A Literature Review on Effects of Ergonomic Hazards on the Work-related Musculoskeletal Disorders in Office Workers

Introduction

Musculoskeletal disorders (MSDs) are conditions affecting the muscles, spinal discs or joints, ligaments, tendons, and nerves [1]. Existing literature has demonstrated the existence of work-related MSDs (WRMSDs) in the general population and various mixed occupation samples [2, 3, 4]. As defined by the Centers for Disease Control and Prevention, WRMSDs are the injuries or conditions in which performing an occupation or the work environment contributes significantly to the condition [5]. A 2023 report by the World Health Organisation estimated the global proportions of disability, disease, and mortality that could be attributed to specific environmental exposures [6]. This report concluded that 38% of lower back pain (LBP) cases reported globally could be attributed to the negative impact of environmental risk factors encountered during paid employment [6].

Work-related musculoskeletal disorders (WRMSDs) are a common problem among office workers in the United Kingdom, as they often spend long periods sitting at a desk or using a computer, which can lead to strains and injuries in the neck, shoulders, back, wrists, and hands [7]. According to the data provided by the Health and Safety Executive (HSE), in 2018, WRMSDs were the second most common work-related health problem among office workers in the United Kingdom, accounting for 36% of all reported cases [8]. Another report published by the Health and Safety Executive (HSE) indicated that in the UK, in 2019/20, WRMSDs accounted for 38% of all work-related ill health cases and 41% of all working days lost in office workers [9]. This is of major concern recognising that office-based jobs significantly contribute to the UK's economy [10, 11, 12, 13]. This is evident from a report published by the Office for National Statistics (ONS) in February 2023. Data given in this report highlights that the professional, scientific, and technical activities sectors, which include many office-based jobs, contributed £237 billion (or approximately 12.2% of the total UK Gross Value Added) to the UK economy in 2022 [14]. Recognising that WRMSDs have a significant negative impact on the European Union's socio-economic growth owing to affecting office workers' work productivity, there is a need for effective policies and measures to mitigate factors responsible for these conditions.

Various factors that have been identified in the existing literature to worsen physical, mental, and psychological health outcomes of musculoskeletal disorders include poor posture [15, 16], heat or temperature [17]; excessive lightening [18]; and noise [19, 20]. Among these factors, ergonomic hazards or poor postures due to inadequate workspace design or repetitive tasks are the commonly reported factors that negatively affect outcomes of work-related musculoskeletal disorders in office workers [21, 22].

Considering the negative impact of ergonomic hazards or inappropriate postures on the work productivity of office workers, effective workplace-related policies to ensure the implementation of interventions to address or mitigate these issues is important [23]. In this context, the inculcation of relevant high-strength research evidence into the policy-making processes has been recognised as a key strategy for improving occupational workers' health and well-being outcomes globally [24]. According to the hierarchy of evidence pyramid, systematic reviews and meta-analyses provide the highest quality research evidence due to research methodologies that minimise the risk of bias [25]. As systematic reviews and meta-analyses provide a rigorous and transparent approach to synthesising the available evidence on a specific research question or topic, such research studies can provide policymakers with a comprehensive and reliable summary of the available evidence on a specific topic [26]. This can assist in informing policy decisions and guiding the development of evidence-based policies and interventions to improve the overall health of occupational workers in an organisation [27]. Regarding the application of research evidence in guiding policy-making processes, it is recommended to use recent research as it reflects the latest knowledge and understanding of a particular issue or topic. This suggests that policies informed by the most up-to-date evidence are likely to be more accurate and reliable, reducing the risk of negative outcomes or consequences [28].

Related to the effect of ergonomic hazards or inappropriate postures on work-related musculoskeletal disorders, several systematic reviews and meta-analyses have been published in peer-reviewed journals in the last ten years, i.e., 2013-2023. However, these studies have reported incidence and prevalence rates of work-related musculoskeletal disorders in different samples of manual workers [29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39]. Furthermore, existing systematic reviews and meta-analyses have also highlighted the effectiveness of different workplace interventions [40, 41, 42, 43, 44, 45, 46], specifically ergonomic interventions [47, 48, 49, 50, 51] in reducing the risk of work-related musculoskeletal disorders. Despite this broad research on the effect of environmental factors in various occupation samples, none of the high-strength studies, including systematic reviews highlighting the effect of ergonomic hazards or poor postures on WRMSDs in office workers, have been published recently. In order to formulate effective policies to guide the development of ergonomic interventions for office- or desk-based workers, conducting a literature review is imperative.

