Heliyon 10 (2024) e28384

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Review article

A systematic review of research on sitting and working furniture ergonomic from 2012 to 2022: Analysis of assessment approaches

Yifan Bai **, Khairul Manami Kamarudin *, Hassan Alli

Industrial Design Department, Faculty of Design and Architecture, Universiti Putra Malaysia, Selangor, 43400, Malaysia

A R T I C L E I N F O

Keywords:
Systematic literature review
Musculoskeletal disorders
Sitting and working furniture
Furniture comfort
Ergonomic assessment

A B S T R A C T

This study analyses which aspects of sitting and working furniture ergonomics that may be influenced and how they are assessed. To gather information on the types and assessment techniques connected with influencing furniture ergonomics, a systematic review of the literature was conducted. The papers in the systematic review were published between 2012 and 2022. The articles applied the Systematic Reviews and Meta-Analyses (PRISMA) statement guidelines to limit the 41 papers that were eventually included (N = 41) to those containing keywords like ergonomics, human factors, comfort, working furniture, Chair, assessment and evaluation. The research objective of this systematic review is to provide a comprehensive overview of sitting and working furniture and the main findings, obtaining common assessment techniques for this type of furniture and their suitability.

According to the relevant studies, the publications were categorized by summarizing factors like region, gender, research methods, ergonomic assessment techniques and methods used, correlation between assessment techniques and methods, etc. Summaries of the data extracted from the included papers are provided and the applicability of some approaches are assessed. Only a small number of authors have evaluated the ergonomics of furniture used in homes. One of the research gaps is the paucity of research on gender segregation, secular trends, and cultural contexts. These studies heavily rely on quantitative research techniques, and the articles may lack credibility due to the homogeneity of the evaluation techniques. Finally, the authors offer some suggestions for the appropriate ergonomic analysis of furniture.

1. Introduction

In the current high-intensity work and life environment, people have to face many health problems, especially due to sitting activities. Sitting workstations promote inactivity and sedentary behavior, which are linked to detrimental health effects [1]. Some population-based studies show that Americans spend approximately 8–9 h a day sitting at work [2], Australians spend 71%–82% of their work time in a chair [3], and employees using computer workstations in the Netherlands sit for an average of 7 h a day [4]. Whether it's office space related to computer work or school desks and chairs related to learning, these workplaces and furniture are characterized by sedentary and inactivity [5,6]. At least 63% of office workers in such research said they experienced extreme discomfort in one or several regions of the body [7], which could result in Musculoskeletal Disorders (MSD). In 2010, MSD is defined as

* Corresponding author. Khairul Manami Kamarudin
** Corresponding author. Yifan Bai
E-mail addresses: gs60059@student.upm.edu.my (Y. Bai), manami@upm.edu.my (K.M. Kamarudin).

https://doi.org/10.1016/j.heliyon.2024.e28384
Received 23 April 2023; Received in revised form 3 March 2024; Accepted 18 March 2024

a group of inflammatory or degenerative symptoms that affect many body areas, including ~~as~~ the neck, back, arms, or legs, according to the RSPSAT(Réseau de Santé Publique en Santé au Travail Occupational Health Public Health Network) organization of Quebec. These MSDs are a significant problem in many countries around the world. Among them, adults have experienced Work-related Musculoskeletal Disorders (WMSDs) at work [8], while adolescents have to fight against Classroom Musculoskeletal Disorders (CMSDs). Many studies have shown that WMSDs generate significant risks in terms of economic and occupational health [9,10], and it is also one of the major Occupational Diseases (ODs). Some countries and regions have compiled statistics on this data: 38.1% of ODs in Europe are from WMSDs, and this number is gradually increasing among young people and women [11]; while in the United Sates alone, more than 600,000 WMSDs accounted for one-third of all lost workdays in 2014, resulting in a cost of $54 billion in 2014 [12]. In terms of health, WMSDs can damage many parts of the body, such as muscles, tendons, ligaments, cartilage, bones, joints, and/or nerves [13]. Cumulative Trauma Disorders (CTD) and injuries resulting from Manual Material Handling (MMH) fall into several categories for the musculoskeletal system [14]. According to Kroemer (1989), CTD is a general term describing disorders with or without clinical symptoms that are hypothesized to cause pain, impairment, or chronic discomfort in the muscles, joints, tendons, and other soft tissues [15]. These syndromes frequently affect the wrist, neck, hands, and shoulders.

Students are one of many groups at risk of developing CMSDs as a result of a variety of risks or factors. Children and adolescents spend the majority of their day in the classroom, sitting on school furniture, doing activities such as reading and writing [16,17]. Students' health is highly vulnerable to the negative effects of non-anthropometric furniture due to the amount of time they spend sedentarily [18]. Prolonged use of such furniture can cause discomfort and pain, as well as having a direct impact on the spine's posture and physical development during the growth period [19,20]. Poor postural behavior is a significant risk factor for MSD problems, which are influenced by furniture design, teaching orientation, and classroom structure [21]. Furniture designs that correspond to students' anthropometric data are good designs which promote proper sitting posture and help to reduce the incidence of musculoskeletal disorders. Conversely, furniture that mismatch students' anthropometric measurements may have a negative impact on classroom activities such as writing and reading, leading to back, shoulder, neck, leg and eye pain [22]. As a result, every daily human activity necessitates the involvement of ergonomics, which enables the satisfaction of the psychophysiological characteristics of humans seeking comfort, health, and safety [23]. All human-oriented working conditions must be evaluated holistically, as well as all daily activities must adhere to ergonomic principles [24]. When pursuing an individual's total well-being, the workplace, and particularly the furniture, should first meet the basic requirements of safety and comfort [16]. Based on the discussion above, designers require a good understanding of anthropometric and ergonomic aspects, in addition to the use of specific assessment methods, in order to understand risk exposure factors and avoid MSDs [25].

Comfort is an individual nature with subjectivism and is influenced by a variety of factors (physical, physiological, psychological), as well as a response to the surrounding environment, showing continuous dimensional changes [26]. Comfort can be evaluated by subjective evaluation and objective data measurement. Whereas, in ergonomic studies of chairs, Musculoskeletal Disorders (MSD) can be caused due to prolonged discomfort. In the analysis of MSD in office environments, subjective comfort evaluation as well as pressure distribution are two good criteria [23]. The low back is the most dominant part of WMSD [27]. As for CMSD, the mismatch of desk and chair sizes leads to uncomfortable sitting posture [16].Because of the high global growth rate of WMSDs and CMSDs, many scholars and researchers have conducted extensive research to address the problem of MSDs. In particular, scholars working in the field of Ergonomics or Human Factor(E/HF) have studied the ergonomics of furniture from a quantitative point of view in two broad technical categories. The first is through the biomechanical or physiological application of technical methods such as Electromyography (EMG) and Heart Rate Variability (HRV) to assess comfort and task risk by observing physiological changes in human muscles and heart rate. These techniques are primarily used to objectively evaluate the chest and lower back muscles, along with the heart rate variability caused by high pressure environments. The anthropometric method of ergonomic evaluation falls under the second category. In addition to the two major categories of methods mentioned above, some authors study the ergonomics of furniture through qualitative analysis, such as using observation and interview methods, and literature review to analyze user perception. The health risks associated with work and daily activities, mismatched dimensions of furniture, exercise frequency and duration, heart rate load, furniture design, etc., are evaluated using all available technical methods. The majority of researchers utilized two or more approaches, and some authors combined subjective and objective methods, therefore the authors thought it was crucial to compare the results and conclusions of each method.

Currently, methods including the Rapid Entire Body Assessment (REBA), the Rapid Upper Limb Assessment (RULA), and the Nordic Musculoskeletal Questionnaire (NMQ) are used by numerous researchers for ergonomic assessment. The REBA is a scoring system for muscle activity caused by static, dynamic, rapid changes or instability and uses five levels of action to assess the level of corrective measures [28]. The method is a tool for analyzing posture and is used in some service industries to sensitively identify unpredictable types of work posture, based on the REBA body part map analysis of areas including the upper arms, lower arms, wrists, trunk, neck and legs [29]. The RULA is a method for assessing work posture through the use of a checklist that focuses on the upper body but does not exclude the lower body, and includes an assessment of the neck, the shoulders, trunk, wrists and arms in particular. It indicates the level of intervention required to reduce the risk of injury caused by the physical load on the worker through a determination of four levels of action [30]. It is a tool for screening risk factors for work-related upper limb disorders, taking into account the static movements and strength that may be required to perform the task [29]. The NMQ standardized questionnaire on general or low back and neck and shoulder discomfort is primarily aimed at screening for musculoskeletal disorders in an ergonomic context, as well as for use in occupational health services [31].

Viviani et al. [32] provided a systematic summary on the accuracy, precision and reliability of ergonomic measurements in the adult working population, suggesting that more attention should be on the procedures used to collect anthropometric data for ergonomic purposes. Meanwhile, Shaikha et al. [33] presented the causative and risk factors for musculoskeletal disorders in miners, arguing that the prevalence of musculoskeletal disorders among underground machine operators should be studied on a massive scale, so that more attention should be paid to mitigating specific WMSD causative factors. Based on the literature over the past 20 years, Anwer et al. [34] systematically examined the association between physical or psychosocial risk factors and work-related musculoskeletal disorders in construction workers, and the authors summarized the prevalence of WMSD and synthesized new evidence on the association between various physical or psychosocial risk factors and WMSD among construction workers in different industries. Radwan et al. [35] provided a summary of whether adults with and without back pain were facilitated by different mattress designs for sleep quality, pain reduction and spinal alignment, concluding that a medium-sized mattress with custom inflatable (self-adjusting) mattress was best suited to promote sleep comfort, quality and spinal alignment. Subsequently, Joshi et al. [25] systematically compared workplace ergonomic assessment techniques, focusing on REBA, RULA, and the Ovako Working posture Assessment System (OWAS) for comparison, and the authors recommended the use of multiple techniques for postural assessment.

As a result, there is no comprehensive review of methods for assessing ergonomics in furniture, and a summary of methods for assessing E/HF is more fragmented. Many researchers have focused more on E/HF in work scenarios rather than summarizing the evaluation of E/HF in furniture used in schools, homes and other scenarios. Thus, it is difficult for researchers on furniture to find suitable evaluation methods to design good furniture with reduced MSDs at the beginning of the study.

1.1. Research objective

To address the problems mentioned above, this paper presents a systematic analysis of E/HF assessment methods involving the furniture category. This study has three main objectives.

(RO1) provides a comprehensive overview of the current state of research on the use of sitting and working furniture ergonomics, focusing on geographic scope, types of subjects, methods, sample characteristics, and major findings.

(RO2) Common evaluation techniques in sitting and working furniture ergonomics.

(RO3) Reviews the applicability of assessment methods.

