SYSTEMATIC REVIEW

Associations Between Design Professionals Working on Computers and Risks of Musculoskeletal Diseases: A Systematic Review

Kodsiah Mohd Juzad[1], Shamsul Bahri Mohd Tamrin[1], Ng Yee Guan[1], Rozanah Ab. Rahman[2]

[1] Department of Environmental and Occupational Health, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
[2] School of Business and Economics, Universiti Putra Malaysia, 43400 Serdang, Malaysia.

ABSTRACT

Introduction: This systematic review emphasises on the risk factors of musculoskeletal diseases (MSDs) among design professionals such as designers and architects due to long hours of working in front of computers. **Aims:** This study aimed to identify MSDs and its associated factors among design professionals such as designers and architects who relied heavily on computers to complete their design tasks. **Methods:** This review adopted the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) guideline. Two databases namely Scopus and PubMed were searched. **Results:** The systematic search retrieved 16 articles for analysis. Four main themes emerged from the thematical analysis, namely computer usage risk, computer mouse risk, body posture and anthropometric as well as risk assessment. A total of 11 sub-themes were formulated based on the four main themes. **Conclusion:** Long hours spent with the computer increased the risk of MSDs and design professional users were found to spend more hours working on the computer compared to office workers and students. As an intense computer user, mouse usage and unergonomic workstation were identified associated with MSDs risk among design professionals based on various MSDs assessment. The systematic review suggested future compressive studies among design professionals such as designers, design engineers and architects on MSDs risk due to lack of previous research on this intense computer user group.

Keywords: Design Professionals, Musculoskeletal, Carpal Tunnel Syndrome, Anthropometric & Ergonomic

Corresponding Author:
Shamsul Bahri Mohd Tamrin, PhD
Email: shamsul_bahri@upm.edu.my
Tel: +603 8947 1193

INTRODUCTION

Musculoskeletal disorders (MSD) is the second highest occupational disease reported in Malaysia (1). Musculoskeletal disorder is defined as an illness of the musculoskeletal system of the human body (2). In Malaysia, the statistics from the Social Security Organisation (SOCSO) showed that one-quarter of industrial workers suffered from upper limb injuries (Tengku Zawawi, 2018). Industrial accidents have become the main contributor of occupational injuries and disabilities with an increasing number of cases from 55,186 in 2016 to 57,639 in 2017. As for MSD, the number of cases showed an increment of 174% with a rise of 32 cases in 2016 to 85 cases in 2017 (3).

Out of all the MSD cases reported from 2006 to 2010 by SOCSO, 24% of cases were contributed by Carpal Tunnel Syndrome (CTS) (1). CTS is the commonest entrapment neuropathy of the upper limbs with an occurrence rate of 3.3-3.5 per 100 person-year and a prevalence rate of 1-5% in the general population (1-4). CTS can produce undesirable musculoskeletal conditions such as numbness, tingling, weakening, or muscular damage on the hand and fingers.

Computer professionals in design areas such as designers, architects, and design engineers are a group of creative people that are tasked to translate conceptual ideas into the end products including magazines, furniture, houses, or even aircraft. Traditionally, design professionals perform and complete their artworks manually using drawing stationeries such as drawing board or table, T-square, pens, pencils, colour pencils, marker pens, and other design materials (4). After the 1970s, with the emergence of the digital era, many artworks started to be produced commercially aided by computers (5). In today's modern designing world, design professionals and computers are almost inseparable. Although manual sketches are still in practice during the development of initial design ideas, the computer has become an essential tool in the designing process.

Design professionals literally sketch or draw using the computer mouse, in substitution of pencil or pen used in manual sketching. This process of manipulating the mouse as a design input and to master keyboard shortcuts to accelerate design process requires years of professional training. In the daily work of design professionals, various software including Adobe Photoshop, Illustrator, Adobe In design, Adobe Premier, Sketch Pro, Computer Aided Design (CAD), CATIA and others are used. Most artworks start with simple hand sketches before being converted into the data or soft copy form in the final design stage. Therefore, many design professionals spend most of their working time in front of computers. Furthermore, they are expected to observe the deadlines given by the clients to comply with the project schedule or industrial production lines. In the United States, as high as 74% of full-time employed design professionals work between 40 to 50 hours a week to complete their given assignments (6). With such a high percentage of design professionals who are working long hours, occupational health issues are likely to abound among them.

The need for a systematic review
According to Higgins (2016), a systematic literature review is used to comprehensively identify and synthesise particular research aims and to replicate procedures on each step in an organised and transparent way. In short, the various elements in the systematic review process are in essence the motivation factors for researchers to gather evidence that can produce more significant findings (7).

