; Kihlstedt & Hägg, 2011; Minghelli et al., 2023; Rodacki et al. 2006). Within their workstations at the checkout counter, cashiers often find themselves frequently leaning forward, tilting to the side, and twisting their torsos, thereby subjecting their backs to significant risks (Maciukiewicz et al., 2017; Rodacki et al., 2006). These risks are further exacerbated by the weight of the products, as emphasized in research by Maciukiewicz et al. (2017) and Rodacki et al. (2006).

Is it important to note that in this occupation, the most vulnerable body regions for injury include the neck, upper limbs (shoulders, elbows, hands/wrists) and lower back as indicated by studies by Algarni et al. (2020), Balogh et al. (2016), Erick et al. (2023), and Maciukiewicz et al. (2017).

One significant risk factor contributing to the development of WMSD is the mismatch between workers' anthropometric characteristics and the physical demands of their job functions and tasks (Darvishi et al., 2022; Grobelny & Michalski, 2020). Workplaces with inadequate designs that fail to consider the anthropometric variations among individuals can deeply improve the risk of WMSD. Therefore, enhancing workplace conditions is essential not only from an economic standpoint but also from a medical perspective (Grobelny & Michalski, 2020).

Anthropometry is a branch of human sciences that studies measurable characteristics of individuals, including body segments, lengths, circumferences, widths, heights, strength, and work capacity (Pheasant & Haslegrave, 2006). The data obtained from anthropometric measurements is vital for the purpose of designing jobs and tasks as it provides probabilistic information about the positioning of body reference points for a population of users within a specific workspace (IISE, 2023). Anthropometry, when actively employed to significantly improve well-being, functional efficiency, ease of use, comfort, and health and safety, becomes a focal point in various studies that seek out product improvement (Castellucci et al., 2019; Pheasant & Haslegrave, 2006). Therefore, the availability of up-to-date anthropometric data is crucial (Castellucci et al., 2019; Pheasant & Haslegrave, 2006).

At the time of conducting this research, there are currently no studies in Portugal that specifically examine the main risk factors for WMSD in cashiers, related to adjustments in work equipment dimensions and the anthropometric characteristics of the workers. Hence, the objectives of this study are to conduct the assessment of WMSD risk in employees working in the Cashier's department of a Food Retail company and to develop the anthropometric database of these workers to in the future design new checkouts. To achieve the two main objectives of this work, the following steps were undertaken:

- Analysis of workers' postures and body movements in the cashier's department: Through a body movement analysis system called Xsens MVN, workers' postures and body movements were determined. Moreover, using data gathered from Xsens, a comprehensive risk analysis using postural assessment methodologies such as REBA and RULA was developed. This analysis enabled us to establish the level of risk exposure faced by the workers.
- Gathering of anthropometric dimensions of company workers: To ensure the optimal design of job roles within this department, we collected precise anthropometric measurements from the employees in the company under investigation.
- Expansion of the existing anthropometric database in Portugal: Our research contributed to the enrichment of the prevailing anthropometric database in Portugal. By incorporating the measurements obtained during this study, we are aiding in the development of a comprehensive database that covers the adult population of Portugal.

During this investigation, two studies were developed that resulted in two articles that are part of this master thesis: (1) Understanding the risk of work-related musculoskeletal disorders among checkout counter cashiers: A biomechanical analysis; (2) Anthropometric characteristics of Portuguese supermarket workers for ergonomic and design purposes.

Chapter 1: Understanding the risk of work-related musculoskeletal disorders among checkout counter cashiers: A biomechanical analysis

Understanding the risk of work-related musculoskeletal disorders among checkout counter cashiers: A biomechanical analysis

Tânia Silva[a], Catarina Sousa[b], Ana Colim[c], Matilde A. Rodrigues[a,b,c]

[a]Center for Translational Health and Medical Biotechnology Research – T.BIO

[b] Department of Environmental Health, School of Health of the Polytechnic Institute of Porto, Porto, Portugal

[c] Algoritmi Centre, School of Engineering, University of Minho, Guimarães, Portugal

Abstract: Work-related musculoskeletal disorders (WMSD) are highly prevalent among supermarket cashiers. These disorders are frequently related to the adoption of awkward postures and manual material handling. The aim of this study was to analyze the risk of WMSD in supermarket cashiers, considering the handling of different products and different checkouts design. To accomplish this, we employed the inertial motion capture system (Xsens) to measure full-body kinematics while simulating 19 cashier tasks. The study included five female cashiers from a supermarket in Northern Portugal, ranging in age from 19 to 61 years old. Utilizing joint angles and materials load as input parameters, we conducted a risk assessment using the RULA and REBA methods. Results showed that RULA scores were at the highest risk for the microtasks that involved product scanning. Regarding REBA, the microtask involving the replacement of paper rolls, for the receipt machine, at the checkout counter yields the highest scores. Based on these findings, there is a compelling need to redesign supermarket checkout stations to alleviate the physical demands placed on cashiers.

Keywords: Cashier; Ergonomics; Food Retail; Work-related musculoskeletal disorders.

1.1 Introduction

Work-related musculoskeletal disorders (WMSD) are a high prevalent among supermarket cashiers (Kihlstedt & Hägg, 2011; Skovlund et al., 2022). This is also a public health problem due to the high number of professionals conducting such activity. In fact, in Portugal, in 2021, the food retail sector accounted for 1,760 retail food trade units in operation and employed 84.9 thousand workers (INE, 2021). Additionally, there has been a gradual rise in the number of food retail establishments in recent years, with an average annual growth rate of 0.7% between 2018 and 2023 (IBISWorld, 2023).

The cashier is responsible for carrying out a set of functions, ranging from reading, weighing and recording the price of goods, as well as packaging and bagging goods for customer convenience, to receiving and verifying payments (INE, 2023; Erick et al. 2023). Within the range of tasks undertaken by supermarket employees, the responsibilities of cashiers stand out as posing a significant risk of developing WMSD. According to Lehman (2001), cashiers are among the top 10 occupations with a heightened susceptibility to these disorders.

Body regions most susceptible to injury include the neck, upper limbs (shoulders, elbows, hands/wrists), and lower back (Algarni et al., 2020; Balogh et al., 2016; Erick et al., 2023; Maciukiewicz et al., 2017). A study developed in Portugal revealed prevalent injuries among hypermarket cashiers, including non-specific pain, cervical, and lumbar pain, primarily affecting the shoulder, cervical spine, and lumbar spine (Minghelli et al., 2023). Additionally, findings showed that neck and back pain significantly hindered cashiers from performing their regular tasks, prompting them to seek medical attention from nurses, doctors, or physiotherapists. Some even had to modify their job responsibilities and reduce their activities at home due to the discomfort caused by severe pain (Erick et al., 2023).

The work of a cashier is typically performed at a checkout counter. In this workstation, tasks are characterized by repetitive and monotonous movements of the upper limbs, as well as manual handling of heavy and/or bulky loads (Rodacki et al., 2006). This, related to the poor checkout design, contributes to musculoskeletal disorders in the neck, shoulders, and wrists (Ryan, 1989). To address the physical strain caused by sitting and standing, the workstation is designed for the cashier to primarily work in a standing position, with periodic breaks to sit (Lannersten & Harms-Ringdahl, 1990; Ryan, 1989; Shinnar et al., 2004). This helps to prevent muscle fatigue in the lower limbs during the shift and allows the cashier to alternate positions and rest different muscle groups (Draicchio et al., 2012; Shinnar et al., 2004). However, to fulfil their job responsibilities, cashiers frequently engage in forward flexion, leaning sideways, and trunk rotation, placing them at risk for developing back pain, as noted by Maciukiewicz et al. (2017) and Rodacki et al. (2006). Consequently, checkout cashiers commonly experience postural issues due to the inherent strain in their work, which is further exacerbated by improper biomechanics in their workstations (Rodacki et al., 2006). Despite some checkout counters being replaced by smart solutions that are reducing their presence in some supermarkets, the work of cashiers is still considered relevant, and their role will not disappear. They serve as the company's frontline representatives, often being the initial and final point of contact for many customers. Due to their substantial responsibilities and integral role in the organization, they are highly regarded as essential and trusted employees (Cvetkovic, 2022; Wang, 2012). Given their pivotal role, it is imperative to enhance their working conditions to ensure the continuity of their job duties and safeguard their health and safety. Therefore, it is critical to better understand the risk of WMSD that cashiers are exposed. Postural analysis holds significant potential as an effective technique for assessing work activities. The evaluation of ergonomic workplace postures can play a substantial role in identifying the risk of musculoskeletal injuries and can contribute considerably to the implementation of necessary changes. Therefore, having access to field techniques such as Rapid Entire Body Assessment (REBA) and Rapid Upper Limb Assessment (RULA) is advantageous for ergonomists (Hignett & McAtamney, 2020).