From the perspective of the sitting and working furniture industry, this paper summarizes the methods and tools for E/HF from

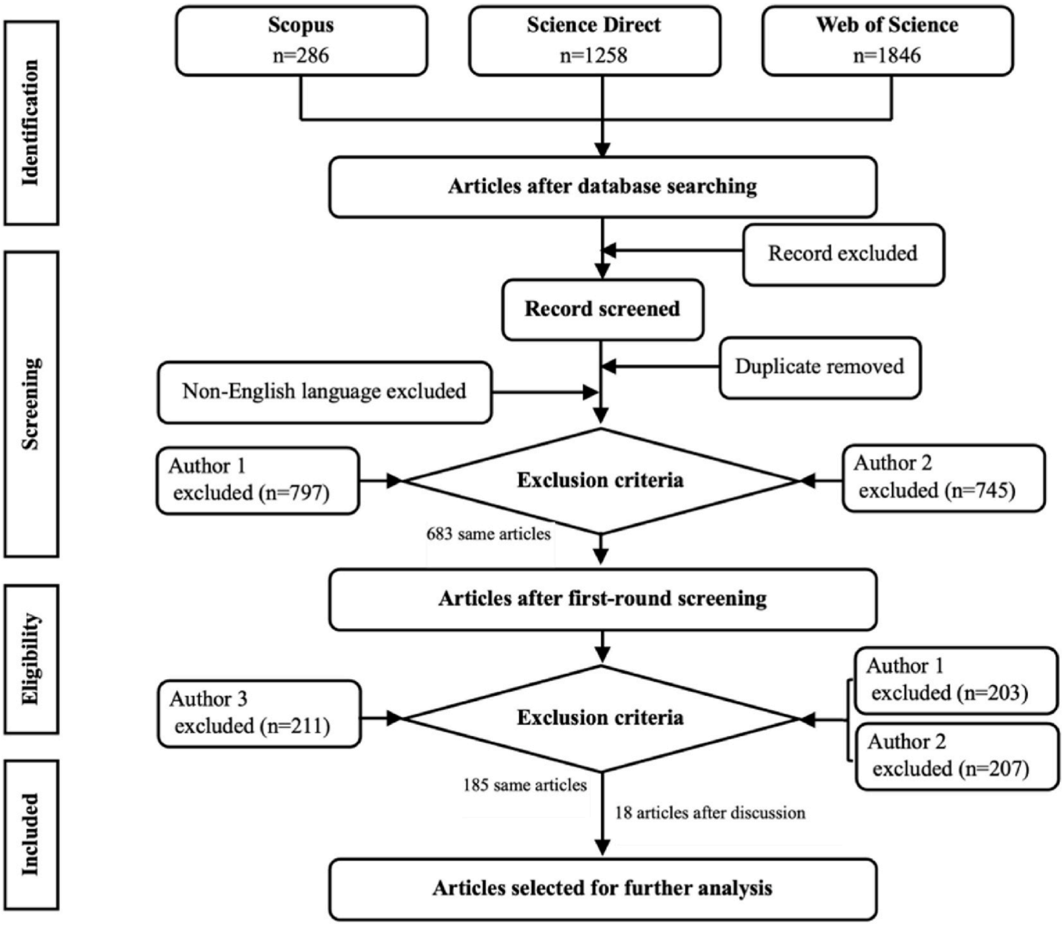

Fig. 1. Screening procedure and flow chart of PRISMA.

Table 1
Abstract of the publication.

Author(s)	Year of publication	Title	Source	Types	Respondent sample characteristics	Region	Sample size	Gender	Age
Taifa [38]	2022	A student-centred design approach for reducing musculoskeletal disorders in India through Six Sigma methodology with ergonomics concatenation	Safety Science	Classroom furniture	College undergraduate	India	478	M + F	19.9 ± 2.26
Fidelis & Ogunlade [39]	2022	Anthropometric perspective to classroom furniture ergonomics and the need for standards in Nigerian schools	Work	School furniture	Students from primary school, secondary schools and University	Nigerian	936	M + F	
Shohel et al. [40]	2022	Assessment of Musculoskeletal Problems among Bangladeshi University Students in Relation to Classroom and Library Furniture	Journal of The Institution of Engineers (India): Series C	Library furniture	Fourth-year undergraduate students	Bangladeshi	400	M + F	22 ± 0.82
Champion et al. [41]	2022	Chair design for older immobile people: Comparison of pressure mapping and manual handling outcomes	Applied Ergonomics	Chair	Employees or University staff or students	Australia	10	M + F	
Cabegi de Barros et al. [42]	2022	Effects of workstation adjustment to reduce postural exposure and perceived discomfort among office workers - A cluster randomized controlled trial	Applied Ergonomics	Workstation	Office workers	Brazil	61	M + F	18–60
Wang et al. [43]	2022	Improvement of Chair in Ladder Classroom Based on Human Data and Behavior Investigation of College Students	International Conference on Digital Human Modeling and Applications in Health, Safety, Ergonomics and Risk Management	Classroom furniture	College students	China	69	M + F	
Rodrigues et al. [44]	2022	Ergonomic assessment of office worker postures using 3D automated joint angle assessment	Advanced Engineering Informatics	Workstation	Computer users	USA	20	M + F	
Cardoso et al. [45]	2021	A biomechanical analysis of active vs static office chair designs	Applied Ergonomics	Active and static office chair	Office worker	Canada	30	F	23.9 ± 4.1
Famero et al. [46]	2021	Ergonomic Design of a Computer Workstation for Preschool Students Studying at Home	Proceedings of the International Conference on Industrial Engineering and Operations Management Rome, Italy	Desk	Preschool students	Philippines	100	M + F	4–6
Cadiz et al. [47]	2021	Ergonomic Design of Computer Workstations of High School Students Studying at Home	Proceedings of the International Conference on Industrial Engineering and Operations Management Rome, Italy	Workstations	High school students	Philippines	689		
Mao et al. [48]	2021	Automatic Sitting Pose Generation for Ergonomic Ratings of Chairs	IEEE Transactions on Visualization and Computer Graphics	Chair	User	China	10	M + F	20–38
Prasetyo et al. [49]	2021	Evaluation of Chair Dimensions, Anthropometric Measurements and Subjective Comfort Among Filipino High School Students: A Structural Equation Modelling Approach	International Conference on Industrial Engineering and Operations Management Sao Paulo	Chair	High School Student	Philippines	52	M + F	15–19
Bahrampour et al. [50]	2020	Determining optimum seat depth using comfort and discomfort assessments	International Journal of Occupational Safety and Ergonomics	Chair	University students	Iranian	36	M + F	23.3 ± 2.9

(*continued on next page*)

Table 1 (*continued*)

Author(s)	Year of publication	Title	Source	Types	Respondent sample characteristics	Region	Sample size	Gender	Age
Weatherson et al. [51]	2020	Impact of a low-cost standing desk on reducing workplace sitting (StandUP UBC): A randomised controlled trial	Applied Ergonomics	Workplace	Adults	Canada	48	M + F	18–65
Zhang et al. [52]	2020	Research on Ergonomic Design and Evaluation of Office Backrest Curve	International Conference on Ergonomics in Design	Office chair	Workers	China	2000	M + F	20–60
Koma et al. [53]	2019	Barriers to and facilitators for implementing an office ergonomics T programme in a South African research organisation	Applied Ergonomics	Office furniture	Operational managers and employees	South Africa	4		
Kahya [54]	2019	Mismatch between classroom furniture and anthropometric measures of university students	International Journal of Industrial Ergonomics	Classroom furniture	University students	Turkey	225	M + F	
Ncube et al. [55]	2019	Postural risk associated with Wooden Steel Chairs and Stackable Arm Chairs in a low-income country	Work	Wooden Steel Chairs (WSCs) and Stackable Arm Chairs (SACs)	Computer users	Zimbabwe	100	M + F	23.25 ± 1.6
Hong et al. [56]	2019	Research on Body Pressure Distribution of Office Chair with Different BMI	10th International Conference on Digital Human Modeling and Applications in Health, Safety, Ergonomics and Risk Management	Office chair	Adults	China	18	M + F	20–46
Godilano et al. [57]	2018	Design of an Ergonomic Classroom Chair and Desk for Preschool Students of Selected Public Schools in Cabuyao City, Laguna	2018 5th International Conference on Industrial Engineering and Applications	Chair and desk	Preschool students	Philippines	248	M + F	
Weston et al. [58]	2017	A biomechanical and physiological study of office seat and tablet device interaction	Applied Ergonomics	Office chair	Local population	USA	20	M + F	22.4 ± 2.4
Taifa & Desai [59]	2017	Anthropometric measurements for ergonomic design of students' furniture in India	Engineering Science and Technology, an International Journal	School furniture	College students	India	478	M + F	
Rodrigues et al. [60]	2017	Differences in ergonomic and workstation factors between computer office workers with and without reported musculoskeletal pain	Work	Workstation	Computer office workers	Not mention	35	M + F	18–55
Fettweis et al. [61]	2017	Relevance of adding a triangular dynamic cushion on a traditional chair: A 3D-analysis of seated schoolchildren	Clinical Biomechanics	School furniture	Schoolchildren	Belgium	30	M + F	7.8 ± 0.4
Charpe [62]	2017	User-Chair Fit Index (UCFI): An Ergonomic Evaluation Tool for User-Chair Compatibility	International Conference on Applied Human Factors and Ergonomics	Office chair	User	India	839	M	25–35
Ward & Coats [63]	2016	Comparison of the BackJoy SitSmart Relief and Spine Buddy LT1 H/C Ergonomic Chair Supports on Short-Term Neck and Back Pain	Journal of Manipulative and Physiological Therapeutics	Office chair	College students	Not mention	48		
De Carvalho et al. [64]	2016	The Impact of Office Chair Features on Lumbar Lordosis, Intervertebral Joint and Sacral Tilt Angles: a Radiographic Assessment	Ergonomics	Office chair	Healthy adults	Not mention	28	M + F	25 ± 4
Yuhaniz et al. [65]	2016	Anthropometrics evaluation of children between genders	Malaysian Journal of Public Health Medicine	School furniture	Schoolchildren	Malaysia	2400	M + F	grade 1-5

(*continued on next page*)

Table 1 (*continued*)

Author(s)	Year of publication	Title	Source	Types	Respondent sample characteristics	Region	Sample size	Gender	Age
Workineh & Yamaura [66]	2016	Multi-position ergonomic computer workstation design to increase comfort of computer work	International Journal of Industrial Ergonomics	Workstations	User	Japan	14	M + F	28 ± 6
Alojado et al. [67]	2015	Designing an ergonomic chair for pedicurists and manicurists in Quezon City, Philippines	Procedia Manufacturing	Ergonomic chair	Pedicurists and manicurists	Philippines	42	M + F	33
Souza et al. [68]	2015	Ergonomic analysis of a clothing design station	Procedia Manufacturing	School furniture	Students	Brazil	30	M + F	16–35
Altaboli et al. [69]	2015	Anthropometric Evaluation of Proposed Improved Designs of the Classroom Desk for Benghazi Primary Schools	Proceedings of the Human Factors and Ergonomics Society 59th Annual Meeting	Desk	Schoolchildren	Libya	360	M + F	6–10
Castellucci et al. [70]	2014	Applying different equations to evaluate the level of mismatch between students and school furniture	Applied Ergonomics	School furniture	Students	Chile	2261	M + F	11.9 ± 3.5
Lima et al. [71]	2014	Scholar ergonomics—primary schools in Tartu (Estonia) study case	Occupational Safety and Hygiene II	School furniture	Primary school students	Estonia	132	M + F	grade 1-4
Dianat et al. [72]	2013	Classroom furniture and anthropometric characteristics of Iranian high school students: Proposed dimensions based on anthropometric data	Applied Ergonomics	Classroom furniture	High-school students	Iranian	978	M + F	15–18
Bello & Sepenu [73]	2013	Mismatch in body-chair dimensions and the associated musculoskeletal pain among selected undergraduate students in Ghana	Journal of Musculoskeletal Research	Classroom furniture	Undergraduate students	Ghana	126		
Paraizo & De Moraes [74]	2012	An Ergonomic Study on the Biomechanical Consequences in Children	Work	School furniture	Teachers and students	Brazil	193		
Ellegast et al. [75]	2012	Comparison of four specific dynamic office chairs with a conventional office chair: Impact upon muscle activation, physical activity and posture	Applied Ergonomics	Office chair	Office workers	German	22	M + F	35 ± 12.5
Goncalves & Arezes [76]	2012	Postural assessment of school children: an input for the design of furniture	Work	School furniture	Primary school students	Portugal	20	M + F	
Da Silva et al. [77]	2012	School furniture and work surface lighting impacts on the body posture of Para iba's public school students	Work	School furniture	Schoolchildren	Brazil	31	M + F	13–19
Osquei-Zadeh et al. [78]	2012	Ergonomic and Anthropometric Consideration for Library Furniture in an Iranian Public University	International Journal of Occupational and Environmental Medicine	Library furniture	University students	Iranian	267	M + F	18–26

2012 to 2022, providing a more diverse and systematic assessment methodology for the field of E/HF in sitting and working furniture, and thus contributing to the development of the furniture industry.

2. Materials and methods

This systematic review is guided by the systematic review methodology proposed by Tranfield, Denyer, and Smart [36] and PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) [37].This methodology has been widely used in the engineering field and is the accepted method for reporting systematic reviews.