Most of the literature on MSD and CTS from previous studies involved participants in the healthcare, construction, automotive and office work sectors (8–11). However, there are still very limited studies among professionals that perform extensive computer work daily such as designers, architects, and design engineers. Thus, the lack of evidence on MSD and CTS among the above-mentioned group of professional computer users represents a research gap that warrants further attention. The main research question of this review was "What are the risk factors of musculoskeletal diseases among design professionals working with computers?". This section emphasised the need of performing the methodology of a literature review to answer the established research question.

MATERIALS AND METHODS

This section outlines the five steps in the execution of the systematic literature, namely PRISMA, resources, inclusion and exclusion criteria, systematic review process, as well as data abstraction and analysis that were deployed in this research.

PRISMA

PRISMA or Preferred Reporting Items for Systematic Reviews and Meta-Analyses is a comprehensive standard that guides the researchers who are performing systematic reviews(12). The guide ensures that quality and rigorous research are done based on all the required steps outlined in the guide(7).

The method includes four stages: identification, screening, eligibility, and inclusion (12). It is commonly used in medical, agricultural, and psychological sectors and is based on scanning the SCOPUS database using the search string.

Resources

In this review, two databases were searched to retrieve the main source of data, namely SCOPUS and PubMed. Scopus is a very powerful database system that consists of a wide range of up to 256 fields of study, including medical and health science fields. As for PubMed, it is one of the most comprehensive databases for researchers to find the latest research on the medical and health science field. Nevertheless, another two databases i.e. Science Direct and Mendeley were incorporated manually in order to obtain more data that could help to conclude the findings.

The Systematic Review Process

The initial stage involves finding suitable keywords that best represent the research question. Table I shows the search string developed based on keywords relevant to this review to be used in SCOPUS and PubMed.

Table I: The Search String.

SCOPUS Search String	TITLE-ABS-KEY (("carpal tunnel syndrome" OR "musculoskeletal" OR "repetitive strain injuries") AND ("computer usage" OR "computer mouse") AND ("ergonomics" OR "awareness" OR "designe*" OR "archite*")) * AND (LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015)) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SRCTYPE , "j"))
PubMed Search String	(("carpal tunnel syndrome"[MeSH Terms] OR ("carpal"[All Fields] AND "tunnel"[All Fields] AND "syndrome"[All Fields]) OR "carpal tunnel syndrome"[All Fields]) AND ("computers"[MeSH Terms] OR "computers"[All Fields] OR "computer"[All Fields]) AND ("ergonomics"[MeSH Terms] OR "ergonomics"[All Fields]) AND ("hand"[MeSH Terms] OR "hand"[All Fields])) AND ("2010/04/15"[PDat] : "2020/04/12"[PDat])

Screening
In the early stage, an initial screening process was performed to identify and exclude any duplicate articles. For this current review, research articles were the only publication type included. This is because the research article is considered a reliable source evidence due to its use of empirical data. Based on the inclusion and exclusion criteria listed in Table II, a total of 32 articles remained after screening the 126 articles.

Table II: The Inclusion and exclusion criteria.

Criterion	Eligibility	Exclusion
Literature type	Journal (research articles)	Journals (review), book series, book, chapter in book, conference proceeding
Language	English	Non-English
Timeline	Between 2010 and 2019	<2010
Subject area	Ergonomics, Occupational Safety & Health science	Other than Ergonomics, Occupational Safety & Health science

Eligibility
Following that, the 32 included articles were tested for eligibility in the third stage of the systematic review. All the articles selected from the previous screening stage were evaluated by examining the abstract, important notes, content, and main text of the articles. Following the evaluation, half of the studies (n=16) were found to be not aligned with the inclusion criteria and were excluded from the next stage of review.

Data Abstraction and Analysis
In this study, the data from all research methods whether qualitative, quantitative or mixed method were integrated, analysed, and synthesised. The synthesised outcomes were transformed into another set of quantitative or qualitative data. Figure 1 shows the systematic review process of extracting qualitative data in this study (12). The process of establishing themes and sub-themes in this study led to the creation of four main themes, namely computer usage risk, computer mouse risk, body posture and anthropometric risk and lastly risk assessment. A total of 11 related sub-themes that were associated with the four main themes created earlier were identified.

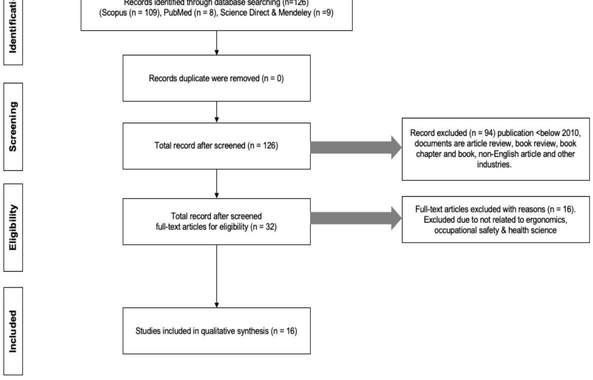

Figure 1: Flow Diagram of study (Adapted from Moher et.al 2009)

RESULTS

In this review, 16 articles were selected. The results of the themes and sub-themes established in the current study are shown in Table III. All the studies were conducted in 11 different countries as mentioned in Figure 2 and year of each publication in Figure 3.