This study aimed to understand how checkout design can influence the risk of WMSD, characterizing its implications among workers with different anthropometric characteristics and dominant hand, as well as among checkouts with different designs and product features.

1.2 Methodology

1.2.1 Subjects

The study was conducted in one retail company located in Northern Portugal. To this study end, a supermarket with almost 400 employees was selected. The existence of two different checkouts and their size was one of the criteria for this choice.

The sample consisted of five cashier workers who voluntarily agreed to participate in this study and met the inclusion criteria: Portuguese nationality and female gender. To ensure compatibility with the Xsens system, participants were excluded if their BMI was higher than or equal to 30, as the system's larger shirt sizes were not suitable for these subjects.

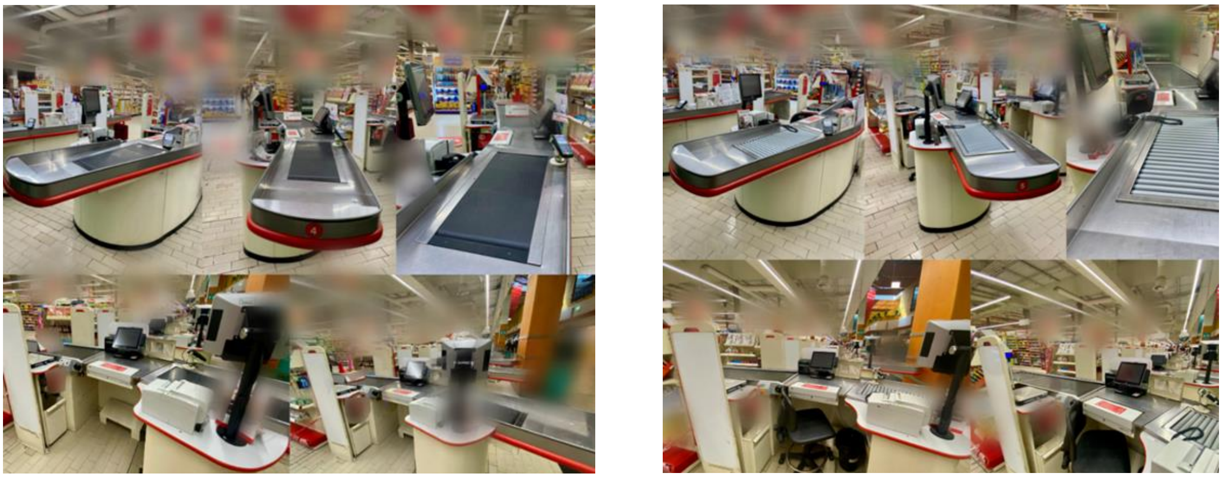
Subjects exhibited variations in anthropometric measures and dominant hand, and experience: three participants were older ($\bar{x}$= 56 years old; sd= 6.2) while the other two were younger ($\bar{x}$= 21 years old; sd= 2.82), two had shorter stature ($\bar{x}$= 155 cm; sd= 2.82) and three were taller ($\bar{x}$= 166.3 cm; sd= 5.1). Additionally, one participant was ambidextrous, another left-handed, and the remaining three were right-handed.

The study was approved by Ethics Committee of the School of Health of the Polytechnic Institute of Porto (CE0061D).

1.2.2 Motion analysis

1.2.2.1 Workstation and tasks

To conduct ergonomic analyses, each participant was evaluated at two checkout stations that were designed to be either a standing or sitting workstation. These stations simulated 19 distinct microtasks that are characteristic of the work in this section. The checkout counters are equipped with registers arranged from left to right. The primary distinction between the two evaluated checkout stations is the presence of an additional conveyor belt. In one of the analysed counters, this conveyor belt is sliding, facilitating the delivery of items to the customer, while the other counter, does not possess this sliding feature and its conveyor belt remains stationary. Figure 1 portrays the checkout counter both without and with the conveyor belt, respectively.



(a) (b)

Figure 1. (a) Checkout counter without conveyor belt; (b) Checkout counter with conveyor belt

Table 1 displays the dimensions of the checkout counter.

Table 1: Checkout counter dimensions

Area	Height (cm)	Width (cm)	Depth (cm)	Reach (of the worker) (cm)
Counter	86	_	50	_
Touch-screen monitor	31	29	_	36
Scanner	20	_	_	48
Money drawer	10	46	15,5	_
Thrash can	40	_	52	_
Shelf 1	52,2	50	44,4	_
Shelf 2	27	50	44,4	_
Shelf 3	3	50	44,4	_
Shelf 4	49	30,5	24,5	_
Shelf 5	3	44,5	24,5	_
Scale	4,5	-	-	-
Scale counter	83,5	-	-	-
Support counter	83	-	-	-
Receipt printer	6,3	-	_	_
Telephone	6,3	_	_	_
Magazine Display	_	50	_	87,3

Table 2 displays the processes, macrotasks and corresponding microtasks per-formed by cashiers at the checkout counter.

Table 2. Processes, macrotasks and microtasks performed at the checkout counter

Process	Macrotask	Microtask
Storage	Treatment of values	Carrying the cash drawer to the checkout counter
Storage	Exhibition and Replacement	Carrying paper rolls, for the receipt machine, to the checkout counter
Storage	Exhibition and Replacement	Replacing paper rolls, for the receipt machine, at the checkout counter
Storage	Customer services	Collecting customer baskets and transport them to the basket storage area
Storage	Treatment of values	Carrying the cash drawer and other materials to the vault room
Sales	Customer services	Opening the checkout counter opening
Sales	Customer services	Closing the checkout counter opening
Sales	Customer services	Picking up and delivering the client's card and delivering the receipt
Sales	Customer services	Scanning bulky / heavy items, while standing (with a conveyor belt)
Sales	Customer services	Scanning bulky / heavy items, while standing (without a conveyor belt)

Table 2. Processes, macrotasks and microtasks performed at the checkout counter *(cont.)*

Process	Macrotask	Microtask
Sales	Customer services	Scanning light products, while standing (with a conveyor belt)
Sales	Customer servisse	Scanning light products, while standing (without a conveyor belt)
Sales	Customer services	Scanning light products, while sitting (with a conveyor belt)
Sales	Customer services	Scanning light products, while sitting (without a conveyor belt)
Sales	Customer services	Weighing fruits and vegetables
Cleaning	Cleaning of the Section, Equipment and Utensils	Cleaning the checkout counter (with a conveyor belt)
Cleaning	Cleaning of the Section, Equipment and Utensils	Cleaning the checkout counter (without a conveyor belt)
Support	Treatment of values	Placing money in safety bags and sealing them
Support	Treatment of values	Placing the money safety bags in the safe

1.2.2.2 Instruments and measurement protocol

Kinematic analysis was conducted through the Xsens MVN whole-body motion capture system (Xsens technologies, Enschede, Netherlands) which comprises 17 inertial motion (MTw) sensors that tracked the motion data during the predefined tasks. This system provides data about 3D joint angles, the center of body mass, as well as temporal parameters, such as segment position, which facilitates gait analysis.