1.1. Aims and Objectives

This literature review explores existing evidence to assess the effects of ergonomic hazards or inappropriate postures on work-related musculoskeletal disorders (WRMSDs) in office workers. Various objectives of this review are:

- To identify the relationship between ergonomic factors or inappropriate postures at the workplace and work-related musculoskeletal disorders in office-based employees

- To investigate existing research to quantify the impact of inappropriate postures affecting WRMSDs on the working efficiency of office workers

The potential impact of the study's findings is on improving workplace health and productivity by guiding effective workplace policy-making processes.

1. Research Methodology

The present study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for conducting and reporting findings of the current systematic review [52]. The rationale for selecting the PRISMA guidelines is that these guidelines provide a standardised and comprehensive reporting framework for reviews, increasing rigour in the systematic review process. Furthermore, using the PRISMA flow diagram helps visualise the flow of studies throughout the review process, indicating the number of studies included and excluded at each stage. This transparency allows readers to understand the selection process and assess the potential impact of bias [52].

2.1. Research Paradigm

Determining the research paradigm for a literature review is crucial as it facilitates the selection of appropriate methodology for data collection and analysis and enables critical evaluation of the literature [53]. The research paradigm of this literature review is based on a positivist approach. The rationale for this is that, alike the oncological perspectives of positivism, which aims to establish cause-effect relationships, this literature review aims to examine existing research evidence to explore a particular reality (effects of ergonomic hazards or poor postures on the work-related musculoskeletal disorders in office workers), which is independent of the researcher as a reviewer of the existing literature [54]. Via focusing on establishing cause-effect relationships, a positivist approach limited the exploration of other contextual factors, such as the broader socio-cultural, psychological, and organisational factors that influence work-related musculoskeletal disorders [55]. Nevertheless, positivism is an appropriate approach to examining the impact of ergonomic hazards on WRMSDs on the targeted population.

The epistemological perspectives of the positivist approach facilitate establishing a causal relationship between independent and dependent variables [56]. This literature review sought to explore the existing evidence to investigate the causal relationship between the independent variable or cause (ergonomic hazards or poor postures) and the dependent variable or outcome (work-related musculoskeletal disorders) [57]. To explore this relationship, a comprehensive literature search strategy was formulated to identify and select relevant research studies. This allowed for a more objective assessment of the existing research evidence regarding the effects of ergonomic hazards on work-related musculoskeletal disorders (WRMSDs) in office workers. [58].

Positivism uses quantitative research methods to examine and test theories by employing hypothetico-deductive reasoning [59]. Based on this approach, a researcher typically formulates a hypothesis and then verifies it by employing a trial and test process involving data collection and analysis [60]. In this literature review, a narrative approach was adopted for analysing data obtained from the existing literature, and no hypothesis was tested. However, the positivist paradigm is suitable for this review because the analysed data was primarily quantitative [61].

2.2. Research Question

Formulating a research question is a crucial step in conducting a literature review because it assists in producing clinically relevant results that can be implemented in evidence-based practice [62]. In this SLR, the PEO (**P**opulation, **E**xposure, and **O**utcome(s)) tool was used to formulate the research question [63] (See Table-1). The justification for adopting this model is that it has been reported to be an effective tool for summarising the research question of a study aiming to establish cause-effect relationships between an exposure or cause and its outcome(s) or effect on a targeted population [64].

Population	**Office workers**
Exposure	Ergonomic hazards or inappropriate postures
Outcome(s)	Work-related musculoskeletal disorders

Table- 1: Research Question- PEO Tool

Applying the PEO tool, the research question for the current literature review is as follows: **What are the effects of ergonomic hazards or inappropriate postures on the incidence rates of work-related musculoskeletal disorders in office workers?**

The expected outcomes or implications of answering the research question have the potential to guide interventions, policy development, and resource allocation to create healthier and more ergonomically sound work environments for office workers.