2.1. Search strategy and selection

The search for this study was initiated in October 2022 and only peer-reviewed academic literature published in English during the period 2012–2022 was studied to identify relevant articles. The authors conducted a search using three databases (Scopus, Science Direct & Web of Science). By setting the search terms ("chair" OR ″ working furniture" OR ″ sitting furniture") AND ("ergonomic" OR "human factors" OR "comfort") AND ("assessment" OR "evaluation"), (n = 3390) initial screening data were obtained. From the initial

Table 2
Types of furniture in publications and methods of assessment.

Publication Serial No.	Working furniture	School furniture	Chairs	Assessment techniques
1		*		Six Sigma Methodology (SSM); Anthropometric; Questionnaire
2		*		Anthropometric
3		*		Anthropometric; Nordic Musculoskeletal Questionnaire (NMQ)
4			*	Motion Laboratory Study; Interviews; Pressure Mapping
5	*			Questionnaire; Anthropometric; Visual Analogue Scale (VAS)
6		*		Questionnaire; Interview; Anthropometric
7	*			3D Automated Joint Angle Assessment (3D-AJA); Rapid Upper Limb Assessment (RULA)
8	*			Rate of Perceived Discomfort questionnaire (RPD); Seating Discomfort Questionnaire (SDQ); Electromyography (EMG)
9		*		Anthropometric; Body Discomfort Scale (Corlett's and Bishop's Scale); Rapid Upper Limb Assessment (RULA)
10	*			Anthropometric; Discomfort Questionnaire; Rapid Upper Limb Assessment (RULA)
11			*	Checklist; Ergonomic Rating; User Rating;
12			*	Anthropometric; Subjective Comfort Questionnaire
13			*	Chair Evaluation Checklist (CEC); Anthropometric
14	*			Online Questionnaire; 9-item Utrecht Work Engagement Scale (UWES-9); Need For Recovery (NFR) survey
15	*			Questionnaire; Qualisys Motion Capture
16	*			Focus Group Interviews (FGI)
17		*		Anthropometric
18			*	Modified Nordic Musculoskeletal Questionnaire (NMQ); Rapid Upper Limb Assessment (RULA)
19	*			5-level Comfort Meter; Pressure Test
20			*	Rapid Upper Limb Assessment (RULA); Anthropometric; Mismatch Evaluation
21	*			Electromyography (EMG); Subjective Visual Analogue Scale Discomfort Surveys; Heart Rate Variability (HRV)
22		*		Anthropometric
23	*			Rapid Upper Limb Assessment (RULA); Rapid Office Strain Assessment (ROSA); Maastricht Upper Extremity Questionnaire revised Brazilian Portuguese version (MUEQ-Br revised)
24		*		3D analysis; Electromyography (EMG); Dynamographic analysis
25	*			User-Chair Fit Index (UCFI)
26	*			Nordic Musculoskeletal Questionnaire (NMQ)
27	*			Radiographic
28		*		Anthropometric
29	*			Real Time User Comfort (RTUC)
30			*	Rapid Entire Body Assessment (REBA); Observations; Survey Anthropometric
31		*		Nordic Musculoskeletal Questionnaire (NMQ); Rapid Entire Body Assessment (REBA) and Diagnosis
32		*		Anthropometric
33		*		Literature Review; Anthropometric
34		*		Questionnaire; Observations
35		*		Anthropometric
36		*		Anthropometric
37		*		Observational Assessment; Rapid Upper Limb Assessment (RULA); Survey and Questionnaire; Postural Assessment
38	*			Electromyography (EMG); Kinematics
39		*		Portable Ergonomic Observation (PEO)
40		*		Questionnaires; Body Part Discomfort Scale (BPDS)
41		*		Anthropometric; Short Interview

Table 3
Thirty-two assessment techniques.

Publication Serial No.	Quantitative Methods													
	Anthropometric	BPDS	CEC	DQ	EMG	HRV	ME	MLS	MUEQ	NFR	NMQ	PA	Questionnaire	Radiograph
1	Y												Y	
2	Y													
3	Y										Y			
4								Y						
5	Y												Y	
6	Y												Y	
7														
8					Y									
9	Y	Y												
10	Y			Y										
11			Y											
12	Y													
13	Y		Y											
14										Y				
15													Y	
16														
17	Y													
18											Y			
19														
20	Y						Y							
21					Y	Y								
22	Y													
23									Y					
24					Y									Y
25														
26											Y			
27														Y
28	Y													
29														
30	Y													
31											Y			
32	Y													
33	Y													
34													Y	
35	Y													
36	Y													
37												Y	Y	
38					Y									
39														
40		Y											Y	
41	Y													
total	19	2	2	1	4	1	1	1	1	1	4	1	7	2

BPDS= Body Part Discomfort Scale; CEC= Chair Evaluation Checklist; DQ = Discomfort Questionnaire; EMG = Electromyography; HRV= Heart Rate Variability; ME = Mismatch Evaluation; MLS= Motion Laboratory Study.
MUEQ = Maastricht Upper Extremity Questionnaire revised Brazilian Portuguese version; NFR= Need For Recovery survey; NMQ= Nordic Musculoskeletal Questionnaire; PA= Postural Assessment; REBA = Rapid Entire Body Assessment.
ROSE = Rapid Office Strain Assessment; RPD = The Rate of Perceived Discomfort Questionnaire; RULA = Rapid Upper Limb Assessment; SCQ=Subjective comfort questionnaire; SDQ=Seating Discomfort Questionnaire; SSM=Six Sigma Methodology.
UCFI=User-Chair Fit Index; UWES-9 = 9-item Utrecht Work Engagement Scale; VAS=Visual Analogue Scale; 5-LCM = 5-Level Comfort Meter; RTUC=Real Time User Comfort; 3D-AJA = 3D Automated Joint Angle Assessment; FGI=Focus Group Interviews.
LR=Literature Review; PEO= Portable Ergonomic Observation.

data, those outside of 2012–2022 were first excluded based on time, followed by the exclusion of undesirable publication type literature such as books, chapters, reviews, and discussions (n = 2463).

Based on the initial search records, the two authors carried out further screening on the remaining 927 search records to clarify whether the records were relevant to the research objectives. Among them, 152 papers were excluded due to duplicates, and some with languages other than English (n = 84) were excluded. Records with only two authors confirming at the same time were excluded (n = 683). A second round of screening was conducted by the first two authors and one other, independently. Records that were confirmed by all three authors and those with different opinions that should be deleted after a discussion between the three authors were excluded. These articles were excluded due to their low relevance to the keywords “working furniture”, “chair" and "ergonomics", and the fact that they did not report the corresponding assessment methods (n = 203). Therefore, 41 articles were selected for evaluation. Fig. 1 shows a flow chart of the standard PRISMA methodology for study identification, screening, eligibility and inclusion.

Quantitative Methods													Qualitative Methods					Total
REBA	ROSA	RPD	RULA	SCQ	SDQ	SSM	UCFI	UWES-9	VAS	5-LCM	RTUC	3D-AJA	FGI	Interview	LR	Observation	PEO	
						Y												3
																		1
																		2
														Y				2
									Y									3
														Y				3
			Y									Y						2
		Y			Y													3
			Y															3
			Y															3
																		1
				Y														2
																		2
								Y										2
																		1
													Y					1
																		1
			Y															2
										Y								1
			Y															3
									Y									3
																		1
	Y		Y															3
																		2
							Y											1
																		1
																		1
																		1
											Y							1
Y																Y		3
Y																		2
																		1
															Y			2
																Y		2
																		1
																		1
			Y													Y		4
																		1
																	Y	1
																		2
														Y				2
2	1	1	7	1	1	1	1	1	2	1	1	1	1	3	1	3	1	77

2.2. Data analysis

Table 1 shows the abstracts of the 41 papers, which were used to extract the required data from the articles, namely.

- Author(s)
- Year of publication
- Title

Table 4
Meaning and abbreviations of seven techniques used to primarily assess ergonomics.

SN	Abbr.	Meaning	Functions
1	Anthropometric	Anthropometric	Measurement of individual humans
2	EMG	Electromyography	Task risk assessment of human muscles
3	NMQ	Nordic Musculoskeletal Questionnaire	Standardized questionnaire for general or low back and neck and shoulder discomfort
4	QNR	Questionnaire	Collecting Information from Respondents
5	RULA	Rapid Upper Limb Assessment	Methods of assessing upper body working posture
6	Interview	Interview	One-to-one conversations between interviewers and interviewees
7	Observation	Observation	Active access to information from primary sources

Table 5
Types and summaries of questionnaires and scales used.

Questionnaire Name	Publication Serial No.																
	1 [38]	3 [40]	5 [42]	8 [45]	10 [47]	12 [49]	14 [51]	15 [52]	18 [55]	23 [60]	25 [62]	26 [63]	29 [66]	31 [68]	34 [71]	37 [74]	40 [77]
RPD				Y													
SDQ				Y													
Questionnaire	Y		Y					Y			Y				Y	Y	Y
NMQ		Y							Y			Y		Y			
MUEQ-Br revised										Y							
Qualtrics (online)							Y										
DQ					Y												
SCQ						Y											
RTUC													Y				

RPD = The Rate of Perceived Discomfort Questionnaire; SDQ=Seating Discomfort Questionnaire; NMQ= Nordic Musculoskeletal Questionnaire.
MUEQ = Maastricht Upper Extremity Questionnaire revised Brazilian Portuguese version; DQ = Discomfort Questionnaire; SCQ=Subjective comfort questionnaire.
RTUC=Real Time User Comfort.

Table 6
Methodology of publications by phase and conclusions.

Author(s)	Qualitative/ Quantitative/ Mix methods	Assessment methods	Objective/ Subjective/ Mix methods	Data collection methods	Software analysis tool	Conclusion	Limitations
Taifa [38]	Quantitative	Six Sigma Methodology (SSM), Anthropometric, Questionnaire	Objective	Questionnaire, Observation, On-site measurements	Minitab® version 17	The Ergonomics and Six Sigma Methodology approach has been successful and effective in its deployment. However, the implementation of the ESSM method is not a popular one because it takes too long.	Design not manufactured and lack of product testing. Anthropometric data is very limited geographically and not universally applicable
Fidelis & Ogunlade [39]	Quantitative	Anthropometric	Objective	On-site measurements	Microsoft Excel, SPSS (version 21)	High mismatch between different furniture sizes and the user's anthropometric measurements	Anthropometric data is very limited geographically and not universally applicable
Shohel et al. [40]	Quantitative	Anthropometric, Nordic Musculoskeletal Questionnaire (NMQ)	Mix	Questionnaire, On-site measurements	SPSS (version 21)	There is a significant relationship between students' MSD problems and furniture size. Reducing the frequency of MSD problems and improving student comfort is critical.	The results' reliability is limited. There are no psychological or geographical studies included.
Champion et al. [41]	Mix	Motion Laboratory Study, Interviews, Pressure mapping	Mix	On-site measurements, Interview, Observation	Vicon Nexus, MATLAB (2017b)	Comparing a motorised high support chair to a conventional chair reveals measurable differences in joint angles and power for the person pushing the chair as well as reduced pressure for the person sitting in it.	Small number of participants
Cabegi de Barros et al. [42]	Quantitative	Questionnaire, Anthropometric, Visual Analogue Scale (VAS)	Mix	Questionnaire, On-site observation	Specific software, SPSS	Workstation adjustments to reduce postural exposure and perceived discomfort among office workers.	The absence of a low back posture assessment.
Wang et al. [43]	Mix	Questionnaire, Interview, Anthropometric	Mix	Questionnaire, Interview		The classroom folding seats generally fit the human body of college students, but there are still issues.	Small number of participants.
Rodrigues et al. [[44]]	Quantitative	3D Automated Joint Angle Assessment (3D-AJA), Rapid Upper Limb Assessment (RULA)	Mix	RGB-D camera, Questionnaire	Kinect SDK	3D-AJA outperformed the Kinect SDK body joint capture method for estimating all three selected angles with significant differences in shoulder flexion and elbow flexion angles. In terms of determining the resulting classification model for RULA score A, the dataset from 3D-AJA provided a better classification model for all RULA score A classes included in the dataset.	The upper part of the body occludes itself, thus reducing the performance of the algorithm. A longer period of postural monitoring and evaluation is needed to fully check the accuracy of the algorithm. The sample size was insufficient to assess differences based on gender, age, or ethnicity. Only the upper limbs were investigated and other key postures and areas need to be included. Excessive cost.
Cardoso et al. [45]	Quantitative	The Rate of Perceived Discomfort Questionnaire (RPD), Seating Discomfort Questionnaire (SDQ), Electromyography (EMG)	Mix	Sensor, Questionnaire, On-site measurements	SPSS	A split seat pan design office chair has the potential to provide biomechanical and physiological benefits to the sitter.	Lack of control of the participants' engagement of the chairs' active elements.
Famero et al. [46]	Quantitative	Anthropometric, Body Discomfort Scale (Corlett's and Bishop's Scale), Upper Limb Assessment (RULA)	Mix	On-site observation , Questionnaire	Minitab, Sketchup	The body parts with the highest level of discomfort were determined to be the upper back, lower back and shoulders, and different models were	