Computer Usage Risk

Computer Usage
MSDs are a type of major occupational disease caused by computer-related activities that mentioned in 15 articles in this systematic review (13–27). The prevalence of MSD are mostly found in workplaces (13,15,17,25,26,28). Since the 1970s, computers have been incorporated as part of the business operation in line with the rise of automation technology in many industries(24).

Apart from workplaces, studies in a learning environment such as schools, colleges, and universities have also reported an association between computer use and MSD (14,29). Study in Ankara, Turkey found that MSD had a significant association with computer usage in a local university whereby the common complaint included pain over the shoulder, neck, and wrist areas (22). In addition, a study among university students in India also

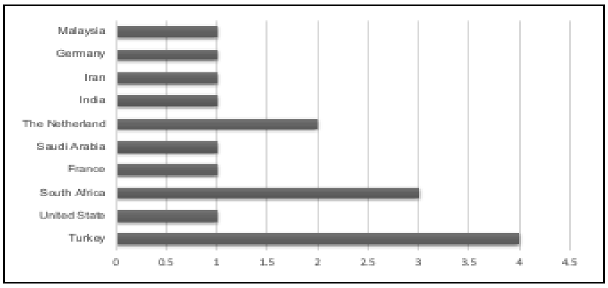

Figure 2: Countries where the studies were conducted.

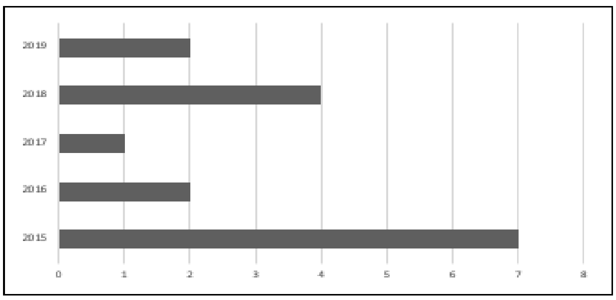

Figure 3: Year of publication.

Table III (a): The main themes and the sub themes.

NO.	AUTHOR & YEAR	COMPUTER USAGE RISK				COMPUTER MOUSE RISK		BODY POSTURE & ANTHROPOMETRIC RISK		RISK ASSESSMENT		
		CU	HS	BR	PI	MU	MA	SP	WM	PP	LE	AM
1	Ardahan & Simsek, 2016	/	/	/				/				
2	Brink et al., 2015	/	/					/				
3	Sirajudeen et al., 2018	/	/	/		/		/				
4	Celik et al., 2018	/	/	/		/			/			
5	Ekinci et al., 2018	/										
6	Rakhadani et al., 2017	/		/					/			
7	Sahu et al., 2019	/			/	/				/		
8	Labbafinejad et al., 2019	/					/				/	
9	Kluth and Keller, 2015	/					/	/			/	
10	Baba and Daruis, 2016	/							/	/		
11	Schmid et al., 2015	/					/			/		
12	Niekerk et al., 2015	/				/		/			/	
13	Huysmans et al. 2018	/							/	/		/
14	Mediouni et al., 2015	/			/	/				/		
15	Toosi et al., 2015	/			/							
16	Dogru et al.,2015				/	/				/		

Table III (b): The main themes and the sub themes legend.

COMPUTER USAGE RISK	COMPUTER MOUSE RISK	BODY POSTURE & ANTHROPOMETRIC RISK	RISK ASSESSMENT
CU= Computer Usage	MU= Mouse Usage	SP= Sitting Position & Posture	PP= Pen & Paper Exposure Assessment
HS= Hours Spent on Computer	MA= Mouse Alternative	WM= Workstation Mismatch & Anthropometric	LE= Laboratory Exposure Assessment
BR= Break During Prolong Computer Usage			AM= Assessment Model
PI= Professionals & Intense Computer User			

discovered that computer usage were associated with MSD besides sitting position, non-ergonomic chairs and stress (23).

Hours Spent on Computer

The combination of long hours of computer use, prolonged sitting, and working on the desk predisposed many office workers to MSDs (13,21). A study from South Africa reported a significant association between 9 hours or more of weekly computer usage and neck pain among high school students (14). Professionals were reported to spend another additional hour working with computers at home (24). Sirajudeen (2018) highlighted the association between years of computer usage and the prevalence of MSDs, especially computer users with less than 5 years of use (29). Study done in Turkey mentioned that average hours office worker working with computer is 7 hours (13) however researched in Saudi Arabia recorded association of MSDs prevalence with 1-5 hours of computer usage (23).