2.3. Key Words and Medical Subject Headings (MeSH)

To facilitate the literature search across various electronic databases, a set of keywords and medical subject headings (MeSH) was developed by utilising the PEO (Population, Exposure, and Outcome(s)) tool (Appendix- 1 highlights the keywords and MeSH and their rationales). In order to limit the search results to potentially-relevant research articles and to broaden the search results, Boolean operators, such as 'AND' and 'OR,' were used, respectively [65].

2.4. Databases

Electronic databases searched to retrieve articles relevant to the research question include CINAHL Ultimate, MEDLINE, and AMED - The Allied and Complementary Medicine Database. The rationale for selecting these databases was that they cover a broad range of medical disciplines, including physical therapy, occupational therapy, and rehabilitation. Via searching across these databases, the researcher could access literature specifically related to the health aspects of office workers, musculoskeletal disorders, and ergonomic hazards [66]. Additionally, these databases were chosen as they provide access to high quality, peer-reviewed research articles relevant to the topic of the current literature review.

For accessing these databases, the EBSCOhost search engine was used. This platform was chosen because its unique search features facilitate a simultaneous search across multiple databases the user selects [67].

2.5. Eligibility Criteria

To devise the eligibility criteria (inclusion and exclusion criteria) for this literature review, the PEO(S) (Population, Exposure, Outcome(s), and Study Design) tool was employed (See Appendix- 2). The rationale for choosing this framework is that it assists in gathering potentially relevant research articles by defining all the research question components [68]. When using the PEO(S) tool, the population criterion would be "office workers" or any other specific subgroups within the office worker population that are relevant to the study (e.g., specific occupations or age groups). Secondly, in the PEO(S) tool, the exposure criterion would be "ergonomic hazards" or any related terms that capture the specific exposures of interest (e.g., poor postures, inappropriate postures, or specific ergonomic risk factors). The research question identifies the outcomes of interest as "work-related musculoskeletal disorders" and their incidence rates. In the PEO(S) tool, the outcome criterion would be "work-related musculoskeletal disorders" or any specific types or sub-categories of musculoskeletal disorders that are relevant to the study (e.g., back pain, neck pain, and upper limb disorders). Although the research question does not explicitly mention a specific study design, the PEO(S) tool includes study design as a criterion for defining eligibility criteria. Depending on the research question, the study design criterion could be specified as "observational studies" or "cohort studies" if the aim is to examine the effects of ergonomic hazards on the incidence rates of work-related musculoskeletal disorders over time.

2.5.1. Population

Studies involving office workers as the targeted population were included. To collect a large amount of research material related to the research question, no studies were excluded based on the gender, age, ethnicity, and geographic location of the participants. Studies involving occupational workers other than the office or desk workers were excluded.

2.5.2. Exposure

Studies assessing the effect of ergonomic hazards on the targeted population were included. Contrarily, studies assessing the effect of environmental factors, such as heat, noise, excessive lights, etc., were excluded. As this study focuses on determining the effects of inappropriate postures on work-related musculoskeletal disorders in office workers, studies assessing the impact of other ergonomic hazards, i.e., lifting heavy loads, repetitive tasks, strenuous activities, etc., were excluded. To facilitate the gathering of several studies, articles not involving a control group were also included.

2.5.3. Outcome(s)

Research studies in which the primary outcome is work-related musculoskeletal disorders were included. Studies not determining the effect of the exposure on WRMSDs were excluded.

2.5.4. Study Design

As the research paradigm of the current study is based on positivism, quantitative studies, such as cross-sectional studies, longitudinal studies, etc., were included [69]. Similarly, primary studies based on a qualitative approach were excluded. Due to the risk of selective reporting bias in secondary studies, literature reviews and meta-analyses were excluded [70].

2.5.5. Other Criteria

To gather a significant amount of research material relevant to the research question, a customised time limiter "2000 – 2023" was set across the chosen databases to include studies published between 2000 and 2022 [71]. Due to a lack of external funding sources for seeking translation services, another limiter was applied to include studies published in the "English language only" [72]. Furthermore, to retrieve studies available for free download, a limiter, "Free Full Text" was applied [73]. Additionally, a limiter was set to only gather studies published in peer-reviewed journals [74].