For each participant, anthropometric data were collected, encompassing measurements such as stature and shoe length. These collected data points were subsequently employed to construct the MVN human model utilized by Xsens.

Following the placement of accelerometers on the subjects' body landmarks, calibration procedures were meticulously executed, strictly adhering to the previously established protocol, which was developed with consideration of previous studies (see e.g., Colim et al., 2021a; Colim et al., 2021b), and the guidelines outlined in the Xsens Manual. These procedures involved having the participant assume the N-pose and subsequently perform a walking trial.

Afterwards, each participant performed the 19 simulated microtasks, which are representative of the work in this section. Microtask assessments were initially conducted at one of the checkout stations, without of a conveyor belt. Subsequently, for tasks involving "scanning products" and "cleaning the checkout counter," necessitating evaluation at a separate checkout station, participants were relocated to an alternative workstation equipped with a conveyor belt. All tasks were executed with participants standing, except for those explicitly described as involving sitting.

In Figure 2, two study participants and their avatars can be observed engaged in distinct tasks. On the left, there is scanning of bulky/heavy products while standing in a checkout counter with a conveyor belt, while on the right, scanning of lightweight products is depicted while sitting in a checkout counter without a conveyor belt).

(a) (b)

Figure 2. Study participants and their corresponding Xsens outputs: (a) scanning heavy items, while standing, at a checkout counter with a conveyor belt; (b) scanning light products, while sitting, at a checkout counter without a conveyor belt

Regarding the microtask that involved scanning products, common purchase items were chosen. For lightweight items (< 5kg), the following were chosen: 1 bag of rice, 1 can of tuna, 1 pack of portuguese bread (5 units), 1 bottle of shampoo, 1 pack of pasta, 1 cheese ball, 1 can of sausages, 1 pack of cherry tomatoes, 1 razor blade box (with an alarm), 1 pack of flour and 1 pack of 4 liquid yogurts. For heavier or bulkier products (≥ 5kg), the selected items were: 1 pack of 6 water bottles (1.5L each), 1 codfish, 1 dustbin, 1 pack of potatoes (5kg), 1 pack of diapers (144 units), 1 baby car seat (with an alarm), 1 pack of beer bottles (24 units), 1 clothes drying rack, 1 liquid laundry detergent, 1 bottle of water (6L), 1 pack of 6 milk cartons (1L each), 1 pack of wood pellets (15kg), 1 pack of wood (10kg) and 1 pack of dry dog food (20kg). Concerning the microtask of "weighing fruits and vegetables," the selected items were 1 courgette, 4 oranges, and 1 papaya.

The system technology was employed to track various aspects such as orientation, position, movement, and center of mass across different body parts. Subsequently, the collected data was sent wirelessly to a computer equipped with software capable of observing, recording, and analyzing the movements.

The raw data were initially collected and processed using Xsens MVN software version 2021 (Xsens technologies, Enschede, Netherlands). This analysis entailed the use of graphical representations depicting joint angles, as well as the assessment of movement speed and duration. Subsequently, the data was exported to the .xlsx format and imported into an Excel file previous developed and validated, facilitating the conversion of the gathered information into REBA and RULA values. These values were derived by entering "muscle" and "force" values for RULA, and "load/force," "coupling," and "activity" values for REBA. The resulting REBA and RULA values were subsequently presented in tabular form. Tables 3 and 4 display the REBA and RULA action levels, respectively. Tasks involving the entire body were assessed using the REBA method, while those exclusively engaging the upper body were evaluated using RULA.

Table 3: REBA action levels

Action level	REBA score	Risk level	Action (including further assessment)
0	1	Negligible	None necessary
1	2-3	Low	May be necessary
2	4-7	Medium	Necessary
3	8-10	High	Necessary soon
4	11-15	Very high	Necessary now

Source: Hignett & McAtamney (1999)

Table 4: RULA action levels

Action level	RULA score	Risk level
1	1-2	Acceptable
2	3-4	Further investigation is required and changes may be required
3	5-6	Investigation and changes are required soon
4	7	Investigation and changes are required immediately

Source: Adapted from McAtamney & Corlett (1993)

Tasks involving the entire body were assessed using the REBA method, while those exclusively engaging the upper body were evaluated using RULA.

1.3 Results

Table 5 presents the RULA and REBA scores derived from the analysis of microtasks conducted at the cashier station. Results denoted the high risk of WMSD to which cashier workers are exposed. However, risk level differ according to the microtask under analysis. Tasks requiring the engagement of the entire body were found to be less detrimental to the assessed workers than tasks exclusively involving the upper body.

However, some of the tasks that required all body movements were classified with high risk levels. The microtask "Replacing paper rolls in the receipt machine at the checkout counter" has demonstrated a propensity for causing physical strain on workers, with REBA scores ranging from 7 to 11 (scores varying based on the participant under analysis). This microtask often necessitates workers to assume precarious positions, occasionally requiring them to kneel on the floor or adopt a squatting posture. Notably, the participant who exhibited the highest REBA score for this microtask was participant 1, who is taller and younger and has only a few years of work experience.

Table 5 highlights the microtasks that pose the greatest risk to workers, notably "Scanning products," which received a RULA score of 7, signifying the maximum risk level for all the assessed participants. This microtask is characterized by continuous wrist rotation, elevated shoulders, and repetitive movements of the upper limbs. When comparing the two checkout counters, no noticeable distinctions were detected regarding the presence of the conveyor belt. Regarding the selected products, despite conducting a distinct evaluation between lighter and heavier / bulkier items, the resulting values remained equally elevated.

The evaluation of "Scanning bulky/heavy items, while sitting" was not conducted given the fact that cashiers typically perform this microtask while standing, as it is more convenient and less physically demanding to handle and maneuver products in that posture.

Another critical microtask is "Weighing Fruits and Vegetables," with RULA scores of 5, 6, and 7 (scores varying based on the participant under analysis). In this activity, employees must rotate their trunks to the left to access the scale, further contributing to the ergonomic challenges faced by the workers.

Microtasks that appeared to pose lower risks included "Carrying the cash drawer to the checkout counter," "Carrying the cash drawer and other materials to the vault room," and "Cleaning the checkout counter," as indicated by REBA scores of 4, 5, and 6, which mean a medium risk.

In terms of differences among employees, a comprehensive analysis unveiled that Participant 1, who is the tallest, youngest and right-handed had the highest REBA and RULA values along the different microtasks under analysis. Closely behind was Participant 4, who is left-handed, taller, and older.

Concerning hand dominance, Participant 3 was ambidextrous, Participant 4 was left-handed, while the other 3 participants were right-handed. This variable demonstrated no influence on the analyzed microtasks, as there were no differences in the reported values of REBA and RULA.

It was observed that both working in a standing position and working in a sitting position conceded consistent RULA assessments for the microtasks involving product scanning. As previously mentioned, these assessments consistently reached the maximum RULA score of 7 with changes in the work environment being required immediately.