Break During Prolong Computer Usage

In the study by Rakhadani (2018), it was mentioned that computer users should take a break from prolonged computer usage to avoid health issues (23). Working with computers for more than 7 hours per day and without a break for 3 hours continuously can increase the risk of developing MSDs, especially for workers who have been using computers for more than 15 years (13). Studies in Saudi Arabia discovered that pain related to MSDs can affect the shoulder, elbow, and wrist/hand as a result of a lack of break or rest time. Moreover, Sirajudeen (2018) stated female laptop users who did not use an external mouse or take breaks during prolonged computer use were prone to develop MSDs compared to males (29). Neck pain was commonly associated with married female office workers who reported prolonged hours of sitting at the workplace with low numbers of breaks in between (21). According to Ardahan (2016), computer users are advised to take a break at least every 3 hours in between (13).

Professionals & Intense Computer User

Occupational works that involved repetitive, forceful motions of hand and wrist contribute to an increasing risk of developing CTS (19). Study in India found that professionals who work with Computer Aided Design (CAD) software are vulnerable to developing CTS (24). In this study CAD designers spent longest time to perform CAD designing tasks on computers compared to other typical office worker. The study also showed that CAD users spent another additional hour using the computer at home after office hours. One of the main causes of the prolonged hours of computer work was the need to complete the design assignment (24). Rapid Upper Limbs Assessment (RULA) was deployed to evaluate the workstation. CAD designers that scored greater than 4 in RULA assessment were given ergonomics training, wrist pad and suggested to use high adjustable chair with height and armrest adjustable as part of intervention. The ergonomic interventions are highly recommended to improve the workstations of CAD designers for them to adopt neutral postures during CAD designing tasks, apart from ensuring that Rapid Upper Limbs Assessment (RULA) is satisfactory (24).

Furthermore, a study amongst architecture student in a university in Turkey found that the prevalence of CTS increased with the years spent in university, likely due to the amount of manual design and digital computer works they had to do (22). Based on these findings, it is not surprising that MSDs and the risk of CTS among professional computer users started as early as their professional training during tertiary education, way before their employment days as architect.

Computer Mouse Risk

Mouse Usage

Continuous and repetitive use of mouse while writing or drawing with computers can lead to arm and hand pain. In a long run, it can also result in other collective traumas (21). In addition, many previous studies have outlined the evidence that associated common mouse usage with the development of CTS among heavy computer users (18,24,30). Study by Sahu et. al. (2019) reported professionals designer who work with CAD software complained of pain in the wrist, shoulder, and back as a result of extensive mouse usage (24). Intense computer user such as final year architecture student who designed mostly with computer using mouse were found to developed more significant risk of CTS compare to freshmen (22).

Celik (2018) found that a computer mouse placed at a distance away from the keyboard is associated with more significant complaints of pain in the upper back, shoulder, and arm from office workers. Celik (2018) mentioned in the research that female workers have experienced shoulder pain due to the position of the mouse and the type of chair used when performing computer works (21). Whilst the use of a mouse could trigger MSDs, ironically the absence of an external mouse while using the laptop could also contribute to MSDs that affect the upper limbs and spine. External mouse and keyboard while working with the laptop can decrease awkward and static posture, thus lowering the risk of MSDs (20). Lastly, mouse operation requires hand-eye coordination and visual focus that could contribute to a rigid sitting posture (16). Therefore, RULA analysis on the wrist position at the workstation is a vital intervention to reduce the risk of MSDs from mouse usage (24).

Mouse Alternative

Awkward hand and arm position while performing computer-aided data entry and text processing as well as mouse operation caused by the weight of the kinematic chain can result in MSDs such as Repetitive Strain Injury (RSI) syndrome and CTS (26). RSI is also known as the "mouse arm" as a result of the extensive use of the computer mouse. In addition, experiments have been done in Germany to find an alternative standard mouse or roller bar mouse with a lower risk of MSDs as an input device (26). Apart from that, unnatural wrist position during computer operation with the mouse has also been associated with the risk of developing CTS (15). The operation of standard mouse was perceived as very uncomfortable as it involves the single use of the index finger alone, thus leading to possible fatigue of finger muscles. In comparison, the roller bar mouse can be operated with a variety of methods, including scrolling the wheel with just the thumb or moving the scroll wheel with the whole hand. Therefore, the roller bar mouse is an ideal replacement for the standard computer mouse to reduce musculoskeletal complaints such as CTS and RSI suggested by Kluth and Keller (2015) (26).

Another alternative to the typical mouse with ergonomic features is the vertical mouse. Schmid et al. (2015) reported an increased carpal tunnel pressure was detected among operators of the computer mouse due to an increase in the wrist angles (15). Besides reducing the amount of ulnar deviation, the vertical mouse also provides support from ergonomic wrist pads to reduce wrist extension compared to the standard mouse.