(*continued on next page*)

Table 6 (*continued*)

Author(s)	Qualitative/ Quantitative/ Mix methods	Assessment methods	Objective/ Subjective/ Mix methods	Data collection methods	Software analysis tool	Conclusion	Limitations
						designed according to user preferences.	
Cadiz et al. [47]	Quantitative	Anthropometric, Discomfort Questionnaire, Upper Limb Assessment (RULA)	Mix	On-site observation , Questionnaire	Minitab, Sketchup	Each student's risk of developing musculoskeletal disorders (MSD) in various parts of the body. To achieve the best level of comfort for the student, the dimensions of the computer workstation must be ergonomically adjusted.	
Mao et al. [48]	Quantitative	Checklist, Ergonomic rating, User rating	Objective	RGB-D camera	C++	The fitting results enable us to quantitatively assess chair models based on various ergonomic criteria. Our method is adaptable and effective, and it can be used with users of various body types and chairs.	
Prasetyo et al. [49]	Quantitative	Anthropometric, Subjective Comfort Questionnaire (SCQ)	Mix	On-site Measurements, Questionnaire	Structural Equation Modelling (SEM)	The chair's dimensions had a massive effect on subjective comfort. The latent variable of anthropometry was also found to have a significant positive effect on subjective comfort.	
Bahrampour et al. [50]	Quantitative	Chair Evaluation Checklist (CEC), Anthropometric	Mix	On-site Measurements , On-site observation	SPSS	The 5th percentile is an ideal anthropometric criterion for seat depth design because it provides the target population with the most comfort and least discomfort.	
Weatherson et al. [51]	Quantitative	Online questionnaire, 9-item Utrecht Work Engagement Scale (UWES-9), Need For Recovery (NFR) survey	Mix	Questionnaire, On-site observation	The activPAL3 software	Low-cost standing desk converters have some potential as a scalable workplace health intervention.	The results may not be generalizable to a different population/setting.
Zhang et al. [52]	Quantitative	Questionnaire; Qualisys motion capture	Mix	Questionnaire, Camera		Most existing office chairs are not designed to conform to the shape of the human spine in the workplace. The main issue is that the waist depth is excessive, together with the backrest and headrest, as well as the distance between the human body.	
Koma et al. [53]	Qualitative	Focus group interviews	Subjective	Interview		The office lacks well-developed ergonomic projects.	This study may not be applicable to all of the Organization's sites.
Kahya [54]	Quantitative	Anthropometric	Objective	On-site measurements		There is a considerable mismatch between classroom furniture sizes and anthropometric measurements.	
Ncube et al. [55]	Quantitative	Modified Musculoskeletal Questionnaire (NMQ), Upper Limb Assessment (RULA)	Mix	Photographs, Questionnaire	SPSS	Wooden Steel Chairs (WSCs) appear to be a greater postural risk factor for lower back pain than Stackable Arm Chairs (SACs).	The pain levels were not measured. Small number of participants.
Hong et al. [56]	Quantitative	5-level comfort meter, Pressure Test	Mix	On-site measurements	Novel software	Different BMI people have different feelings about the comfort level of the same office chair. As a result, in order	

(*continued on next page*)

Table 6 (*continued*)

Author(s)	Qualitative/ Quantitative/ Mix methods	Assessment methods	Objective/ Subjective/ Mix methods	Data collection methods	Software analysis tool	Conclusion	Limitations
						to improve the comfort of office chairs, different seat contribute for people with different BMIs must be designed.	
Godilano et al. [57]	Quantitative	Upper Limb Assessment (RULA), Anthropometric, Mismatch Evaluation	Objective	On-site observation		The majority of preschool students have mismatches between their anthropometric dimensions and the measurements of the chair and desk.	
Weston et al. [58]	Quantitative	Electromyography (EMG), Subjective VAS discomfort surveys, HRV	Mix	Cameras, Heart rate monitor, Sensors	Kubios open-source software，JMP 11.0 software	Individual, chair, and device interaction is associated with low back and overall postural loading.	Predicted under laboratory conditions. Subject population was young and physically fit
Taifa & Desai [59]	Quantitative	Anthropometric	Objective	On-site measurements	Minitab® version 17, SPSS 16.0, Microsoft Excel	Classroom furniture must be adaptable to reduce the chances of MSDs.	
Rodrigues et al. [60]	Quantitative	Upper Limb Assessment (RULA), Rapid Office Strain Assessment (ROSA), Maastricht Upper Extremity Questionnaire revised Brazilian Portuguese version (MUEQ-Br revised)	Mix	Video recordings, Questionnaire and Checklists		Inadequate workstation conditions, specifically chair height, arm and back rest, are linked to incorrect upper limb postures and contribute to MSP in computer office workers.	Small number of participants. The method of video recording analysis should be researched further.
Fettweis et al. [61]	Quantitative	3D analysis, Electromyography (EMG), Dynamographic analysis	Objective	On-site measurements	Statistical software “R”. (Version 3.3.0)	Cushions can help prevent low back pain by improving the torso-thigh angle, lumbar lordosis, anterior pelvic tilt, and foot-to-floor supports.	Tests in the laboratory do not always reflect the natural sitting position of the student in the classroom.
Charpe [62]	Quantitative	User-Chair Fit Index (UCFI)	Subjective	Scale		According to the reliability estimates and validity, User-Chair Fit Index (UCFI) scale was highly reliable and valid for determining the user-chair fit in the VDT workstation. For the interpretation of the raw scores, z-Score norms were developed.	
Ward & Coats [63]	Quantitative	Musculoskeletal Questionnaire (NMQ)	Subjective	On-site observation, Questionnaire	SPSS Version 20.0	Short-term and single use of an office chair support product had no additive effect on reducing neck and back pain.	A more ideal study would have recruited participants with neck or back pain and the use of a harder, less cushioned chair.
De Carvalho et al. [64]	Quantitative	Radiographic	Objective	Radiographs	eFilm Workstation TM software, SAS	Although no single feature was statistically superior in terms of minimising spine flexion, seat pan tilt resulted in significantly improved pelvic posture.	Missing some of the more common pelvic parameters.
Yuhaniz et al. [65]	Quantitative	Anthropometric	Objective	On-site measurements	SPSS version 16	Male and female anthropometrics are distinct. However, only a few parts of the body were significantly different, while others were not.	
Workineh & Yamaura [66]	Quantitative	Real Time User Comfort (RTUC)	Objective	Questionnaire		RTUC evaluation indicate that the new design can improve the comfort of computer work by supporting the	Further evaluations should be conducted by using subjects in

(*continued on next page*)

Table 6 (*continued*)

Author(s)	Qualitative/ Quantitative/ Mix methods	Assessment methods	Objective/ Subjective/ Mix methods	Data collection methods	Software analysis tool	Conclusion	Limitations
						user's body in a balanced way in any working position. The flexible footrest facilitates the overall comfort of seated computer work. Combining the chair and desk facilitates the design of ergonomically effective mechanisms.	different body mass index (BMI) categories.
Alojado et al. [67]	Quantitative	REBA, Observations, Survey, Anthropometric	Mix	On-site observation		Subjects suffered pain and stress due to the poor posture they usually adopt at work, so a better work chair was designed for nail technicians to improve their posture and reduce stress on the body.	Materials should also be taken into account
Souza et al. [68]	Mix	Musculoskeletal Questionnaire (NMQ), Rapid Entire Body Assessment (REBA) and Diagnosis	Subjective	Observation, Questionnaire, Video recording and photographs		The seats were not positioned at an appropriate angle to accommodate the students, and the backs were not sufficiently sloped. Students suffered physical pain as a result of not ensuring consistent posture during school activities because of these non-anthropometric furnishings.	
Altaboli et al. [69]	Quantitative	Anthropometric;	Objective	On-site measurements		The use of multiple sizes of fully adjustable breakaway seats and tables to cover all ranges of student anthropometric indicators can be considered as a solution to school furniture and anthropometric mismatch.	Anthropometric data is very limited geographically and not universally applicable
Castellucci et al. [70]	Mix	Literature review, Anthropometric	Mix	On-site measurements	SPSS (v20.0)	The interrelationship between the equations for evaluating the level of mismatch of Seat to Desk Clearance (SDC) and Desk Height (DH) is based on contradictory criteria, so new equations for these parameters must be developed and validated.	
Lima et al. [71]	Mix	Questionnaire, Observations	Subjective	Non-participant observation, Questionnaire	SPSS software version 21	There is a clear mismatch between anthropometric characteristics and furniture dimensions.	
Dianat et al. [72]	Quantitative	Anthropometric	Objective	On-site measurements		There was a significant mismatch between the body dimensions of the school students and the classroom furniture available to them.	No consideration is given to other attributes that may affect the sitting position and user comfort
Bello & Sepenu [73]	Quantitative	Anthropometric	Objective		SPSS	The high percentage of incompatibility indicated that the school chairs were not designed with anthropometric dimensions, so it **provides** ~~ing~~ insight into the source of the pain.	

(*continued on next page*)

Table 6 (*continued*)

Author(s)	Qualitative/ Quantitative/ Mix methods	Assessment methods	Objective/ Subjective/ Mix methods	Data collection methods	Software analysis tool	Conclusion	Limitations
Paraizo & De Moraes [74]	Quantitative	Observational Assessment, Upper Limb Assessment (RULA), Survey and Questionnaire, Postural Assessment	Mix	Questionnaire, Observation, Scanned images	Posturograma	RULA tool for assessment shows need for more research and change in school furniture.	
Ellegast et al. [75]	Quantitative	Electromyography (EMG), Kinematics	Objective	On-site measurements	CUELA software	Many aspects of workplace design, such as task variability and work organizational factors, should be considered in order to avoid physical inactivity and prevent MSDs.	The subjects' limited use of each chair type.
Goncalves & Arezes [76]	Qualitative	Portable Ergonomic Observation (PEO)	Subjective	Observation, Video recording	Microsoft Excel	The use of a school desk with a tilted table surface reduced trunk and neck flexion while maintaining natural lordosis in the lumbar and cervical regions.	
Da Silva et al. [77]	Quantitative	Questionnaires, Body Part Discomfort Scale (BPDS)	Mix	Photographs, Questionnaire	SAPO software, SAS	Performing tasks on a desk that is too high or on a chair too low may cause lateral displacement of the arms, increasing the motion and load on the lumbar spine. A desk which is too low requires bending of the head and neck, which positively correlates with the load on the lumbar spine.	
Osquei-Zadeh et al. [78]	Mix	Anthropometric, Short interview	Mix	On-site measurements, Interview	SPSS	Iranian students' furniture sizes should be adjusted to accommodate their anthropometric measurements.	