Table 5: Postural analysis, through REBA and RULA in the checkout station

Process	Macrotask	Microtask	Method	Participant P1	P2	P3	P4	P5
Storage	Treatment of values	Carrying the cash drawer to the checkout counter	REBA	6	4	4	4	5
Storage	Exhibition and Replacement	Carrying paper rolls, for the receipt machine, to the checkout counter	REBA	5	5	4	7	4
Storage	Exhibition and Replacement	Replacing paper rolls, for the receipt machine, at the checkout counter	REBA	11	7	8	9	9
Storage	Customer services	Collecting customer baskets and transport them to the basket storage area	REBA	6	6	6	6	5
Storage	Treatment of values	Carrying the cash drawer and other materials to the vault room	REBA	6	5	5	4	4
Sales	Customer services	Opening the checkout counter opening	REBA	5	4	4	4	4
Sales	Customer services	Closing the checkout counter opening	REBA	7	5	4	5	4
Sales	Customer services	Picking up and delivering the client's card and delivering the receipt	RULA (L/R)	5 5	4 4	4 4	6 6	4 5
Sales	Customer services	Scanning bulky / heavy items, while standing (with a conveyor belt)	RULA (L/R)	7 7	7 7	7 7	7 7	7 7
Sales	Customer services	Scanning bulky / heavy items, while standing (without a conveyor belt)	RULA (L/R)	7 7	7 7	7 7	7 7	7 7
Sales	Customer services	Scanning light products, while standing (with a conveyor belt)	RULA (L/R)	7 7	7 7	7 7	7 7	7 7
Sales	Customer servisse	Scanning light products, while standing (without a conveyor belt)	RULA (L/R)	7 7	7 7	7 7	7 7	7 7
Sales	Customer services	Scanning light products, while sitting (with a conveyor belt)	RULA (L/R)	7 7	7 7	7 7	7 7	7 7
Sales	Customer services	Scanning light products, while sitting (without a conveyor belt)	RULA (L/R)	7 7	7 7	7 7	7 7	7 7
Sales	Customer services	Weighing fruits and vegetables	RULA (L/R)	7 7	5 5	6 5	7 7	6 7
Cleaning	Cleaning of the Section, Equipment and Utensils	Cleaning the checkout counter (with a conveyor belt)	REBA	6	5	4	5	4
Cleaning	Cleaning of the Section, Equipment and Utensils	Cleaning the checkout counter (without a conveyor belt)	REBA	5	5	5	5	4
Support	Treatment of values	Placing money in safety bags and sealing them	RULA (L/R)	6 6	5 7	3 5	6 6	4 5
Support	Treatment of values	Placing the money safety bags in the safe	RULA (L/R)	4 4	7 7	6 7	7 6	4 4

Note: P1= Participant 1; P2= Participant 2; P3= Participant 3; P4= Participant 4; P5= Participant 5; RULA (L/R)= RULA (Left/Right)

1.4 Discussion

This study emphasises the high risk of WMSD to which cashier workers are exposed. These findings were already expected since numerous studies have consistently reported a high prevalence of musculoskeletal symptoms among grocery workers (Draicchio et al., 2012; Maciukiewicz et al., 2017).

Higher risk levels were found for microtasks related to costumer services, in particular the ones of scanning and weighings. These tasks are related to repetitive movements, manual material handling, rotation and lateral tilting of the trunk, as well as difficult reaches (Rodacki et al., 2006). This, along insufficient rest and long journeys, is related to musculoskeletal discomfort in shoulders, neck, and lower back (Maciukiewicz et al., 2017).

Our findings denoted the high risk of WMSD in both standing and sitting positions in the scanning and weighings microtasks. This was not expected since some findings indicate that standing position offers biomechanical advantages for the upper limbs and trunk (Draicchio et al., 2012; Lehman, 2001). However, the RULA score obtained for these microtasks was the highest, not allowing a distinction between two positions that are both risky. However, it is important to be aware that is advisable to incorporate a combination of both standing and sitting for optimal ergonomics (Draicchio et al., 2012). This approach mitigates the risk of lower limb muscle fatigue throughout the work shift, underscoring the importance of having chairs available at each checkout station. Furthermore, the implementation of scheduled rest breaks is essential for cashiers, even given the demanding nature of their work, to safeguard their well-being (Draicchio et al., 2012).

Our finds also show that taller workers are at high risk of WMSD. This emphasizes the importance of customizing workstations to accommodate the individual stature of cashiers. This means that considering average heights, females should have access to a lower bagging area compared to males. Considering this, is imperative that the checkout counter is height-adjustable to guarantee ergonomic and comfortable working postures, as emphasized in the study by Lang et al. (2018). It is also recommended to investigate the effects of rotating cashiers between mirrored configurations to assess whether this strategy has the potential to mitigate the overloading of one arm (Lang et al., 2018).

In the present study no differences in risk level between different checkouts designs were observed. This was because the maximum risk was achieved in both, not allowing to distinguish between both designs. This suggest that new design solutions are needed for checkouts.

One contemporary challenge rises from the increasing prevalence of self-checkout stations in supermarkets. Nonetheless, it is crucial to underscore that the significance of cashiers' roles cannot be overstated. However, the frequent errors and the expectation for customers to assume a more active role at self-checkout counters have resulted in many customers favouring the traditional checkout counter with a cashier, where the checkout process is typically smoother and more reliable (Meyersohn, 2022). Additionaly, cashiers function as the primary face of the company, interacting with a multitude of customers on a daily basis. The enduring importance of this job role highlights the necessity to continuously enhance working conditions, ensuring the seamless execution of their duties while prioritizing their health and safety (Meyersohn, 2022).

Applying ergonomic principles to the design processes, workplace, and organizational structure serves not only as a response to legal requirements but also as a strategic alignment with companies' objectives. Hence, checkout counters should be redesigned with meticulous attention to ergonomic and anthropometric principles (Comentaleet al. 2018).

Despite the relevance of this study results it is important to realize that only five subjects were included in the assessments. Additional, results were limited to the design of the checkouts under analysis. Different results can be obtained in other checkouts design.

1.5 Conclusion

The findings indicate considerably high-risk levels for cashiers developing WMSD in their workstation. To significantly reduce the risk of developing these disorders the checkout counter should offer adjustability in all directions to accommodate 95% of the cashier population. In cases where this is not feasible, the height dimensions should be determined based on the tallest individuals followed by the provision of equipment to adjust the height to accommodate smaller individuals. Reach dimensions, on the other hand, should be determined based on the smallest individuals. The workstation should enable cashiers to adopt various safe working postures during task performance while keeping their joints in neutral positions. Future studies should evaluate the match between the dimensions of supermarket checkout counters and the anthropometric dimensions of the workers. Supermarket checkouts should be redesigned, with careful consideration of the workers' anthropometric measurements, to ease the physical demands of the job.

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Chapter 2: Anthropometric characteristics of Portuguese supermarket workers for ergonomic and design purposes

Anthropometric characteristics of Portuguese supermarket workers for ergonomic and design purposes

Tânia Silva[a], Eduarda Dias[b], Ana Colim[c], Paulo C.A. Filho[c], Pedro Arezes[c], Matilde A. Rodrigues[a,b,c]

[a]Center for Translational Health and Medical Biotechnology Research – T.BIO

[b] Department of Environmental Health, School of Health of the Polytechnic Institute of Porto, Porto, Portugal

[c] Algoritmi Centre, School of Engineering, University of Minho, Guimarães, Portugal

Abstract: Current anthropometric databases serve as valuable tools for optimizing workstation and equipment design, thereby reducing the likelihood of occupational accidents and disorders. This study aims to establish an anthropometric database specific to a food retail company and enhance the existing anthropometric datasets for the Portuguese working population. In this study, an anthropometric database for a food retail company was established. Data were collected from 155 workers in a supermarket located in Northern Portugal (117 women and 38 men; ages between 18 and 64 years old). A set of 28 static anthropometric measures was obtained for each subject. The statistical analysis included exploring correlations among the 28 anthropometric dimensions, age, and BMI. Men generally exhibited larger average dimensions than women, apart from hip breadth. Furthermore, men had a higher likelihood of being overweight, whereas women were more likely to be obese. The present study revealed a growth trend in the population. These findings highlight the urging need for a revision of Portuguese anthropometric data and the proper ergonomic design of workplaces.

Keywords: Anthropometric database; Design; Ergonomics; Food Retail; Supermarket; Working population.

2.1 Introduction

Anthropometry involves the study of body characteristics such as body segments, lengths, circumferences, widths, heights, strength, and work capacity (Pheasant & Haslegrave, 2006). It plays a significant role in the field of human sciences but also in the design of different kinds of products and spaces, such as clothing, tools, and work equipment (Pheasant & Haslegrave, 2006). In fact, when properly applied to the design, anthropometry can enhance well-being, functional efficiency, usability, comfort, and health and safety (Castellucci et al., 2019; Pheasant & Haslegrave, 2006).