In an Iranian study, the muscle activity when using four (4) types of mouse, namely slanted, standard, trackball, and track pad was evaluated using Electromyography (EMG) by Labbafinejad (2019). Three (3) of them, namely standard, trackball, and trackpad mouse indicated no significant difference in terms of the electrical activity of muscle during the study. However, the activity of Extensor Digitorum Communis (EDC), Extensor Carpi Radialis (ECR), and Flexor Pollicis Longus (FPL) muscles reduced while working with the slanted mouse. It could be due to the fact that slanted mouse cast a lower impact on muscle activity. Therefore, it represents a better ergonomic choice in reducing the MSDs on the hand and wrists of mouse users (25).

Body Posture & Anthropometric Risk

Sitting Position and Posture

Prolonged sitting is significantly associated with developing MSDs (13,16,20,26) such as Upper Quadrant Musculoskeletal Paint (UQMP) (14). Using a three-dimensional posture analysis tool (3D-PAT), the sitting position of high school students aged between 15-17 years who were undertaking the course of Computer Application Technology in a South African high school were assessed. The results showed that 34% of the participants recorded a seating position that was associated with UQMP complaints after six to twelve months of intervention. The head flexion (HF) caused by seating related UQMP increased the pain score by 90%.

In addition, bad posture among teenage computer users is indicative of prolonged sitting that affects the head, neck, and shoulder. In view of that, classroom ergonomic and postural hygiene awareness among adolescents who use computers should be enhanced to reduce their risk of developing UQMP (14). Another study on postural dynamics in South Africa used the 3D motion analysis system and managed to capture a number of postural changes when using mouse and keyboard typing during computer activities (16). In the study, less postural dynamics were observed in the cervical and thoracic spine regions during the use of computer mouse and keyboard typing activity. Limited height adjustment of the typist chair in the workstation environment can also influence postural dynamic (16).

Workstation Mismatch & Anthropometric

A study in one of the Malaysian telecommunication companies found that the design of workstation is significantly correlated with the prevalence of RSI (28). The common areas affected in RSI are the neck, shoulder, hand, and wrist. This could be attributed to uncomfortable workstations in which some of the workers commented that they were too tall, too short, or too overweight to fit into the non-ergonomic designed workstation (28). Therefore, it Is vital to provide training on the relevant computer ergonomic principles apart from reorganising and adjusting the workstation (23). Population data should be utilised to obtain the ergonomic requirements based on the anthropometric measurement that is unique to the age and gender of the population (21). In the Netherlands, a study was done to evaluate two different models in the examination of physical exposure factors of occupational MSDs symptoms. The model based on the software that recorded patterns with additional features of anthropometric measurement of workstation set-up for each participant displayed a better predictive result compared to the model with only self-reported factors and recorded computer usage patterns (17).

Risk Assessment

Pen & Paper Exposure Assessment

There are a few popular and established questionnaires to evaluate the exposure of pen and paper towards the development of MSDs. The Rapid Upper Limb Assessment (RULA) is one of the preferred methods of assessment. It is based on the observational method to evaluate the risk of MSDs (22,24).

Next, the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) is a tool to measure the frequency of occurrence and severity of the condition. It also assessed if the discomfort affects the capability to perform work and task by eleven body parts, namely neck, shoulders, back, upper arms, forearms, wrists, waist, hips, upper legs, knees, and lower legs (13). The Nordic Musculoskeletal Questionnaire (NMQ) is another widely used and reliable surveillance method to evaluate musculoskeletal problems (29).

Laboratory Exposure Assessment

A common method to evaluate the correlation between mouse design and the risk of MSDs is by Electromyography (EMG) (25,26). The device is capable to measure the potential action produced by muscles. A laboratory study by Labbafinejad (2019) evaluated six muscles, including Extensor Carpi Ulnaris (ECU), Extensor Digitorum Communis (EDC), Extensor Carpi Radialis (ECR), Pronator Quadrates (PQ), Flexor Digitorum Superficialis (FDS) and Flexor Pollicis Longus (FPL) (25). All these muscles play a significant role when an individual is working with a mouse.

Van Niekerk (2015) deployed The Vicon Motion Analysis system (Vicon, Oxford, United Kingdom) to examine the postural dynamism during the use of a computer mouse and keyboard. The system included eight (either wall-mounted or tripod-mounted) T-10 MX cameras for recording purposes to obtain data that were reliable and highly accurate (16). The Vicon system captured marker positions in three dimensional by reconstruction of the retro-reflective markers volume. Nexus software was used to process the data. The anthropometric measurement was taken based on the Conventional

Gait Model in compliance with the industrial standard in motion analysis.