2.6. Data Extraction

As the current study was a single-student, Masters-level dissertation, one researcher accomplished the data extraction process. This, however, could introduce the extraction bias. To minimise this bias, the researcher utilised several strategies. Firstly, to collect data from the selected studies, a standardised tool based on Cochrane Collaboration [75] and Garrard (2007) [76] data extraction tools was adopted. Various elements of this modified tool included: author(s) and date of publication; study setting/ context; population; exposure; outcome(s); and findings [75, 76]. Secondly, before proceeding with the full data extraction process, a pilot test was conducted to ensure that the researcher understood and applied the extraction protocols correctly. Thirdly, the extraction process was documented by maintaining a detailed record of the entire data extraction process by formulating tables relevant to various concepts, i.e., population, exposure, and outcome(s) of the research question.

2.7. Methodological Quality Assessment

Methodological quality assessment is a critical step in conducting a review to evaluate the strength and validity of the evidence presented in the included studies. For the current literature review, this process aimed to identify any potential biases or limitations that might have affected the accuracy and reliability of the study's findings [77]. In this literature review, the selected studies' quality assessment was conducted using the Mixed Methods Appraisal Tool (MMAT) version 2018 [78]. The rationale for using this tool is that it is a comprehensive and flexible tool that provides clear and consistent criteria to assess the quality of studies across a range of quantitative research designs, cross-sectional studies, non-randomised control trials, etc. [79]. The eligibility criteria for the current literature review involved selecting studies with variable quantitative research designs, so the choice of MMAT version 2018 is the most appropriate.

The Mixed Methods Appraisal Tool (MMAT) version 2018 consists of different criteria depending on the study design. To assess the methodological quality of the selected studies, the researcher selected the appropriate set of criteria based on the study design of each included study. This was followed by evaluating each study based on binary responses (Yes/ No) under each criterion. After scoring each criterion, the researcher summarised the quality of methodological evidence based on the individual criteria.

The researcher conducted the quality assessment process singly, which could introduce bias in the assessment process of research studies. In order to ensure the validity and reliability of the assessment, the researcher utilised several strategies. Firstly, before conducting the quality assessment, the researcher pilot-tested the process on a small sample of studies. Secondly, the quality assessment process was periodically reviewed and reflected on any potential biases or limitations. This self-reflection helped the researcher improve the rigour and objectivity of the assessment over time.

2.8. Risk of Bias Assessment

During a review, it is important to assess the methodological quality of individual studies to interpret research findings and understand heterogeneity across primary research articles [80]. As the research question explicitly identifies the study design of observational or cohort nature for the studies selected for the current review, it was important to utilise a bias assessment tool that incorporates various elements to assess the risk of bias in such studies. Hence, the ROBINS-E tool was used to evaluate the risk of bias in each study included in this review [81]. Additionally, this tool was utilised to visualise the overall risk of bias in the selected studies.

2.9. Data Synthesis/ Data Analysis

Data synthesis combines and analyses data collected from research studies to draw meaningful conclusions or develop new insights related to the research topic [82]. For the current literature review, data synthesis involved analysing the findings of individual studies and combining them to develop a summary of the gathered evidence. As this review follows a quantitative methodology, the empirical data extracted from primary studies has been analysed via narrative synthesis. This involved summarising and presenting the research findings numerically through tables and charts. This data analysis approach allows for the contextualisation and interpretation findings within the broader literature or theoretical frameworks [83]. Nevertheless, it has its limitations, such as the potential for subjectivity and bias in the interpretation process [84]. In this context, the researcher maintained transparency and rigour in the analysis process by taking feedback from the dissertation supervisor to ensure a more balanced and objective synthesis.

2.10. Ethical Considerations

Several ethical considerations were met to ensure the integrity of the research process while conducting this review. Firstly, the researcher provided clear and detailed descriptions of the search strategy, inclusion and exclusion criteria, data extraction process, and synthesis methods, which ensured transparency in the methodology and reporting of the literature review. Secondly, to minimise bias in the selection of studies, the inclusion and exclusion criteria (See Table-3) were applied consistently and without bias [85]. Furthermore, including studies from different geographic regions, specifically setting the criteria not to exclude the articles based on gender, age, and ethnicities of study populations, contributed to avoiding any undue bias or exclusion of relevant research findings [85].