Despite the relevance of the use of anthropometric data in the design and the numerous studies have focused on utilizing anthropometry to improve products, it is important to keep in mind that the use of up-to-date anthropometric data is crucial (Castellucci et al., 2019; Pheasant & Haslegrave, 2006). When unappropriated data is used to support the design of workplaces and equipment, or even when the design do not consider ergonomics requirements, it will not tailor to the majority of workers, inducing biomechanical stress on joints and muscles, elevating the risk of musculoskeletal disorders and occupational diseases (Castellucci 2019). Additionally, greater disparities in alignment are likely to harmfully impact the posture (Castellucci, 2017).

To ensure the utility of anthropometric data, it must surely reflect the dimensions of the target population—those for whom the design is intended. Hence, it is crucial to perform a survey of workers' body dimensions before implementing new products or equipment in their workplace (Liu & Lien, 2012). Gathering such data at a national scale can be time-consuming, expensive, and complex. As a result, there is a rising inclination to acquire anthropometric data locally, particularly within specific industries (Barroso et al., 2005).

The retail sector is one where specific anthropometric data is relevant. The prevalence of Work-related Musculoskeletal Disorders (WMSD) is notably high in this sector, as reported by Kihlstedt & Hägg (2011) and Skovlund et al. (2022). The unappropriated design of workstations (e.g. cashiers station) and equipment (e.g. shelves) are frequently reported as important risk factors of WMSD in the retail sector. In fact, over the years, numerous investigations have explored the prevalence of WMSD within this sector (Baron & Habes, 1992; Violante et al., 2005; Sansone et al., 2014; Anton & Weeks, 2016; Deng et al., 2019). These studies identified various contributing factors related to the design, including the features of the scanner (Lehman et al., 2001; Palm et al., 2012; Palm et al., 2016), the checkout dimensions and other features that jeopardize cashier's posture (Lehman et al., 2001; Draicchio et al., 2012; Cudlip et al., 2015; Kihlstedt & Hägg, 2011; Draicchio et al., 2012; Maciukiewicz et al., 2017; Lang et al., 2018).

In retail sector, the problem of mismatch between operators' requirements and the equipment is even bigger due to the presence of clients. For example, checkout design can significantly influence customer behaviour, potentially resulting in stress for cashiers and contributing to the onset of various health issues affecting the neck, shoulders, wrists, and hands (Kihlstedt & Hägg, 2011).

Currently, there is a lack of research focusing on the match between the anthropometric measurements of workers and the dimensions of equipment and workstations in retail sector. Nowadays this even more challenge considering the need of a universal design that ensure comfort for all subjects. In view of this, it is of paramount importance to start with a comprehensive study of the anthropometric characteristics of workers in this sector.

Therefore, the primary goal of this study was to collect anthropometric measurements from adult employees in the retail sector, aiming to enhance Portugal's existing anthropometric information through the creation of a comprehensive database. This database will be instrumental in improving the working environment and minimizing health and safety issues, particularly in reducing the occurrence of musculoskeletal injuries. Additionally, it will allow to better understand the Portuguese active adult population features and its changes along the years and the sector of activity.

2.2 Methodology

2.2.1 Sample characterization

The study was conducted in a Portuguese food retail industry, specifically focusing on a supermarket store located in the North of Portugal with a workforce of around 390 individuals. The sample comprised 155 workers who were randomly selected from the different supermarket sections: Bakery; Bazaar; Bazaar - flows; Bazaar - supply; Butchery; Cafeteria; Cashier station; Charcuterie; Cleaning supplies - flows; Customer Service; Food; Food Safety; Food Supply; Fresh; Fresh - supply; Fruits and vegetables; Grocery/drinks - flows; Non-food; Seafood; Reception; Sales - bazaar; Sales - food; Sales – textile; Takeaway and Textile. This sample accounts for 39.74% of the total supermarket workforce. The age range of the subjects was 18 to 64 years old.

2.2.2 Study design

The data collection process was conducted by two measurers who served as evaluators and recorders. It was carried out at various times of the day, in order to include different shifts.

Prior to the study, each worker was introduced to the study and any questions they had were addressed by the research team. After that, the written consent was obtained from each subject.

A questionnaire was administered to gather demographic data including age, dominant hand, level of physical activity and attire. Additionally, measurements were taken for body composition parameters such as body mass, fat percentage, body water percentage, muscle mass, physical classification, bone mass, and visceral fat were collected using a Tanita body composition scale (Model BC-543, Japan). This data was also used to determine the Body Mass Index (BMI), a measure for indicating nutritional status in adults (World Health Organization, 2010). After these procedures, static anthropometric dimensions were collected.

The study was previously approved by the Ethics Committee of the School of Health of the Polytechnic Institute of Porto (CE0061D).

2.2.3 Equipment and procedure for anthropometric dimensions collection

For the purpose of this study, 28 static anthropometric dimensions, considered relevant for workstation design in the food retail industry, were measured for each participant. Out of these dimensions, 7 were measured with the individual standing, while the remaining 21 were measured in a sitting position. These dimensions were selected according to previous anthropometric studies (see Barroso et al., 2005; Castellucci et al., 2019; Filho et al., 2023) and considering a previous analysis of the target equipment and workstation design requirements.
The anthropometric dimensions were obtained using the following equipment (see Figure 1): (a) a stationary anthropometer, (b) two dynamic anthropometers (one small and one large) (RealMet Institute, Barcelona, Spain) and (c) a height-adjustable stool with four different height settings (300, 350, 400, and 450 mm).

(a) (b) (c)

Figure 1: Equipment used for taking anthropometric measures: (a) stationary anthropometer, (b) dynamic anthropometers, (c) height-adjustable stool

The dynamic and stationary anthropometers were used in conjunction with the height-adjustable stool to accurately measure dimensions while participants were in seated positions. It was ensured that all equipment used was calibrated according to the requirements. Therefore, there was no need to perform calibrations between measurements.

For the measurement of anthropometric dimensions, the procedure followed the ISO 7250-1:2017. All measurements were taken on the right side of the body, and the definitions used for the measurements were according to ISO 7250-1:2017 and Pheasant and Haslegrave (2006) (Appendix 1).

The measurement procedure started with the worker being directed to the stationary anthropometer, where all body dimensions were collected. For measurements that required a seated position, the stool's height was adjusted to ensure a 90-degree knee angle for each worker. Each measurement typically took around 15 minutes.

2.2.4 Pilot study: Intra- and inter- measurers reliability

The anthropometric measurements were collected by two measurers who had prior knowledge of ergonomics and anthropometry. These measurers underwent a comprehensive training period, which included topics such as equipment handling and practical measurement techniques.

To validate the measuring procedure and assess the accuracy of the acquisition procedures, a pilot study was carried out on a group of 22 participants with a diverse range of anthropometric percentiles (i.e., 5th, 50th, and 95th percentiles), encompassing both genders. These subjects were not part of the anthropometric study sample.

Each of the 28 static anthropometric measurements was taken twice to each subject by each evaluator. For data treatment, the intraclass correlation coefficient (ICC) was determined.

The consideration of inter- and intra-measurer reliabilities can enhance measurement reliability (Portney & Watkins, 2009). Inter-measurer reliability assesses the level of consistency or agreement in readings between two measurers for the same subjects. Intra-measurer reliability evaluates the consistency or agreement in readings by the same measurer for the same subjects at two distinct time points (Jamaiyah et al. 2011).

We used the ICC to assess consistency for both within (intra-measurer reliability) and between measurers (inter-measurer reliability). The ICC, ranging from 0.00 to 1.00, is interpreted as follows: ICC ≤ 0.50 indicates weak reliability, 0.50 < ICC ≤ 0.75 suggests moderate reliability, ICC ≥ 0.75 indicates strong reliability and ICC ≥ 0.90 indicates excellent reliability (Koo & Li, 2016).