Assessment Models

One of the interesting findings from this review was the study that used software to compress traditional interviews with prediction models. In The Netherlands study on "Predicting Forearm Physical Exposures During Computer Work Using Self-Reports, Software-Recorded Computer Usage Patterns, and Anthropometric and Workstation Measurements" established two prediction models to compare the evaluation on risk exposure to MSDs during computer work (Huysmans, 2018). The study result showed that, the full model that captured arthrometric data produced better predictive quality compared to the practical model with only captured computer usage patterns.

DISCUSSION

This study systematically analysed 16 studies on the risk of computer usage among computer users. This systematic review initially focused on the prevalence of MSDs and CTS among professionals such as designers and architects. Nevertheless, based on the search string, only a few articles were found related to design professionals and this is due to lack of research on these group of professions.

The first identified theme showed that design professionals could be classified as "intense computer user" as described by previous scholars. CAD designers spent an average of 8 to 10 hours daily working with computers (24), making up an accumulative of 40 to 50 hours a week. A previous study also reported that computer usage of 20 hours a week could predispose the users to various illnesses. As for computer usage of 30 hours and more, the risk of CTS also increased (31). Furthermore, the years spent on computer usage are also associated with a higher risk of developing MSDs (29). The statement is really significant associated to design professionals such as designers and architects as they spent years of professional training in tertiary levels beforehand. Continuous computer usage without a break in between can lead to musculoskeletal pain at the shoulder, elbow, and wrist/hand (29).

Next, the second theme focused on the risk of computer mouse usage. The findings showed that continuous and repetitive mouse usage such as drawing with computers could lead to trauma in a long run turkey (30). Shoulder, back and wrist pain among CAD designers are reported triggered by intense mouse usage while working with CAD software(24). The MSD risk factors reported are similar to intense mouse user risk factors in previous studies.

Ergonomic mouse has been introduced to reduce the risk of developing MSDs or CTS. Although ergonomic mouse such as slanted mouse recorded less impact on muscle activity during computer work (25), the use of ergonomic devices is still dependent on personal preferences (15). Professional users in the design field who rely on the mouse to substitute pen or pencil as the drawing mechanism might not prefer ergonomic mouse such as the slanted mouse. They have been trained to draw digitally with to use the standard mouse on the design software, thus making them more familiar with the type and positioning of the standard mouse.

In the next theme of body posture and anthropometry, it is clear that prolonged sitting is significantly associated with complaints MSDs and UQMP (13,14,16,20,26). The findings showed that the development of UQMP that affects the head, neck, and shoulder due to unergonomic sitting position could have started as early during high school adolescence period before accumulating during university and working time. Poor postural dynamic is also contributed by poor ergonomic workstation, for example, limited height adjustment of the chair during computer mouse and keyboarding activities. A study by Baba (2016) in a telecommunication company showed that poor workstation design is significantly correlated with the prevalence of RSI. Mismatched workstation often fails to accommodate the individual body dimension of each worker. Due to different sizes and measurements of the human body, the anthropometric measurement can be the solution to the issue of mismatched workstation. In short, unique anthropometric data of the designated population based on gender and age should be utilised to fulfil the workplace ergonomic requirement (21).

The final theme found that among the preferred assessment of MSDs risk identified in this review is the Rapid Upper Limb Assessment (RULA) that calculates postural alignment, stability, and the estimated force of the body parts exposed to the risk (22,24). Another two significant assessment methods found in this review were The Cornell Musculoskeletal Discomfort Questionnaire (CMDQ)-Turkey version (13) and the Nordic Musculoskeletal Questionnaire (NMQ) (28,29). Both have been proven as reliable methods to evaluate musculoskeletal problems in previous surveillance studies. In the laboratory environment, Electromyography (EMG) is the common method used to evaluate the correlation between mouse design and risk of MSDs as well as to measure the potential action produced by muscles (25,26). A study from the Netherlands found that the Software-Recorded Computer Usage Patterns model that included anthropometric and workstation measurements produced a better predicting quality (17). The combination of interviews, ECR, and software is a command practice but the addition of individual anthropometric and workstation measurements proved to be a step forward in the approach to evaluate the risk of MSDs during computer work.

It is acknowledged that MSDs can affect the quality of life of individuals apart from jeopardising productivity at work. Even though today's labour market promotes a work life balance to improve the quality of life (32), this idea of a balanced lifestyle is still a rhetorical for this group of professionals. Celik (2018) found that half of the workers experienced pain from MSDs continuously for at least twelve months or more. However, only 20% of them sought treatment while the remaining 80% ignored the pain and refused to seek medical help. As a result, this situation results in a decline in work performance and negative emotional impact among workers who are exposed to MSD risk (21).