2. Results

3.1. Literature Search Results

Performing a detailed literature search across the selected databases using search terms and Boolean functions in Table- 2 gave 287 studies (See Appendix- 3). These research articles were screened based on pre-specified limiters and eligibility criteria.

Setting the customised date range as 2000 – 2023 filtered out 10 studies. Out of the remaining 277 studies, 233 were published in English language. An additional 114 articles were excluded as these did not have linked full-text available for free download. One study of the remaining 119 articles was filtered out as it was published in a non-peer-reviewed journal. Thus, 118 articles (See Table-2) were retrieved and screened based on eligibility criteria (See PRISMA Flow Diagram 2009 in Figure- 1).

Databases	Search Results

AMED - The Allied and Complementary Medicine Database	1
MEDLINE	61
CINAHL Ultimate	48
Total	118

Table- 4: Search Results

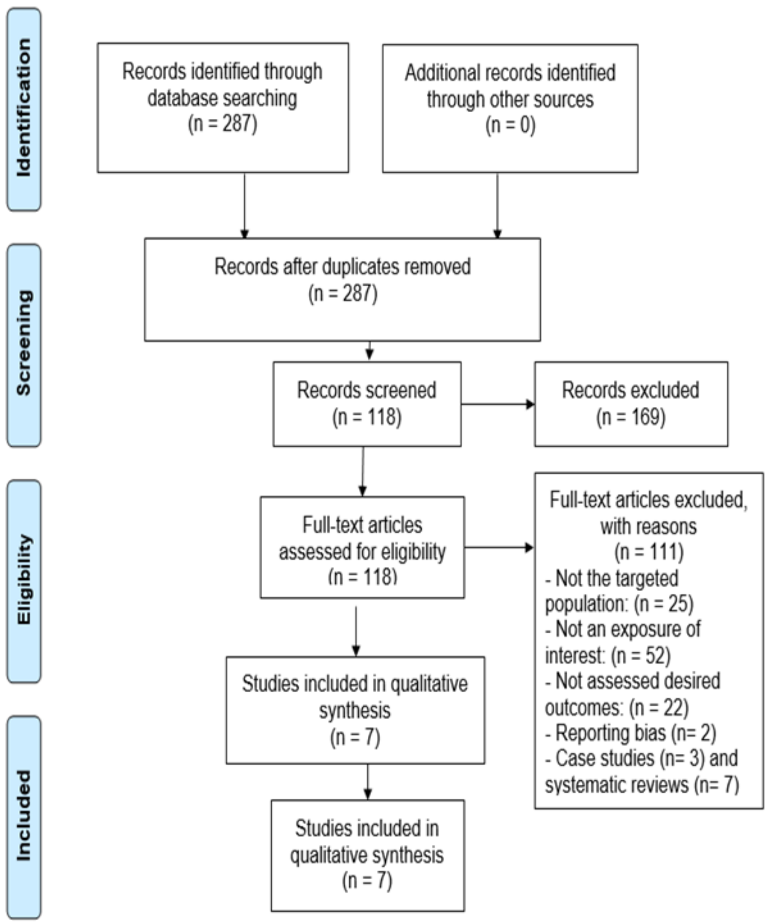

Figure 1: PRISMA Flow Diagram 2009

As indicated in Figure- 1, 25 articles were excluded as the sample population in these studies did not involve office or desk-based workers. Out of the remaining 93 studies, 52 were filtered out as these did not assess the effect of ergonomic hazards. An additional 22 articles were excluded as these studies did not determine the impact of ergonomic hazards on work-related musculoskeletal disorders in the targeted population. Furthermore, 2 studies were filtered out as the researchers did not provide complete data related to the primary outcome, i.e., WRMSDs. Hence, the findings of these studies were subjected to reporting bias. Out of the remaining 17 studies, 3 were excluded as these were low-hierarchy studies, i.e., case studies. Lastly, 7 articles were filtered out as these were systematic reviews. Hence, 7 primary studies were selected for the current literature review [86, 87, 88, 89, 90, 91, 92].

The selected studies were spread across six countries and three continents. The study design of all of the studies was a cross-sectional study design. Appendix- 4 summarises the selected studies' characteristics and main findings.