In the current study, ICC values calculated for intra-measurer 1, ranged from 0,968 to 0,999, while for intra-measurer ranged from 0,989 to 1,00. The inter-measurer ICC values ranged between 0,905 and 0,998, indicating excellent reliability.

2.2.5 Data analysis

All the collected data was stored in Microsoft® Excel (2016) software. After checking the data for errors and validating, it was further analyzed and processed using Excel 2016 (Microsoft) and IBM SPSS Statistics 28. Key information including central tendency averages, normality tests, correlations, errors, and percentiles (specifically, the 5th, 50th, and 95th percentiles) was obtained throughout the mentioned software. Ultimately, the results were presented in the form of an anthropometric table.

2.3 Results

2.3.1 Sample characterization

The sample size of this study (*n* = 155) accurately represented the population of the store, which had a total of 390 workers. The statistical significance was determined to be α = 39.74%. Additionally, the gender proportion in the study closely reflected that of the company, with females accounting for 75.5% in the study compared to 73.33% in the supermarket, and males making up 24.5% in the study compared to 26.67%.

Figure 2 describes the sample according to age category and gender. Data shows that the majority of the studied sample are women (75.5%). Most of the subjects are over 40 years old, with an average age of 45 years (sd= 14.0) for women and 38 years (sd= 14.7) for men, with a concentration in the 55-59 years old category for women. A total of 56.13% of the sampled population is classified as middle-aged, according to the classifications made by the World Health Organization, with age surpassing 45 years (United Nations, 1982).

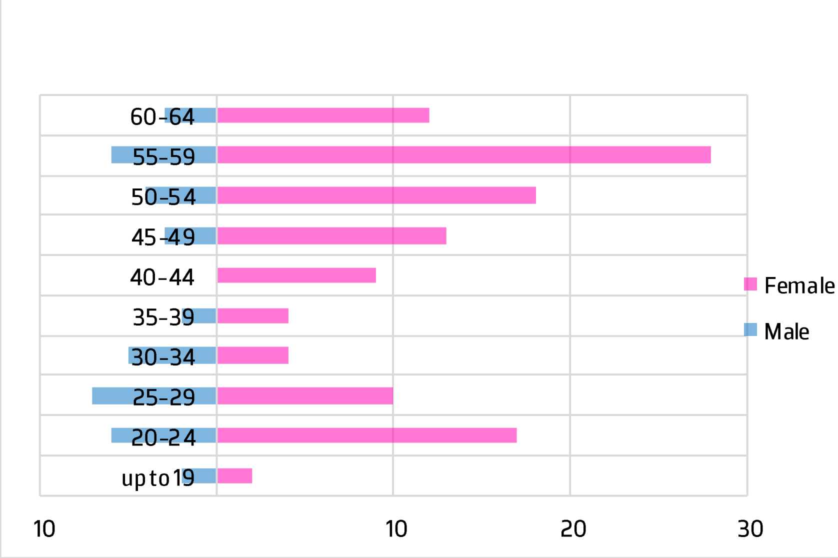

Figure 2: Sample distribution, by age and gender

Regarding the level of physical activity, data collected denoted that most of the sample under study falls under the "Inactive". Out of the total participants, 103 subjects (66.5%) reported doing less than 30 minutes of physical activity per week. Additionally, 21 participants (13.5%) claimed to be "Moderately active", engaging in 30 minutes to 1 hour of physical activity weekly. Finally, 31 participants (20%) assert that they were "Active", dedicating more than 1 hour to physical activity each week.

About the dominant hand, 143 individuals (92.26%) identified themselves as right-handed, while 10 individuals (6.45%) were left-handed, and 2 individuals (1.29%) reported to be ambidextrous.

Regarding the obtained mean body composition parameters, the Tanita body composition scale assesses the percentage of muscle and body fat and classifies the body into one of the nine body types. Most females considered fell under type 4 – under-exercised, with an average amount of body fat and low muscle mass ($\bar{x}$= 4; sd= 2) whereas males tend to be classified as type 3 – solidly built, with a high percentage of body fat and significant muscle mass ($\bar{x}$= 3; sd= 1).

Regarding the remaining parameters assessed by Tanita – Body Fat (%); Total Body Water (%); Bone Mass (kg) and Visceral Fat(kg) - it recommends the values in Table 2.

For the male population under assessment, the body fat percentage ($\bar{x}$ = 22.5%; sd= 7.6%) exceeded the recommended values, taking into account an average age of 38 years (sd= 14.7). The bone mass ($\bar{x}$ = 3.0 kg; sd = 0.3 kg) fell short of the recommended values, given an average weight of 78 kg, but remained within acceptable ranges when considering the average age of 38 years (sd= 14.7). However, body water ($\bar{x}$ = 57.4%; sd= 7.3%) and visceral fat ($\bar{x}$ = 8.5 kg; sd= 5.3 kg) values were within acceptable ranges, although they approached the upper limits of what is considered healthy.

Table 2: Recommended values for the body composition parameters evaluated using the Tanita scale

Parameters	Female			Male		
Body fat (%)	20 – 39 years	40 – 59 years	60 – 79 years	20 – 39 years	40 – 59 years	60 – 79 years
	21% – 33%	23% – 34%	24% – 36.5%	7% – 20%	10.5% – 22%	11,5% – 25%
Total Body Water (%)	45% - 60%			50% - 65 %		
Bone Mass (kg)	less than 50kg	50kg – 75kg	over 76kg	less than 65kg	65kg – 95kg	over 95 kg
	1.95	2.40	2.95	2.65	3.29	3.69
Visceral Fat (kg)	1 – 12			1 – 12		

For the analyzed female sample, visceral fat ($\bar{x}$= 7.1 kg; sd = 3.3 kg) values were within the recommended range. However, when taking into account an average age of 45 years (sd= 14.0), the body fat percentage ($\bar{x}$= 34.7%; sd= 8.9%) slightly exceeded the recommended values. Additionally, the female population exhibited lower levels of body water ($\bar{x}$= 45%; sd= 5.2%) and bone mass ($\bar{x}$= 2.3 kg; sd = 0.2 kg), given an average weight of 69.6 kg (sd= 15.6kg).

2.3.2 Anthropometric dimensions

Table 3 presents the collected anthropometric static dimensions and body mass index (BMI) for both females and males. This data includes values obtained for average and standard deviation, as well as the fifth percentile (P5), fiftieth percentile (P50), and ninety-fifth percentile (P95).
From the anthropometric data collected, it is possible to denote that the average height (stature) and weight (BM) of our sample population were respectively 1,72m and 78,7kg for men, and 1,58m and 69,6kg for women. The average BMI obtained for females was 27.7, while for males, it stood at 26.5. These figures categorized both genders as falling within the pre-obesity range (see table 4). Data also indicates that, except for hip breadth, men exhibited greater average body segmental dimensions compared to women.