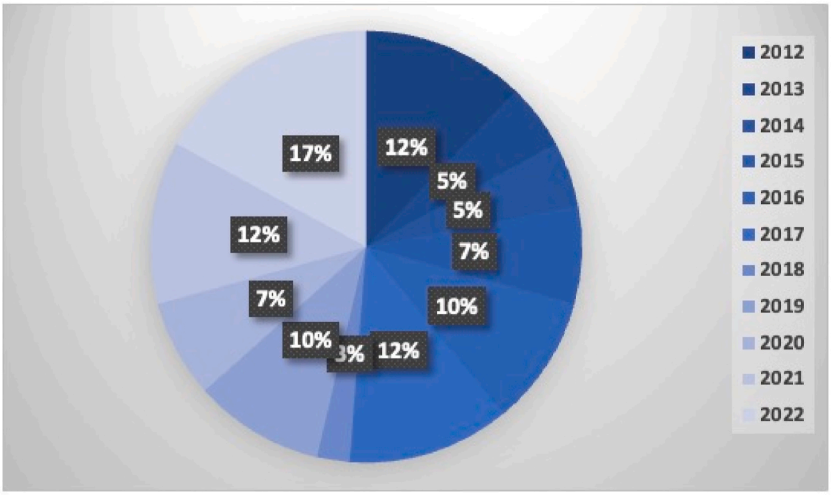

Fig. 2. The percentage of publication years for the selected publications.

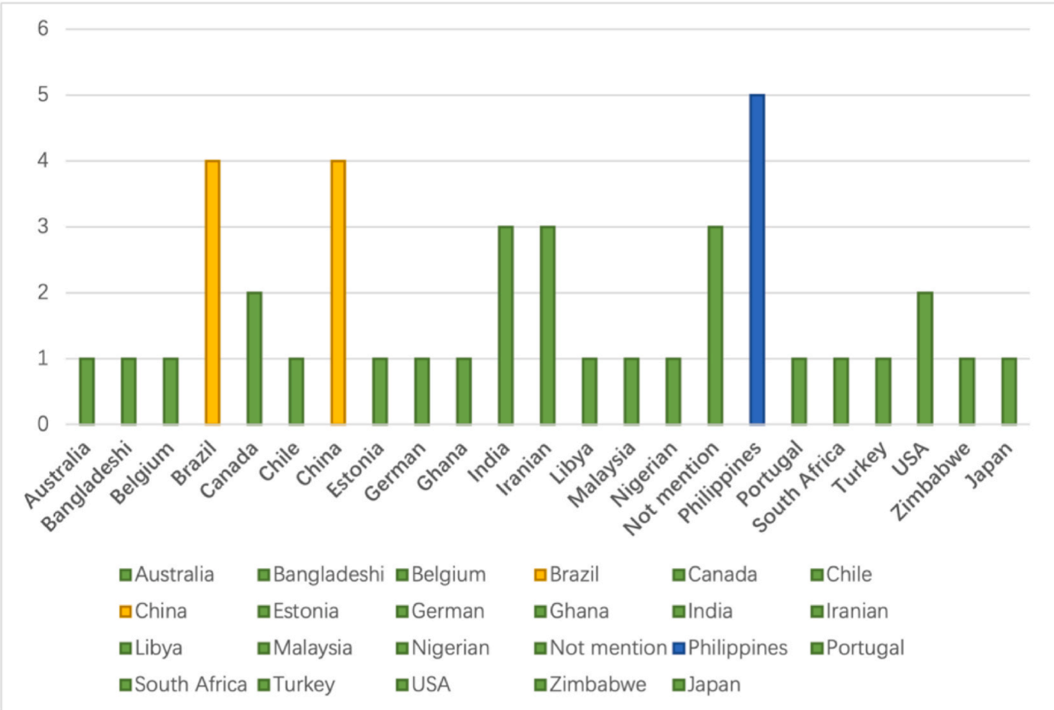

Fig. 3. Distribution of articles by region.

- Source
- Types
- Respondent sample characteristics
- Region
- Sample size
- Gender
- Age

In addition, Table 1 describes the above data and Table 6 detail the methods, conclusions, and limitations of each paper. Depending on the information provided in the papers, the papers will be classified into different categories and the results will be presented in the form of line graphs, pie charts and tables. The percentage of publication years for the selected publications is displayed in Fig. 2.

3. Results

3.1. Comprehensive analysis of the results from this study

3.1.1. Geographic scope

A number of constraints were identified in the articles that were selected. Fig. 3 shows the distribution of articles by country region: five articles from the Philippines; four articles each from China and Brazil; three articles each from India, Iran and no clarified region; two articles from Canada; one article each from Australia, Bangladesh, Belgium, Chile, Estonia, Germany, Ghana, Libya, Malaysia, Nigeria, Portugal, South Africa, Turkey, USA and Zimbabwe.

3.1.2. Types of subjects

In addition, this study illustrates the types of objects studied in the publications. The samples were divided into three main categories according to the type of furniture studied, which include school furniture, working furniture and chairs, and the evaluation methods of each type of furniture were counted to get Table 2. School furniture is mainly applied to school scenes, which can be used by students and other staff, and the desks and chairs used by students are the main furniture in the articles selected for this systematic review. Working furniture is mainly applied to the office and other places used for office work, usually the main furniture with office desks and chairs, workstations, cabinets, sofas, etc., whereby in this systematic review of the selected articles to the work of the office workers' main desk and chair. The furniture included in this classification of chairs is only one type of chair, and the seven articles included in this type are usually studied for one or two special types of chairs, which are not quite settled in their application scenarios, and therefore becomes a separate category. Ergonomic chair also belongs to a special type of chair, so it will be categorized as a chair major category. Based on Table 2, there are 15 articles of working furniture, 19 articles of school furniture and seven articles of chairs. Among them, nine out of 15 articles on work furniture used various types of questionnaires and scales, seven out of 19 articles on school furniture and two out of 7 articles on chairs also used various types of questionnaires and scales. For anthropometrics, it was used in two articles for working furniture and one article for chair, while it was used in up to 12 articles for school furniture. Next, biomechanical or physiological categories of assessment methods such as EMG and HRV were used in only five studies, with the vast majority originating from work furniture (4).

3.1.3. Sample characteristic

Twenty-five articles analyzed the student population, including preschool, primary, secondary and university students, accounting for 61.0% of the total; five studied office workers accounting for 12.2%; three (7.3%) focused mainly on adults; and five included users (12.2%); one analyzed operational managers and employees (2.4%); one conducted a study for a specific population of pedicurists and manicurists (2.4%); and one recruited the local population (2.4%).

Most articles investigated the ergonomics of furniture by gender, with all studies being mixed gender except for one focusing only on female office workers [45] and one focusing only on male computer users [62].

3.1.4. Common evaluation techniques

Through a comprehensive review of the data (Fig. 4), thirty-three (80.5%) studies used quantitative methods, such as scales and

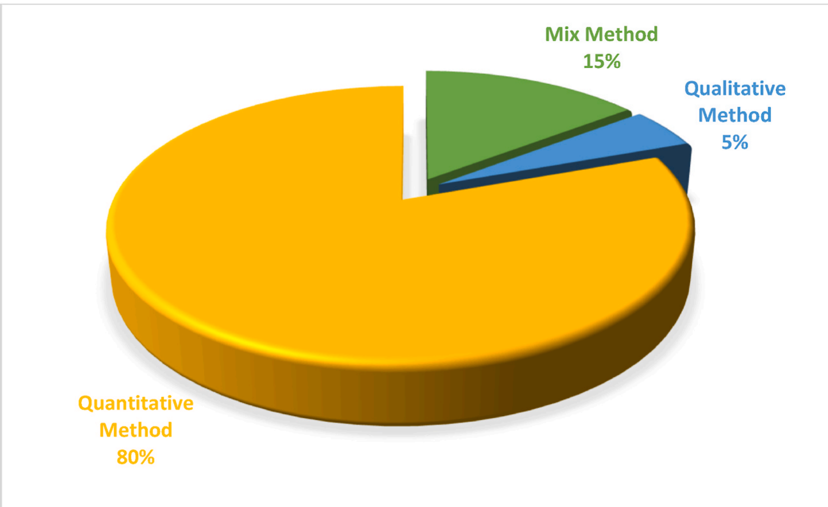

Fig. 4. Percentage of research methodology types.

experiments; two studies (4.9%) used qualitative methods, Focus Group Interview (FGI) [53] and Portable Ergonomic Observation (PEO) [76]; and six (14.6%) studies used mixed methods [41,43,68,70,71,78].

3.2. Assessment techniques and methods

In a review of 41 papers, a total of 32 ergonomic assessment techniques and methods emerged in the available literature to assess ergonomic risk. One of these, Charpe [62], also developed a new assessment method, called User-Chair Fit Index (UCFI). Table 3 summarizes the techniques and methods used in all the articles and provides the meaning and abbreviations of the seven techniques and methods used to primarily assess ergo-nomics (those used more than three times inclusive) (Table 4). The authors' survey found that the number of questionnaires and scales used was very high, so a summary of all the questionnaires is given in Table 5. This shows that there were nine types of questionnaires used with a total of 18 questionnaires were used, where the general questionnaire appeared seven times and the second highest ranking being the Nordic Musculoskeletal Questionnaire (NMQ) (four times). Twenty-one of the studies included in this paper used a mixture of subjective and objective methods (51.2%), fourteen studies conducted an objective analysis (34.1%) and a further six studies conducted a subjective judgement (14.6%), as shown in Fig. 5.

4. Discussion

This systematic review synthesizes research from different national regions and explores some assessment techniques and methods for sitting and working furniture ergonomics. The main objective is to provide an analytical summary of some major evaluation techniques and methods. The second objective is to provide an overview about the current state of research on furniture ergonomics from 2012 to 2022.

4.1. Overview of the current state for research on furniture ergonomics

Among the 41 articles studied in this review, Brazil, Turkey, India, and Iran were more concerned with the ergonomics of school furniture, while the United States, Canada, China, and Germany evaluated the ergonomics of working furniture, and the Philippines preferred chairs, with three of the seven publications coming from the Philippines. One conclusion is that different countries and regions have different ergonomic needs for different furniture types, which may be related to the degree of industrialization in the region where the researchers are located. It is obvious from Table 2 that the vast majority of ergonomic studies on sitting furniture by researchers from serial number 29 onwards (during 2012–2015) have been on school furniture, while upwards from serial number 29, which means that from 2016 onwards, researchers have started to focus on working furniture and chairs. This suggests that people are beginning to realise that working furniture and other chairs are slowly revealing injuries to the human body such as MSD, WMSD, and ergonomic assessment of these types of furniture is imminent.

Furthermore, extensive research have shown how ergonomics can actually be affected by gender segregation [79,80]. It has also been mentioned in a number of articles that differences in body shape exist not only in body size and body proportions, but also in gender [81,82]. Treaster & Burr have shown that women have been proven to be more susceptible to upper limb musculoskeletal disorders [83]. In other words, females are positively correlated with the prevalence of musculoskeletal health problems [83]. It has also been shown that the MSD prevalence in the shoulder, neck and upper limb is lower in males than in females [84]. However, out of the 41 studies investigated in this review, only two articles were gender segregated, suggesting that gender is not well considered in ergonomic studies of sitting and working furniture.

The human body is always changing, growing and developing with age, for example, the accelerated growth rate of children and the increase in the obese population [85]. This secular trend has brought about changes in human body size. Studies have shown that human body size has been on an upward trend with the development of society, and furniture design specifications have changed in this context [86].Many ergonomic evaluations are based on human body dimensions, so these population dimensions, which have changed as a result of secular trends, should be taken into account accordingly in the ergonomic evaluation of furniture. On the other hand, there are no articles in the surveyed studies that mention the impact of secular trends on furniture, especially sitting furniture, that adjusts the ergonomic assessment accordingly, so there is an urgent need for improvement in this area.

Although furniture is more commonly used in domestic life, most of the studies included in this paper used groups of students in school settings as subjects, and some as workers. There is a real paucity of research into the ergonomics of furniture used in everyday domestic life scenarios.

4.2. Methods and techniques for assessing furniture ergonomics

4.2.1. Commonly used methods and techniques

Table 6 summarizes the various research methods and detailed data conducted in the 41 studies. It includes aspects such as the assessment methods used, collection methods, software used, conclusions and limitations.