Study found that ergonomic training could reduce the risk of MSDs (13,22) and early ergonomic awareness should be instilled among young computer users as early as possible during their high school years (14). Ekinci (2019) mentioned that individuals who received ergonomic training showed a good apprehension about the appropriate posture of the joints and spine during computer use. They also learned not to stress out body parts that could lead to musculoskeletal pain (22). Ergonomic training between three and six months has been proven to be effective to decrease MSDs-related risk and pain (13). A study in Ankara, Turkey assessed the RULA scores and found that the positive impact of ergonomic training remained in the persons even after receiving the training quite some time ago. The findings showed that the trained group understood the appropriate postures to avoid stress overload on the joints and spine to reduce musculoskeletal pain (22). Another study done by Ardahan (2016) found that three to six months of ergonomic training was effective in reducing the pain from MSDs (13).

CONCLUSION

This systematic review has identified that designers who are working long hours performing artworks digitally using computers are highly associated with risk of developing MSD disease. The first theme revealed that a longer duration spent with the computer increased the risk of MSDs and professional users were found to spend more hours working on the computer compared to office workers and students. In addition, years of computer usage also increases the risk of developing MSDs. Theme two emphasised the fact that mouse usage is essential as an input device in computer work and thus it also represents a risk factor of developing MSDs such as CTS. Extensive mouse usage during design activities that similar to MSD risk develop by typical intense mouse user. The third theme centred on MSDs risk from the sitting posture during computer work and mismatched workstation failed to consider the anthropometric data of the population in mind. As intense user of computer design professionals such as designers and architects need to observe anthropometric data to calibrate workstation ergonomics. Lastly, the final theme touched on refers to the modification of MSDs prevalence assessment from the traditional pen and paper method to the laboratory and model-based environment using computer software. In a nutshell, these four main themes highlighted risk factors of MSDs among designers. Based on the findings, it is vital to conduct further research on the risk factors of MSDs among design professionals. This is crucial to provide better insight of the awareness and disease prevalence among this group of professionals who work long hours with computers as part of their working routine. The outcomes could guide them on how to reduce the risk of MSDs apart from educating them on how to take better care of their hands, the most valuable asset for any design professionals.

ACKNOWLEDGEMENTS

We thanked the Ministry of Higher Education Malaysia (Fundamental Research Grant Scheme Project No: FRGS/1/2016/SKK06/UPM/02/11) and Universiti Putra Malaysia (Putra Grant-Postgraduate initiative GP-IPS/2016/9489500) for the funds granted for this project. Thank you to all participants and individuals who are directly or indirectly involved in this study.

REFERENCES

1. Socso HP. Work-Related Musculoskeletal Disease Compensation. 2019;
2. Pandya M. Systematic Review on Various Risk Assessment Techniques of Musculoskeletal Disorder. Ind Eng J. 2019;12(6):1–7.
3. Tengku Zawawi TNS, Abdullah AR, Jopri MH, Sutikno T, Saad NM, Sudirman R. A review of electromyography signal analysis techniques for musculoskeletal disorders. Indones J Electr Eng Comput Sci. 2018;11(3):1136–46.
4. Design C, Ages M. CAD History: Chapter 2 A Brief Overview of the History of CAD. 2008;1–22.
5. Tornincasa S, Torino P. the Future and the Evolution of Cad Ii-1 Ii-2. 2010;(September):11–8.
6. American Institute of Graphic Arts (AIGA)AI of GA. Understanding the state of design and the people who make it 2 [Internet]. 2019. Available from: https://designcensus.org/data/2019DesignCensus.pdf
7. Mohamed Shaffril HA, Samah AA, Samsuddin SF, Ali Z. Mirror-mirror on the wall, what climate change adaptation strategies are practiced by the Asian's fishermen of all? Vol. 232, Journal of Cleaner Production. Elsevier Ltd; 2019. p. 104–17.
8. Vujica Herzog N, Vujica Beharic R, Beharic A, Buchmeister B. Ergonomic analysis of ophthalmic nurse workplace using 3d simulation. Int J Simul Model. 2014;13(4):409–18.
9. Boschman JS, Frings-Dresen MHW, Van Der Molen HF. Use of Ergonomic Measures Related to Musculoskeletal Complaints among Construction