Table 3: Anthropometric data collected in the present study

Anthropometric Dimensions*	Female					Male				
	Average	**SD**	**P5**	**P50**	**P95**	**Average**	**SD**	**P5**	**P50**	**P95**
1 HandL (mm)	83	60	71	65	85	89	18	80	86	98
2 HandB (mm)	171	12	159	171	183	184	19	165	188	199
3 FootL (mm)	237	12	221	236	259	260	13	241	263	277
4 FootB (mm)	93	6	85	92	102	99	6	90	99	110
5 Stature (mm)	1582	60	1499	1580	1676	1725	80	1616	1725	1863
6 VGR (mm)	1869	92	1716	1863	2005	2080	98	1942	2080	2258
7 EyeH (mm)	1481	61	1396	1480	1587	1621	79	1504	1621	1760
8 ShoulderH (mm)	1293	55	1207	1289	1382	1418	70	1308	1415	1552
9 ElbowH (mm)	990	43	934	987	1065	1075	51	997	1077	1182
10 KnuckleH (mm)	653	32	598	654	701	707	42	655	707	782
11 FGR (mm)	676	40	609	675	738	732	45	659	733	804
12 SittingH (mm)	852	33	798	853	904	909	39	849	910	970
13 SittingVGR (mm)	1133	79	1015	1140	1239	1242	98	1138	1252	1344
14 EyeHS (mm)	753	76	688	749	803	798	50	748	805	861
15 ShoudlerHS (mm)	562	39	513	562	611	592	65	548	601	661
16 ElbowHS (mm)	261	42	220	262	315	257	53	220	265	304
17 EGL (mm)	329	39	294	322	360	368	43	323	363	422
18 BKL (mm)	579	34	531	578	628	606	38	546	610	663
19 KneeH (mm)	486	26	451	485	524	533	33	492	530	583
20 BP (mm)	490	32	439	489	533	505	37	446	503	566
21 PoplitealH (mm)	381	24	350	380	417	429	31	385	427	501
22 Abdominal (mm)	223	43	166	216	301	237	39	191	238	311
23 ETEB (mm)	453	54	174	216	301	471	41	403	475	536
24 SBD (mm)	430	38	373	427	498	471	31	424	468	518
25 SBA (mm)	362	23	329	361	404	394	20	365	393	427
26 HipB (mm)	402	40	346	399	459	370	29	323	370	418
27 SSH (mm)	432	26	388	435	470	453	26	410	453	493
28 ThighC (mm)	151	25	114	149	193	151	18	128	146	185
29 BM (kg)	69,6	15,6	49,1	68,8	94,0	78,7	13,1	57,3	76,5	99,3
30 BMI (kg/m2)	27,7	5,6	19,6	27,1	36,6	26,5	3,9	19,2	27,5	31,7

*Hand length (Hand L), hand breadth (HandB), foot length (FootL), foot breadth (FootB), stature (Stature), vertical grip reach (VGR), eye height (EyeH), shoulder height (ShoulderH), elbow height (ElbowH), knuckle height (KnuckleH), forward grip reach (FGR), sitting height (SittingH), vertical grip reach sitting (SittingVGR), eye height sitting (EyeHS), shoulder height sitting (ShoulderHS), elbow height sitting (ElbowHS), elbow grip length (EGL), buttock-knee length (BKL), knee height (KneeH), Buttock popliteal height (BPL), popliteal height (PoplitealH), abdominal depth (Abdominal), elbow to elbow breadth (ETEB), shoulder breadth bideltoid (SBD), shoulder breadth biacromial (SBA), hip breadth (HipB), subscapular height (SSH), thigh clearance (ThighC), body mass (BM), body mass index (BMI).

Table 4 shows the value ranges for BMI.

Table 4: Nutritional status. Source: World Health Organization, 2010

BMI	Nutritional status
Below 18.5	Underweight
18.5 – 24.9	Normal weight
25.0 – 29.9	Pre-obesity
30.0 – 34.9	Obesity class I
35.0 – 39.9	Obesity class II
Above 40	Obesity class III

2.4 Discussion and Study Limitations

Overall, it was observed that men generally displayed higher average body segmental dimensions compared to women, apart from hip breadth. These findings align with the typical patterns observed in adult populations, as previously documented by Barroso et al. (2005) and Filho et al. (2023). The latter employs the same methodology as the present study.

To understand if there were changes in anthropometric dimensions over time, study findings were compared with Barroso et al. (2005), who examined 25 anthropometric dimensions among Portuguese workers in both the industrial and tertiary sectors. Additionally, a comparison was made with the findings of Filho et al. (2023), which collected 27 anthropometric measures from 343 workers in a Portuguese industry, to assess disparities between the current Portuguese working population in the food retail industry and that in a manufacturing company. These comparisons for gender and age are summarized in Table 5.

The present study investigates a broader sample of women, especially those in older age groups, a trait frequently observed in the retail sector (Chang & Travaglione, 2011; Chang et al., 2015; Pilcher, 2007). According to Chang, (2011), in Australia, female employees dominated retail employment in general, with 57.2% of all employees being women. This inclination can be attributed to the fact that females are more likely to engage in homemaking or childcare responsibilities, making them better suited for part-time or casual retail employment compared to males. (Chang & Travaglione, 2011).

Table 5: Sample population characteristics: Barroso et al. (2005) v. Filho et al. (2023) v. present study

Sample characteristics		**Barroso et al. (2005)**	**Filho et al. (2023)**	**Present study**
Gender	*Male*	55.2%	49.3%	24.5%
	Female	44.8%	50.7%	75.5%
Age	Less than 20			
	Male	10.2%	0.6%	1.29%
	Female	8.0%	0.0%	1.29%
	20-50			
	Male	81.9%	86.4%	14,84%
	Female	78.5%	62.1%	39,35%
	More than 50			
	Male	11.4%	13.0%	8,39%
	Female	10.0%	37.9%	34,84%

An examination of the latest data from the Office for National Statistics (ONS) in 2021 reveals that 67% of employees engaged in roles on supermarket shop floors are women, with a significant portion of them aged 45 or older. When focusing specifically on checkout and cashier positions, this percentage rises to 70% as cited by Winton (2023).

Table 6 shows the comparison of BM, stature and BMI between the sample populations in the studies conducted by Barroso et al. (2005), Filho et al. (2023), and the current study. For the study by Barroso et al. (2005) the BMI had to be previously calculated using the average height and weight.

Table 6 shows the comparison of BM, stature and BMI between the sample populations in the studies conducted by Barroso et al. (2005), Filho et al. (2023), and the current study. For the study by Barroso et al. (2005) the BMI had to be previously calculated using the average height and weight.

Table 6: Barroso et al. (2005) v. Filho et al. (2023) v. present study BMI. BM is given in kg, Stature in mm, and BMI in kg/m².

Study	Female			Male		
	BM (kg)	Stature (mm)	BMI (kg/m2)	BM (kg)	Stature (mm)	BMI (kg/m2)
Barroso et al. (2005)	64.0	1565.0	26.1	74.0	1690.0	25.9
Filho et al. (2023)	63.7	1594.7	25.2	77.9	1740.7	25.7
Present study	69.6	1582.0	27.7	78.7	1725.0	26.5

It is possible to realize that the average BM obtained for both the female and male populations is slightly higher in this study. Regarding the stature, results revealed that the population has experienced growth, in the same way as observed previously by Filho et al. (2023).

When comparing results from this study with the ones obtained recently by Filho et al. (2023) in an industry, data reveals that our sample population has slightly shorter stature and higher weight. However, the differences are lower than when compared to Barroso et al. (2005). This outcome was anticipated, as the advent of modernity has witnessed a significant surge in heights within the developed world (Roser & Ritchie, 2013). The trend in adult height and weight has shown a predominantly linear increase since the mid-19th century. However, in the late 20th century, the rate of height increase decelerated and approached a period in Northern Europe, while weight continued to rise steadily as part of the global obesity epidemic (Cole, 2002).

Variations in height within a population result from the interplay of genetic and environmental factors. Greater environmental diversity leads to a wider range of heights.

In a population where access to nutrition and healthcare resources is perfectly equitable, height distribution mainly reflects genetic diversity (Roser & Ritchie, 2013). However, when there is unequal access to these resources within a population, individuals with greater wealth tend to experience better health and nutrition, resulting in increased height. Consequently, a high level of socioeconomic development is often associated with taller average heights (Roser & Ritchie, 2013). Higher per capita incomes, improved sanitation in housing and living conditions, enhanced health and nutrition education, and more robust social services and healthcare systems are key determining factors linked to increasing height (Kelland, 2013).

Even in contemporary times, it remains evident that men and women often engage in distinct types of work (Pilcher, 2007). Excess weight in women may be linked to sedentary work-related activities, such as cashier and customer support positions. Women continue to be overrepresented in the service sector, often occupying 'softer' social roles that demand a substantial degree of emotional labour (Chang et al., 2015; Toynbee, 2006). Meanwhile, men typically fill 'more physically and technically demanding' roles like working in logistics (Chang et al., 2015).