The authors compared all techniques that were used more than three times, with Anthropometric, EMG, NMQ, general questionnaire and RULA being the most widely used. Then, the suitability of these assessment methods was gathered by checking the conclusions of the publications and comparing the data.

Anthropometric, being the most used method, has its advantages. It occupies a highly important place in the ergonomic assessment of school furniture. Almost all studies on school furniture have come to the same conclusion: school furniture does not match human

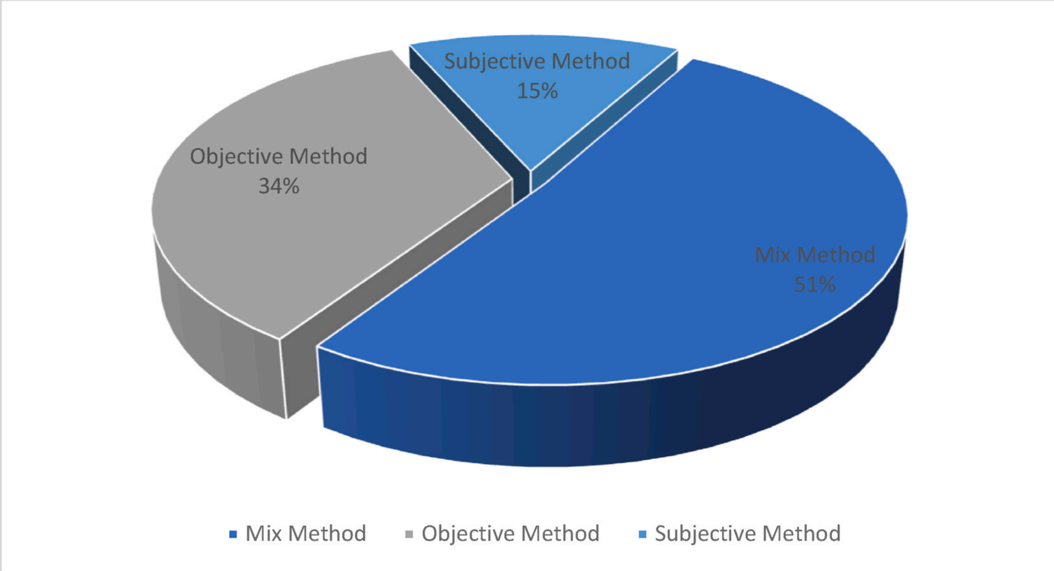

Fig. 5. Use of subjective and objective methods percentage in articles.

body dimensions or school furniture increases student discomfort due to dimensional design issues, and furniture design should be improved to reduce the incidence of MSDs. There are up to nineteen articles in the literature included in the study that used anthropometrics. The vast majority of these articles used anthropometric measurements of student body size to address the risks associated with fitting school furniture to body size.

Meanwhile, EMG is an objective and quantitative assessment method, and for the articles in this survey, it was mostly applied to working furniture. Its advantage is that the objective and quantitative approach improves the quality of the quantitative data of the process for the overall assessment, but it has been shown that subjective evaluation is the only way for comfort and pain to change [23]. Therefore, subjective evaluation is indispensable while using EMG and how to integrate appropriate subjective evaluation methods needs to be further investigated.

Subsequently, the NMQ has been used as a standardised questionnaire to investigate areas such as the lumbar and neck parts of the body, and has been used throughout the assessment of school furniture. It has the advantage of being time-saving, convenient and low-cost, but requires further validation as to the exposure risk of using this method alone.

The general questionnaire is also the more common assessment method in the literature surveyed, and it is flexible enough to allow for specific programmes to be developed for different studies. On the other hand, the flexibility may be associated with higher risks, and it is difficult to accurately assess all the postural risk factors and ratings that need to be assessed by this method.

Although REBA is more suitable than RULA for assessments involving the whole body, RULA is widely used as an ergonomic assessment of working furniture, considering that humans are more active in the upper limbs when using seated furniture and are more susceptible to MSD. If other types of furniture are assessed, such as beds, which require full-body involvement, RULA may underestimate the risk.

4.2.2. Other used methods and techniques

Based on a systematic review of the literature, some studies may offer different technical approaches to the ergonomics of furniture as well as new research ideas, such as the combination of Six Sigma Methods and Ergonomics: tandem ESSM methods are successful and effectively deployed [38]; 3D analysis of sitting posture [61]; 3D assessment is very accurate with a motion detection threshold of $\sim 1^\circ$ [75], etc. These methods could currently fill a research gap in the area of furniture ergonomics. The procedures and factors affecting the experimental results will be considered by each ergonomic assessment technique in order to facilitate relatively accurate conclusions about the level of risk. When investigating articles with two or more research methods, particularly papers combining subjective and objective or mixed methods, it is common for two or more methods to corroborate each other to demonstrate the accuracy of the conclusions from multiple perspectives. When research is conducted using mixed methods, researchers perform some validation of both qualitative and quantitative data, such as using Cronbach's alpha values computation [38]. Some studies also perform post-hoc analyses when any significant interactions are found, such as the Tukey correction [45,58]. Although, each technique and method are well validated, there will be a small number of articles where the two techniques will output significantly different conclusions due to the use of two or more evaluation techniques.

Furthermore, there will also be articles where a different perspective emerges, for example the article [61] states that the Portable Ergonomic Observation(PEO) method can be used as a tool to record the best Sitting Position (SP). However, this assessment is not very accurate as it does not detect segmental movements of less than 20°. In contrast, the three-dimensional assessment is very accurate. Whereas the article [76] by using PEO obtained that by using furniture with inclined surfaces (tables and chairs), the natural balance of the lower back and neck can be maintained with reduced flexion of the trunk and neck. Although the use of PEO yielded some results, the accuracy of the results needs further validation.

There are many articles using scales such as the Visual Analogue Scale (VAS), 9-item Utrecht Work Engagement Scale (UWES-9), Body Part Discomfort Scale (BPDS), Body Discomfort Scale (BDS) (Corlett's and Bishop's Scale), etc. that have been mentioned in the previous section. By using pairs of scales that subjects fill out during or after the experiment, these articles obtain some subjective ratings from the subjects, supplementing the objective data and helping to determine which specific body regions are considered most uncomfortable under the conditions of the test experiment. There are also studies that uses more than two common ergonomic assessment techniques, for example, Rodrigues et al. [60] used the ergonomic assessment tool RULA, the tool ROSA which assesses biomechanical and ergonomic factors, and the tool MUEQ which assesses a mixture of ergonomic and psychosocial factors. A better approach may be a hybrid design that includes self-report and observational assessments to capture factors in the workplace. This scenario includes ROSA assessing office stress by classifying risk factors to get the appropriate score; while RULA screens risk factors for upper limb disorders by the four action levels of posture; and MUEQ assesses the occurrence, nature and possible work-related physical and psychological factors of Complaints of the Arms, Neck, and Shoulders (CANS) among computer users. By comparing the scores of the three, it was concluded that there was a correlation between ROSA and RULA. On the other hand, if the study involved the assessment of whole-body posture, then REBA would be more advantageous than RULA, for example the article uses the REBA technique to assess the nail technician's posture. Due to the nature of the nail technician's work, it is clear that assessing the upper limbs alone is not sufficient. In addition to this, many studies suffer from geographical limitations, small sample sizes and laboratory data that are not representative of real-world data, which needs to be refined over time in further studies. With the results of the above analysis, there is still much progress that can be made in these studies to improve accuracy.

4.3. Limitations

One of thelimitations from this study is that only the ergonomic assessment of sitting and working furniture was considered. Although sitting furniture is the focus of ergonomic assessment of furniture, ergonomic assessment of other furniture such as beds, cupboards, wardrobes etc. is also essential. On the other hand, there are many other branches of ergonomics, such as safety, easy-to-use, etc., which may not be taken into account in some articles due to the wide variety of terms used to refer to the same issues. Last but not least, some types of articles, such as reports, were not included in this analysis and are only used as a reference, since normally some reports are not publicly available, which makes peer-reviewed papers published in scientific journals the most common type of ergonomics used to evaluate sitting and working furniture. This systematic review only used publications from three databases, namely Scopus, Science Direct & Web of Science, and although these three databases have extensive coverage, it does not mean that all publications can be covered. If other databases are considered, additional articles relevant to the research may be available.

5. Conclusions and future scope

The ergonomic assessment of sitting and working furniture is crucial as it effectively reduces the occurrence of MSDs through the analysis of various aspects such as posture in order to improve the quality of human life. The authors conducted a systematic review of 41 studies as well as analyzing and comparing the valid information in the articles. A comprehensive overview of the current state of research in the articles summarizes 32 methods and techniques for the assessment of furniture ergonomics and assesses the applicability of some of the methodological techniques.

(1) However, the number of relevant publications in this field is extremely limited, so it is possible that some of the ergonomic evaluation methods and techniques are not used in the context of furniture. While many researchers have conducted in-depth studies on school and office furniture, there are very few ergonomic evaluations of furniture in the domestic scenario. In particular, most researchers have carried out studies on chairs. Ergonomic assessment of everyday furniture such as sofas, beds and cabinets are also crucial. In addition, the need for ergonomic assessment of different furniture types differs from region to region, and these may be related to the degree of industrialization in the researcher's region. Researchers should extend their assessments beyond chairs to improve the ergonomics and human well-being of furniture.

(2) The vast majority of studies have focused on ergonomic evaluation indicators for seating and work furniture and have examined these ergonomic evaluations as a stand-alone component, with little or no consideration of a number of other factors affecting ergonomics. For example: women have been shown to be more susceptible to musculoskeletal disorders of the upper limbs, but almost all of the studies have not considered gender segregation; the impact of changes in human body dimensions brought about by secular trends on ergonomic evaluations; and the risk of bias due to local cultural backgrounds, habits, and cultural preferences, among others. In other words, the existing research is more directed to the interpretation and quantitative analysis of broad ergonomic assessments, and pays less attention to relatively qualitative insights such as culture, which should be used as a research gap. Attention should be paid to the effects of some factors on ergonomics and the risk of bias that these effects may bring, and a more integrated approach should be used to improve the accuracy and reliability of ergonomics assessment.

(3) Anthropometric and NMQ are more often used in the assessment of school furniture; EMG is more commonly used in the assessment of working furniture but needs to be assessed by integrating subjective evaluation methods; general questionnaires can be used for a wide range of furniture types but the difficulty is how to improve the accuracy of the questionnaires; and RULA is more suitable for assessing evaluations involving the ergonomics of the upper limbs. Most of the ergonomic assessments of sitting and working furniture have used time-saving, convenient and low-cost assessment methods. However, the suitability of

the assessment methods should be considered, and in the literature surveyed there is a tendency to use one method for each element of work involved, without considering suitability. In some cases, the results may be correct. The production of different results may be due to differences in methodology and is an issue that requires further research. The suitability of the assessment methodology for the type of furniture being studied needs to be determined.

(4) For the assessment techniques and methods of sitting and working furniture ergonomics, fewer researchers used mixed research methods, with quantitative methods being the main research method among them. Articles that use two and more techniques are likely to get biased results. Hence, the reason for such results may be due to differences in the way the two techniques are scored or analyzed. Few attempts were made in the investigated literature to determine the cause of the variation. Based on the analyses of the results, it is recommended that a mixed subjective and objective research approach be used so that the data complement each other to increase accuracy.

Data availability statement

The data associated with our study have not been deposited in a publicly available repository. Data will be made available on request.

Funding statement

This research received no external funding.

CRediT authorship contribution statement

Yifan Bai: Writing – original draft, Funding acquisition, Data curation. **Khairul Manami Kamarudin:** Writing – review & editing, Supervision, Conceptualization. **Hassan Alli:** Writing – review & editing, Supervision, Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e28384.