Workers: A 2-year Follow-up Study. Saf Health Work [Internet]. 2015;6(2):90–6. Available from: http://dx.doi.org/10.1016/j.shaw.2014.12.003
10. Shariat A, Cleland JA, Danaee M, Kargarfard M, Sangelaji B, Tamrin SBM. Effects of stretching exercise training and ergonomic modifications on musculoskeletal discomforts of office workers: a randomized controlled trial. Brazilian J Phys Ther. 2018;22(2).
11. Wanberg J, Caston M, Berthold D. Ergonomics in Alternative Vehicle Design: Educating Students on the Practical Application of Anthropometric Data. Ergon Des. 2019;27(3):24–9.
12. Moher D, Liberati A, Tetzlaff J, Altman DG, Altman D, Antes G, et al. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. PLoS Med. 2009;6(7).
13. Ardahan M, Simsek H. Analyzing musculoskeletal system discomforts and risk factors in computer-using office workers. Pakistan J Med Sci. 2016;32(6):1425–9.
14. Brink Y, Louw Q, Grimmer K, Jordaan E. The relationship between sitting posture and seated-related upper quadrant musculoskeletal pain in computing South African adolescents: A prospective study. Man Ther. 2015;20(6):820–6.
15. Schmid AB, Kubler PA, Johnston V, Coppieters MW. A vertical mouse and ergonomic mouse pads alter wrist position but do not reduce carpal tunnel pressure in patients with carpal tunnel syndrome. Appl Ergon [Internet]. 2015;47:151–6. Available from: http://dx.doi.org/10.1016/j.apergo.2014.08.020
16. Van Niekerk SM, Fourie SM, Louw QA. Postural dynamism during computer mouse and keyboard use: A pilot study. Appl Ergon [Internet]. 2015;50:170–6. Available from: http://dx.doi.org/10.1016/j.apergo.2015.03.009
17. Huysmans MA, Eijckelhof BHW, Bruno Garza JL, Coenen P, Blatter BM, Johnson PW, et al. Predicting Forearm Physical Exposures During Computer Work Using Self-Reports, Software-Recorded Computer Usage Patterns, and Anthropometric and Workstation Measurements. Ann Work Expo Heal. 2018;62(1):124–37.
18. Mediouni Z, Bodin J, Dale AM, Herquelot E, Carton M, Leclerc A, et al. Carpal tunnel syndrome and computer exposure at work in two large complementary cohorts. BMJ Open. 2015;5(9).
19. Toosi KK, Hogaboom NS, Oyster ML, Boninger ML. Computer keyboarding biomechanics and acute changes in median nerve indicative of carpal tunnel syndrome. Clin Biomech [Internet]. 2015;30(6):546–50. Available from: http://dx.doi.org/10.1016/j.clinbiomech.2015.04.008
20. Sherif Sirajudeen M, Saad Mohamed Siddik S. Knowledge of Computer Ergonomics among Computer Science Engineering and Information Technology Students in Karnataka, India. Asian J Pharm Res Heal Care. 2017 Apr 10;9(2):64.
21. Celik S, Celik K, Dirimese E, Tasdemir N, Arik T, Вьуькkara İb. Determination of pain in musculoskeletal system reported by office workers and the pain risk factors. Int J Occup Med Environ Health. 2018;31(1):91–111.
22. Ekinci Y, Atasavun Uysal S, Kabak VY, Duger T. Does ergonomics training have an effect on body posture during computer usage? J Back Musculoskelet Rehabil. 2019;32(2):191–5.
23. Rakhadani PB, Goon DT, Mandeya A. Musculoskeletal problems associated with university students computer users: A cross-sectional study. Online J Heal Allied Sci. 2017;16(2):1–7.
24. Sahu M, Alfred Sunny K, Kumar MW, Baburao G, Gnanasaravanan S. Effect of work postures on the musculoskeletal stresses on computer aided designers and office staff working on computer in India. Int J Sci Technol Res. 2019;8(11):1120–3.
25. Labbafinejad Y, Eslami-Farsani M, Mohammadi S, Ghasemi MS, Reiszadeh M, Dehghan N. Evaluating muscle activity during work with trackball, trackpad, slanted, and standard mice. Iran Rehabil J. 2019;17(2):121–8.
26. Kluth K, Keller E. Rollerbar mouse as an ergonomic alternative to a standard computer mouse. Occup Ergon. 2015;12(1–2):33–48.
27. Mohamad D, Deros B, Ismail AR, Darina D, Daruis I. Development of a Malaysian Anthropometric Database. World Eng Congr 2010, Conf Manuf Technol Manag. 2010;(August).
28. Baba NH, Daruis DDI. Repetitive Strain Injury (RSI) among computer users: A case study in telecommunication company. Malaysian J Public Heal Med. 2016;2016(Specialissue):48–52.
29. M.S. S, H. M, M. A, M. W, A.K. J. Computer-related health problems among university students in Majmaah region, Saudi Arabia. Biomed Res [Internet]. 2018;29(11):2405–15. Available from: http://www.embase.com /search/ results?subaction =viewrecord&from= export&id =L623047287%0A http://dx.doi.org/ 10.4066 /biomedicalresearch. 61-18-418
30. Dogru E. Researching Effects of Drawing on Prevalence of Carpal Tunnel Syndrome with Architecture Students. Sci J Public Heal. 2015;3(2):237.
31. Faraji A, Farahmand MR. An ergonomic computer mouse for professional designers. Appl Mech Mater. 2013;440:194–8.
32. Mohd Kasmuri SH, Ismail Z, Mohd Nordin R, Hashim N. A Systematic Review of Employee Turnover Antecedents in the Construction Industry. Environ Proc J [Internet]. 2020;5(13):65. Available from: http://dx.doi.org/10.21834/e-bpj.v5i13.2100