Both male and female employees experience overwork and physical conditions that could be improved by increasing physical activity and enhancing water intake. The study unveiled significantly low levels of physical activity, with over half of the participants reporting less than 30 minutes of physical activity per week. This can be attributed to the physically demanding nature of food retail work, coupled with irregular schedules as noted by Skovlund et al. (2022), along with the relatively advanced age of the workers.

Observations revealed that, on average, males exhibited greater dimensions than females, with the anticipated exception of hip breadth, supported by findings from previous anthropometric studies such as Castellucci et al. (2019), Molenbroek et al. (2017) and Filho et al. (2023). Additionally, both genders had a consistent thigh clearance value of 151 mm.

Despite the significance of the obtained results, it is important to acknowledge the limitations of this study. Data collection was only conducted in one supermarket. While this supermarket is the largest in the group and has a larger workforce, populations with different anthropometric characteristics may exist in other stores and regions of the country. Another significant limitation was the potential occurrence of measurement errors, including misread values, inadequately collected data, and improperly positioned equipment.

2.5 Conclusion

In the present study, an anthropometric database for the food retail industry was developed. These results contribute to both, equipment and workstation design, as well as to characterize the Portuguese adult population anthropometric measures. In future designs of supermarket sections or work equipment and workstations, it is essential to consider the anthropometric measurements of the workers obtained in this study.

The data obtained was also relevant to understanding some characteristics of the retail workers' bodies, that can jeopardize their health, as well as to better understand the tendency of the Portuguese population in relation to their measures.

BMI values showed that both men and women appear to be overweight, with these findings being in accordance with overall global trends of overweight and obesity.

In the future, it is advisable to conduct a more comprehensive investigation of the workers' body composition to gain a deeper understanding of this matter.

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Appendix 1

Table 1: Description of the measured anthropometric dimensions

Equipment[a]	Dimension	Abbreviation	Definition[b]
Standing			
SA + SDA	Stature	Stature	Vertical distance between the floor and the top of the head measured with the subject erect and looking straight ahead (Frankfort plane)
SA + SDA	Vertical grip reach	VGR	Distance from the floor to the centre of a cylindrical rod grasped in the palm of the hand, with the arm raised vertically above the head in an easy reach (without excessive stretch)
SA + SDA	Eye height	EyeH	Vertical distance from the floor to the outer corner of the eye
SA + SDA	Shoulder height	ShoulderH	Vertical distance from the floor to the acromion
SA + SDA	Elbow height	ElbowH	Vertical distance from the floor to the lowest bony point of the bent elbow
SA + SDA	Knuckle height	KnuckleH	Vertical distance from the floor to metacarpal III
SA + SDA	Forward grip reach	FGR	Horizontal distance from a vertical surface to the grip axis of the hand while the subject leans both shoulder blades against the vertical surface
Sitting			
SA + SDA + AS	Height (Sitting)	SittingH	Vertical distance between subject's seated surface to the top of the head measured with the subject erect and looking straight ahead (Frankfort plane)
SA + SDA + AS	Vertical grip reach sitting	SittingVGR	Distance from the seat surface to the centre of a cylindrical rod grasped in the palm of the hand, with the arm raised vertically above the head in an easy reach (without excessive stretch)
SA + SDA + AS	Eye height sitting	EyeHS	Vertical distance between the sitting surface to the inner canthus (corner) of the eye (head in Frankfurt plane)
SA + SDA + AS	Shoulder height sitting	ShoulderHS	Vertical distance from subject's seated surface to the acromion
SA + SDA + AS	Elbow height sitting	ElbowHS	Taken with a 90 ◦ angle elbow flexion. Vertical distance from the bottom of the tip of the elbow (olecranon) to the subject's seated surface
SA + SDA + AS	Buttock-knee length	BKL	Horizontal distance from the foremost point of the kneecap to the rearmost point of the buttock

[a] Stationary anthropometer (SA), Large Dynamic anthropometer (LDA), Small Dynamic anthropometer (SDA), Adjustable stool (AS),

[b] Sources: (ISO 7250-1:2017 and Pheasant & Haslegrave, (2006)

Table 1: Description of the measured anthropometric dimensions *(cont.)*

Equipment[a]	Dimension	Abbreviation	Definition[b]
Sitting			
SA + SDA + AS	Knee height	KneeH	Vertical distance from the floor or footrest to the highest point of the superior border of the patella
SA + SDA + AS	Buttock-popliteal length	BPL	Horizontal distance from the popliteal surface to the rearmost point of the buttock
SA + SDA + AS	Popliteal height	PoplitealH	Vertical distance from the floor or footrest to the posterior surface of the knee (popliteal surface)
LDA + AS	Thigh clearance	ThighC	Vertical distance from the highest uncompressed point of thigh to the subject's seated surface
SA + SDA + AS	Elbow grip length	EGL	Horizontal distance from back of the upper arm (at the elbow) to grip axis, with elbow bent at right angles
LDA + AS	Abdominal depth	Abdominal	Maximum horizontal distance from the vertical reference plane to the front of the abdomen in the standard sitting position
LDA + AS	Elbow to elbow breadth	ETEB	Maximum horizontal breadth across the elbows
LDA + AS	Shoulder breath (bideltoid)	SBD	Distance across the maximum lateral protrusions of the right and left deltoid muscles
LDA + AS	Shoulder breath (biacromial)	SBA	Distance between the outermost bony points on the top of each shoulder
LDA + AS	Hip breadth	HipB	Horizontal distance measured in the widest point of the hip in the sitting position
LDA + AS	Subscapular height	SSH	Vertical distance from the lowest point (inferior angle) of the scapula to the subject's seated surface
LDA + AS	Hand length	HandL	Perpendicular distance from a line drawn between the styloid processes to the tip of the middle finger
SDA + AS	Hand breadth	HandB	Projected distance between radial and ulnar at the level of the metacarpalphalangeal joint of digit 1 to the ulnar side of the hand second to the fifth metacarpal
LDA + AS	Foot breadth	FootB	Maximum distance between medial and lateral surfaces of the foot perpendicular to the longitudinal axis of the foot

[a] Stationary anthropometer (SA), Large Dynamic anthropometer (LDA), Small Dynamic anthropometer (SDA), Adjustable stool (AS),

[b] Sources: (ISO 7250-1:2017 and Pheasant & Haslegrave, (2006)

Table 1: Description of the measured anthropometric dimensions *(cont.)*

Equipment[a]	Dimension	Abbreviation	Definition[b]
Sitting			
LDA + AS	Foot length	FootL	Maximum distance from rear of the heel to tip of the longest (first or second) toe, measured parallel to the longitudinal axis of the foot
Calculated			
Calculated through a formula	Body Mass Index	BMI	Calculated using the formula: BMI (kg/m^2) = Weight (kg)/ Stature (m^2)

[a] Stationary anthropometer (SA), Large Dynamic anthropometer (LDA), Small Dynamic anthropometer (SDA), Adjustable stool (AS),

[b] Sources: (ISO 7250-1:2017 and Pheasant & Haslegrave, (2006)

Conclusion and future research

This study aimed to conduct an ergonomic assessment in the cashier's section at a supermarket. It also focused on gathering anthropometric measurements of the workers in the specified supermarket.

The findings reveal significant concerns regarding the ergonomic aspects of the cashier station. During the anthropometric study, workers often complained about their workplace conditions and frequently reported experiencing musculoskeletal problems. A comparative analysis of the collected anthropometric data with existing records supported the evidence of growth within the Portuguese population.

Future research should investigate into assessing the match between supermarket checkout counter dimensions and the anthropometric measurements of the workers. Furthermore, redesigning checkout counters and other supermarket sections or work equipment with meticulous attention of the workers' anthropometric measurements is recommended.

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