References

[1] S. Parry, L. Straker, The contribution of office work to sedentary behaviour associated risk, BMC Publ. Health 13 (1) (2013) 296, https://doi.org/10.1186/1471-2458-13-296.
[2] G.N. Healy, B.K. Clark, E.A.H. Winkler, P.A. Gardiner, W.J. Brown, C.E. Matthews, Measurement of adults' sedentary time in population-based studies, Am. J. Prev. Med. 41 (2) (2011) 216–227, https://doi.org/10.1016/j.amepre.2011.05.005.
[3] H.E. Brown, G.C. Ryde, N.D. Gilson, N.W. Burton, W.J. Brown, Objectively measured sedentary behavior and physical activity in office employees: relationships with presenteeism, Journal of Occupational & Environmental Medicine 55 (8) (2013) 945–953, https://doi.org/10.1097/JOM.0b013e31829178bf.
[4] M.P. Jans, K.I. Proper, V.H. Hildebrandt, Sedentary behavior in Dutch workers, Am. J. Prev. Med. 33 (6) (2007) 450–454, https://doi.org/10.1016/j.amepre.2007.07.033.
[5] D. Thivel, A. Tremblay, P.M. Genin, S. Panahi, D. Rivière, M. Duclos, Physical activity, inactivity, and sedentary behaviors: definitions and implications in occupational health, Front. Public Health 6 (2018) 288, https://doi.org/10.3389/fpubh.2018.00288.
[6] A.A. Thorp, G.N. Healy, E. Winkler, B.K. Clark, P.A. Gardiner, N. Owen, D.W. Dunstan, Prolonged sedentary time and physical activity in workplace and non-work contexts: a cross-sectional study of office, customer service and call centre employees, Int J Behav Nutr Phys Act 9 (1) (2012) 128, https://doi.org/10.1186/1479-5868-9-128.
[7] N.L. Black, M. Tremblay, F. Ranaivosoa, Different sit:stand time ratios within a 30-minute cycle change perceptions related to musculoskeletal disorders, Appl. Ergon. 99 (2022) 103605, https://doi.org/10.1016/j.apergo.2021.103605.
[8] E. Occhipinti, D. Colombini, A toolkit for the analysis of biomechanical overload and prevention of WMSDs: criteria, procedures and tool selection in a step-by-step approach, Int. J. Ind. Ergon. 52 (2016) 18–28, https://doi.org/10.1016/j.ergon.2015.08.001.
[9] J.M. Lu, L.J. Twu, M.J.J. Wang, Risk assessments of work-related musculoskeletal disorders among the TFT-LCD manufacturing operators, Int. J. Ind. Ergon. 52 (2016) 40–51, https://doi.org/10.1016/j.ergon.2015.08.004.
[10] Y.C. Lee, C.H. Lee, SEE: a proactive strategy-centric and deep learning-based ergonomic risk assessment system for risky posture recognition, Adv. Eng. Inf. 53 (2022) 101717, https://doi.org/10.1016/j.aei.2022.101717.
[11] V.C.H. Chan, G.B. Ross, A.L. Clouthier, S.L. Fischer, R.B. Graham, The role of machine learning in the primary prevention of work-related musculoskeletal disorders: a scoping review, Appl. Ergon. 98 (2022) 103574, https://doi.org/10.1016/j.apergo.2021.103574.
[12] D. Kang, Y.K. Kim, E.A. Kim, D.H. Kim, I. Kim, H.R. Kim, K.B. Min, K. JungChoi, S.S. Oh, S.B. Koh, Prevention of work-related musculoskeletal disorders, Ann of Occup and Environ Med 26 (1) (2014) 14, https://doi.org/10.1186/2052-4374-26-14.
[13] R.A. Goes, L.R. Lopes, V.R.A. Cossich, V.A.R. de Miranda, O.N. Coelho, R. do Carmo Bastos, L.A.M. Domenis, J.A.M. Guimarães, J.A. Grangeiro-Neto, J.A. Perini, Musculoskeletal injuries in athletes from five modalities: a cross-sectional study, BMC Musculoskelet Disord 21 (1) (2020) 122, https://doi.org/10.1186/s12891-020-3141-8.
[14] J.E. Fernandez, Ergonomics in the workplace, Facilities 13 (4) (1995) 20–27, https://doi.org/10.1108/02632779510083359.

[15] K.H.E. Kroemer, Cumulative trauma disorders: their recognition and ergonomics measures to avoid them, Appl. Ergon. 20 (4) (1989) 274–280, https://doi.org/10.1016/0003-6870(89)90190-7.
[16] B. Iliev, D. Domljan, Z. Vlaović, Comparison of anthropometric dimensions of preschool children and chairs in kindergartens in north Macedonia, Bulgaria and Croatia, Heliyon 9 (3) (2023) e14483, https://doi.org/10.1016/j.heliyon.2023.e14483.
[17] B. Satır, F.Ç. Erdoğan, Comparison of classroom furniture to anthropometric measures of Turkish middle school students, WOR 70 (2) (2021) 493–508, https://doi.org/10.3233/WOR-213587.
[18] F.P. Obinna, A.A. Sunday, O. Babatunde, Ergonomic assessment and health implications of classroom furniture designs in secondary schools: a case study, Theor. Issues Ergon. Sci. 22 (1) (2021) 1–14, https://doi.org/10.1080/1463922X.2020.1753259.
[19] A.M. Hashim, S.Z.M. Dawal, N. Yusoff, Ergonomic evaluation of postural stress in school workshop, Work 41 (SUPPL.1) (2012) 827–831, https://doi.org/10.3233/WOR-2012-0249-827.
[20] S.D. Wami, T.H. Mekonnen, G. Yirdaw, G. Abere, Musculoskeletal problems and associated risk factors among health science students in Ethiopia: a cross-sectional study, Journal of Public Health (Germany) 29 (4) (2021) 943–949, https://doi.org/10.1007/s10389-020-01201-6.
[21] E. Geldhof, D. de Clercq, I. de Bourdeaudhuij, G. Cardon, Classroom postures of 8-12 Year old children, Ergonomics 50 (10) (2007) 1571–1581, https://doi.org/10.1080/00140130701587251.
[22] O.P. Fidelis, B. Ogunlade, S.A. Adelakun, O. Adukwu, Ergonomic analysis of classroom furniture in a Nigerian university, Nig. J. Tech. 37 (4) (2018) 1154, https://doi.org/10.4314/njt.v37i4.40.
[23] R. Zemp, W.R. Taylor, S. Lorenzetti, Are pressure measurements effective in the assessment of office chair comfort/discomfort? A review, Appl. Ergon. 48 (2015) 273–282, https://doi.org/10.1016/j.apergo.2014.12.010.
[24] M. Arefi, A. Pouya, M. Poursadeqiyan, Investigating the match between anthropometric measures and the classroom furniture dimensions in Iranian students with health approach, A Systematic Review. J Edu Health Promot 10 (1) (2021) 38, https://doi.org/10.4103/jehp.jehp_516_20.
[25] M. Joshi, V. Deshpande, A systematic review of comparative studies on ergonomic assessment techniques, Int. J. Ind. Ergon. 74 (2019) 102865, https://doi.org/10.1016/j.ergon.2019.102865.
[26] M.P. De Looze, L.F.M. Kuijt-Evers, J. Van Dieën, Sitting comfort and discomfort and the relationships with objective measures, Ergonomics 46 (10) (2003) 985–997, https://doi.org/10.1080/0014013031000121977.
[27] J. Anderson, A.E. Williams, C. Nester, Musculoskeletal disorders, foot health and footwear choice in occupations involving prolonged standing, Int. J. Ind. Ergon. 81 (2021) 103079, https://doi.org/10.1016/j.ergon.2020.103079.
[28] S. Hignett, L. McAtamney, Rapid Entire body assessment (REBA), Appl. Ergon. 31 (2) (2000) 201–205, https://doi.org/10.1016/S0003-6870(99)00039-3.
[29] D. Kee, Comparison of OWAS, RULA and REBA for assessing potential work-related musculoskeletal disorders, Int. J. Ind. Ergon. 83 (2021) 103140, https://doi.org/10.1016/j.ergon.2021.103140.
[30] L. McAtamney, Nigel Corlett, E. Rula, A survey method for the investigation of work-related upper limb disorders, Appl. Ergon. 24 (2) (1993) 91–99, https://doi.org/10.1016/0003-6870(93)90080-S.
[31] I. Kuorinka, B. Jonsson, A. Kilbom, H. Vinterberg, F. Biering-Sørensen, G. Andersson, K. Jørgensen, Standardised nordic questionnaires for the analysis of musculoskeletal symptoms, Appl. Ergon. 18 (3) (1987) 233–237, https://doi.org/10.1016/0003-6870(87)90010-X.
[32] C. Viviani, P.M. Arezes, S. Bragança, J. Molenbroek, I. Dianat, H.I. Castellucci, Accuracy, precision and reliability in anthropometric surveys for ergonomics purposes in adult working populations: a literature review, Int. J. Ind. Ergon. 65 (2018) 1–16, https://doi.org/10.1016/j.ergon.2018.01.012.
[33] A. Murtoja Shaikh, B. Bhusan Mandal, S. Mangani Mangalavalli, Causative and risk factors of musculoskeletal disorders among mine workers: a systematic review and meta-analysis, Saf. Sci. 155 (2022) 105868, https://doi.org/10.1016/j.ssci.2022.105868.
[34] S. Anwer, H. Li, M.F. Antwi-Afari, A.Y.L. Wong, Associations between physical or psychosocial risk factors and work-related musculoskeletal disorders in construction workers based on literature in the last 20 Years: a systematic review, Int. J. Ind. Ergon. 83 (2021) 103113, https://doi.org/10.1016/j.ergon.2021.103113.
[35] A. Radwan, P. Fess, D. James, J. Murphy, J. Myers, M. Rooney, J. Taylor, A. Torii, Effect of different mattress designs on promoting sleep quality, pain reduction, and spinal alignment in adults with or without back pain; systematic review of controlled trials, Sleep Health 1 (4) (2015) 257–267, https://doi.org/10.1016/j.sleh.2015.08.001.
[36] D. Tranfield, D. Denyer, P. Smart, Towards a methodology for developing evidence-informed management knowledge by means of systematic review, Br J Management 14 (3) (2003) 207–222, https://doi.org/10.1111/1467-8551.00375.
[37] D. Moher, A. Liberati, J. Tetzlaff, D.G. Altman, The PRISMA Group, Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement, PLoS Med. 6 (7) (2009) e1000097, https://doi.org/10.1371/journal.pmed.1000097.
[38] I.W.R. Taifa, A student-centred design approach for reducing musculoskeletal disorders in India through six Sigma methodology with ergonomics concatenation, Saf. Sci. 147 (2022) 105579, https://doi.org/10.1016/j.ssci.2021.105579.
[39] O.P. Fidelis, B. Ogunlade, Anthropometric perspective to classroom furniture ergonomics and the need for standards in Nigerian schools, Work 72 (1) (2022) 279–289, https://doi.org/10.3233/WOR-205317.
[40] M. Shohel Parvez, N. Tasnim, S. Talapatra, A. Ruhani, A.S.M.M. Hoque, Assessment of musculoskeletal problems among Bangladeshi university students in relation to classroom and library furniture, J. Inst. Eng.: Series C 103 (3) (2022) 279–292, https://doi.org/10.1007/s40032-021-00792-7.
[41] S. Champion, C. Barr, B. Lange, L.K. Lewis, M.P. Russo, A. Maeder, S. Gordon, Chair design for older immobile people: comparison of pressure mapping and manual handling outcomes, Appl. Ergon. 98 (2022) 103581, https://doi.org/10.1016/j.apergo.2021.103581.
[42] F. Cabegi de Barros, C.S. Moriguchi, T. de Oliveira Sato, Effects of workstation adjustment to reduce postural exposure and perceived discomfort among office workers - a cluster randomized controlled trial, Appl. Ergon. 102 (2022) 103738, https://doi.org/10.1016/j.apergo.2022.103738.
[43] W.Q. Wang, J. Zhang, Y.C. Cai, Improvement of chair in ladder classroom based on human data and behavior investigation of college students, Lect. Notes Comput. Sci. (2022) 172–184, https://doi.org/10.1007/978-3-031-05890-5_14, 13319 LNCS.
[44] P.B. Rodrigues, Y. Xiao, Y.E. Fukumura, M. Awada, A. Aryal, B. Becerik-Gerber, G. Lucas, S.C. Roll, Ergonomic assessment of office worker postures using 3D automated joint Angle assessment, Adv. Eng. Inf. 52 (2022) 101596, https://doi.org/10.1016/j.aei.2022.101596.
[45] M.R. Cardoso, A.K. Cardenas, W.J. Albert, A biomechanical analysis of active vs static office chair designs, Appl. Ergon. 96 (2021) 103481, https://doi.org/10.1016/j.apergo.2021.103481.
[46] K.E. Famero, J.Z. Paguia, M.T. Yumul, M.J.J. Gumasing, Ergonomic design of a computer workstation for preschool students studying at home, in: Proceedings of the International Conference on Industrial Engineering and Operations Management, 2021, pp. 1300–1310.
[47] R.G.D. Cadiz, C.J.J. Guerrero, M.J.J. Gumasing, Ergonomic design of computer workstations of high school students studying at home, in: Proceedings of the International Conference on Industrial Engineering and Operations Management, 2021, pp. 1311–1319.
[48] A. Mao, H. Zhang, Z. Xie, M. Yu, Y.-J. Liu, Y. He, Automatic sitting pose generation for ergonomic ratings of chairs, IEEE Trans. Vis. Comput. Graph. 27 (3) (2021) 1890–1903, https://doi.org/10.1109/TVCG.2019.2938746.
[49] Y.T. Prasetyo, A. Kumar, J.P. Alyza, K.T.A.M. Ong, M.A. Siochi, A.K.S. Ong, Evaluation of chair dimensions, anthropometric measurements and subjective comfort among Filipino high school students: a structural equation modelling approach, in: Proceedings of the International Conference on Industrial Engineering and Operations Management, 2021, pp. 1738–1747.
[50] S. Bahrampour, J. Nazari, I. Dianat, M. Asghari Jafarabadi, A. Bazazan, Determining optimum seat depth using comfort and discomfort assessments, Int. J. Occup. Saf. Ergon. 26 (3) (2020) 429–435, https://doi.org/10.1080/10803548.2018.1550912.
[51] K.A. Weatherson, K.B. Wunderlich, G.E. Faulkner, Impact of a low-cost standing desk on reducing workplace sitting (StandUP UBC): a randomised controlled trial, Appl. Ergon. 82 (2020) 102951, https://doi.org/10.1016/j.apergo.2019.102951.
[52] Y. Zhang, L. Luo, J. Wang, H. Hu, C. Zhao, Research on ergonomic design and evaluation of office backrest curve, Adv. Intell. Syst. Comput. 955 (2020) 711–720, https://doi.org/10.1007/978-3-030-20227-9_68.

[53] B.S. Koma, A.-M. Bergh, K.M. Costa-Black, Barriers to and facilitators for implementing an office ergonomics programme in a South African research organisation, Appl. Ergon. 75 (2019) 83–90, https://doi.org/10.1016/j.apergo.2018.09.003.
[54] E. Kahya, Mismatch between classroom furniture and anthropometric measures of university students, Int. J. Ind. Ergon. 74 (2019) 102864, https://doi.org/10.1016/j.ergon.2019.102864.
[55] F. Ncube, A. Kanda, P. Dhlakama, Postural risk associated with wooden steel chairs and stackable arm chairs in a low-income country, Work 64 (3) (2019) 579–586, https://doi.org/10.3233/WOR-193019.
[56] P. Hong, Y. Li, H. Hu, M. Cai, Research on body pressure distribution of office chair with different BMI, Lect. Notes Comput. Sci. (2019) 59–70, https://doi.org/10.1007/978-3-030-22216-1_5, 11581 LNCS.
[57] E.C. Godilano, M.K.G. Galang, H.E.O. Ramilo, K.R.F. Velayo, Design of an ergonomie classroom chair and desk for preschool students of selected public schools in cabuyao city, laguna, 420–423, https://doi.org/10.1109/IEA.2018.8387137, 2018.
[58] E. Weston, P. Le, W.S. Marras, A biomechanical and physiological study of office seat and tablet device interaction, Appl. Ergon. 62 (2017) 83–93, https://doi.org/10.1016/j.apergo.2017.02.013.
[59] I.W. Taifa, D.A. Desai, Anthropometric measurements for ergonomic design of students' furniture in India, Engineering Science and Technology, an International Journal 20 (1) (2017) 232–239, https://doi.org/10.1016/j.jestch.2016.08.004.
[60] M.S. Rodrigues, R.D.V. Leite, C.M. Lelis, T.C. Chaves, Differences in ergonomic and workstation factors between computer office workers with and without reported musculoskeletal pain, Work 57 (4) (2017) 563–572, https://doi.org/10.3233/WOR-172582.
[61] T. Fettweis, M.N. Onkelinx, C. Schwartz, C. Demoulin, J.L. Croisier, M. Vanderthommen, Relevance of adding a triangular dynamic cushion on a traditional chair: a 3D-analysis of seated schoolchildren, Clin. BioMech. 49 (2017) 113–118, https://doi.org/10.1016/j.clinbiomech.2017.09.002.
[62] N.A. Charpe, User-chair Fit Index (UCFI): an ergonomic evaluation tool for user-chair compatibility, Adv. Intell. Syst. Comput. 588 (2018) 755–761, https://doi.org/10.1007/978-3-319-60582-1_75.
[63] J. Ward, J. Coats, Comparison of the BackJoy SitSmart relief and spine buddy LT1 H/C ergonomic chair supports on short-term neck and back pain, J. Manipulative Physiol. Therapeut. 40 (1) (2017) 41–49, https://doi.org/10.1016/j.jmpt.2016.10.006.
[64] D. De Carvalho, D. Grondin, J. Callaghan, The impact of office chair features on lumbar lordosis, intervertebral joint and sacral tilt angles: a radiographic assessment, Ergonomics 60 (10) (2017) 1393–1404, https://doi.org/10.1080/00140139.2016.1265670.
[65] H. Yuhaniz, A. Seraila, S.R. Abdul Karim, S. Muhammed, A.H. Saleh, Anthropometrics evaluation of children between genders, Malaysian Journal of Public Health Medicine 2016 (Specialissue) (2016) 22–25, https://doi.org/10.1177/1541931215591090.
[66] S.A. Workineh, H. Yamaura, Multi-position ergonomic computer workstation design to increase comfort of computer work, Int. J. Ind. Ergon. 53 (2016) 1–9, https://doi.org/10.1016/j.ergon.2015.10.005.
[67] R. Alojado, B. Custodio, K.M. Lasala, P.L. Marigomen, Designing an ergonomic chair for pedicurists and manicurists in quezon city, Philippines, Procedia Manuf. 3 (2015) 1812–1816, https://doi.org/10.1016/j.promfg.2015.07.220.
[68] I.T.G. Souza, C.R.B. Buski, E.C. Batiz, A.L.B. Hurtado, Ergonomic analysis of a clothing design station, Procedia Manuf. 3 (2015) 4362–4369, https://doi.org/10.1016/j.promfg.2015.07.432.
[69] A. Altaboli, R. Ahmida, M. Elmgrab, H. Immraga, R. Othman, Anthropometric evaluation of proposed improved designs of the classroom desk for benghazi primary schools, 2015-January, pp. 426–430, https://doi.org/10.1177/1541931215591090, 2015.
[70] H.I. Castellucci, P.M. Arezes, J.F.M. Molenbroek, Applying different equations to evaluate the level of mismatch between students and school furniture, Appl. Ergon. 45 (4) (2014) 1123–1132, https://doi.org/10.1016/j.apergo.2014.01.012.
[71] Lima, F.; Almeida, J.; Figueiredo, J. P.; Ferreira, A. Scholar Ergonomics-Primary Schools in Tartu (Estonia) Study Case; *SHO*2014; pp 175–179. https://doi.org/10.1201/b16490-33.
[72] I. Dianat, M.A. Karimi, A. Asl Hashemi, S. Bahrampour, Classroom furniture and anthropometric characteristics of Iranian high school students: proposed dimensions based on anthropometric data, Appl. Ergon. 44 (1) (2013) 101–108, https://doi.org/10.1016/j.apergo.2012.05.004.
[73] A.I. Bello, A.S. Sepenu, Mismatch in body-chair dimensions and the associated musculoskeletal pain among selected undergraduate students in Ghana, J. Muscoskel. Res. 16 (3) (2013), https://doi.org/10.1142/S0218957713500164.
[74] C. Paraizo, A. de Moraes, An ergonomic study on the biomechanical consequences in children, generated by the use of computers at school, Work 41 (2012) 857–862, https://doi.org/10.3233/WOR-2012-0254-857.
[75] R.P. Ellegast, K. Kraft, L. Groenesteijn, F. Krause, H. Berger, P. Vink, Comparison of four specific dynamic office chairs with a conventional office chair: impact upon muscle activation, physical activity and posture, Appl. Ergon. 43 (2) (2012) 296–307, https://doi.org/10.1016/j.apergo.2011.06.005.
[76] M.A. Gonçalves, P.M. Arezes, Postural assessment of school children: an input for the design of furniture, Work 41 (SUPPL.1) (2012) 876–880, https://doi.org/10.3233/WOR-2012-0257-876.
[77] L.B. Da Silva, A.S. Coutinho, E.J. Da Costa Eulálio, E.V.G. Soares, School furniture and work surface lighting impacts on the body posture of paraíba's public school students, Work 42 (4) (2012) 579–587, https://doi.org/10.3233/WOR-2012-1369.
[78] R. Osquei-Zadeh, J. Ghamari, M. Abedi, H. Shiri, Ergonomic and anthropometric consideration for library furniture in an Iranian public university, Int. J. Occup. Environ. Med. 3 (1) (2012) 19–26.
[79] L.M. Fedorowich, J.N. Côté, Effects of standing on typing task performance and upper limb discomfort, vascular and muscular indicators, Appl. Ergon. 72 (2018) 121–127, https://doi.org/10.1016/j.apergo.2018.05.009.
[80] A. Cui, K. Emery, A.-S. Beaudoin, J. Feng, J.N. Côté, Sex-specific effects of sitting vs standing on upper body muscle activity during text typing, Appl. Ergon. 82 (2020) 102957, https://doi.org/10.1016/j.apergo.2019.102957.
[81] M. Sydor, M. Hitka, Chair size design based on user height, Biomimetics 8 (1) (2023) 57, https://doi.org/10.3390/biomimetics8010057.
[82] D.E. Treaster, D. Burr, Gender differences in prevalence of upper extremity musculoskeletal disorders, Ergonomics 47 (5) (2004) 495–526, https://doi.org/10.1080/00140130310001638171.
[83] A.N. Alias, K. Karuppiah, V. How, V. Perumal, Prevalence of musculoskeletal disorders (MSDS) among primary school female teachers in terengganu, Malaysia, Int. J. Ind. Ergon. 77 (2020) 102957, https://doi.org/10.1016/j.ergon.2020.102957.
[84] N. Busto Serrano, A. Suárez Sánchez, F. Sánchez Lasheras, F.J. Iglesias-Rodríguez, G. Fidalgo Valverde, Identification of gender differences in the factors influencing shoulders, neck and upper limb MSD by means of multivariate adaptive regression splines (MARS), Appl. Ergon. 82 (2020) 102981, https://doi.org/10.1016/j.apergo.2019.102981.
[85] M. Hitka, P. Štarchoň, Ľ. Simanová, M. Čuta, M. Sydor, Dimensional solution of wooden chairs for the adult bariatric population of Slovakia: observational study, Forests 13 (12) (2022) 2025, https://doi.org/10.3390/f13122025.
[86] Hitka Miloš, Milan Naď, Nadežda Langová, Miloš Gejdoš, Denisa Lizoňová, Maciej Sydor, Designing chairs for users with high body weight, Bioresources 18 (3) (2023) 5309–5324, https://doi.org/10.15376/biores.18.3.5309-5324.