3.2. Study Characteristics

3.2.1. Population

The total sample size was N= 1811. The number of male participants in the selected studies was N= 921, while the female population comprised N= 890 participants. One of the studies reported a dropout rate in which one participant was lost before collecting complete data [87]. An inclusion criterion in all of the selected studies involved selecting participants appointed in office-based settings. All of the studies involved office workers who worked via using computers. Only two of the selected studies provided additional information related to the nature of the study participants' work. In one of these articles, the study population comprised staff (N= 17) and faculty members (N= 33) appointed in a university [86], while participants in the other study were public service workers [92].

The mean age of the study population calculated by determining an average of mean ages of participants in the selected studies was 36.38 ± 8.2 years. In only two of these studies, the researchers measured the participants' mean body mass indices (BMI) [87, 88]. The mean body mass index of the study population in one of these studies was within the normal range (BMI between 18.5 and 24.9), i.e., measured at 24.35 ± 4.13 [87], set by the World Health Organisation [93], while in the other study, mean BMI of the participants was slightly above the normal range, i.e., measured at 25.77 [88].

One of the selected studies divided the study population into two sub-categories: subgroup 1, which comprised of N= 17 workers with work-related musculoskeletal pain, and subgroup 2, consisting of N= 18 workers without WRMSK pain report [91].

Appendix- 5 presents details relevant to study participants in the selected studies.

3.2.2. Exposure

Four of the selected studies provided research information related to the average work duration of the study participants [86, 87, 88, 90]. Average work duration calculated as the number of hours per week ranged from minimum of 19.06 hours per week [90] to maximum of 35 hours per week [86, 88]. Thus, the mean work duration of the study populations in the selected studies was 30.78 hours per week.

Five of the studies selected for the current review provided research information related to the number of years for which the participants had occupied the current position [87, 88, 89, 90, 91]. The mean years of participants' experience in these studies were 5.0 ± 2.9 years.

In all of the selected studies, the researchers performed an ergonomic work environment assessment, i.e., work postures. In five of these studies, the researchers used various ergonomic risk factor assessment scales [86, 88, 89, 91, 92]. For instance, ergonomic risk factors were assessed via direct observation of the postures of study participants by utilising the Rapid Office Strain Assessment (ROSA) scale in four of the studies selected for the review [88, 89, 91, 92]. This scale evaluates workstation suitability via measuring indices relevant to the: 1. Workstation: back support, armrest, height of chair, and depth of seat span, 2. Computer: Keyboard, mouse, and monitor, and 3. Telephone and average time spent in each activity or posture [94]. Based on ROSA scores, the instrument quantifies the ergonomics risk as low, medium, and high. One of the selected studies utilised items on the Army Instrument relevant to awkward postures [94] for ergonomic risk factor assessment [86].

Appendix- 6 demonstrates details regarding 'exposure' in the selected studies.

3.2.3. Outcome(s)

All selected studies evaluated the effect of ergonomic risk factors on work-related musculoskeletal disorders. All studies assessed work-related musculoskeletal pain in the upper extremity, neck, and lower pain, excluding one study which only evaluated the impact of ergonomic hazards on neck WRMSDs [92]. Researchers in six studies utilised various outcome measures to facilitate the assessment of WRMSDs [87, 88, 89, 90, 91, 92]. Two scales commonly used across the selected studies included: the Nordic musculoskeletal questionnaire [87, 88, 89, 92] and Rapid Upper Limb Assessment (RULA) scale [88, 91]. Some other scales utilised by researchers in different studies were as follows: Oswestry disability index (ODI) [87]; Disabilities of the arm, shoulder, and hand questionnaire short-form (Q-DASH) [87]; Neck disability index (NDI) [87]; visual analogue scale [90]; and Maastricht Upper Extremity Questionnaire revised Brazilian Portuguese version (MUEQ-Br revised) [91].

Appendix- 7 presents characteristics of outcome(s) evaluated by the selected studies.

3.3. Critical Appraisal and Risk of Bias Assessment

Appendix- 8 presents a tabulated version of the critical appraisal of the selected studies using the Mixed Methods Appraisal Tool (MMAT) version 2018.

Figures- 2 and -3 highlight the risk of bias in individual studies and the overall risk of bias in the selected studies, respectively.

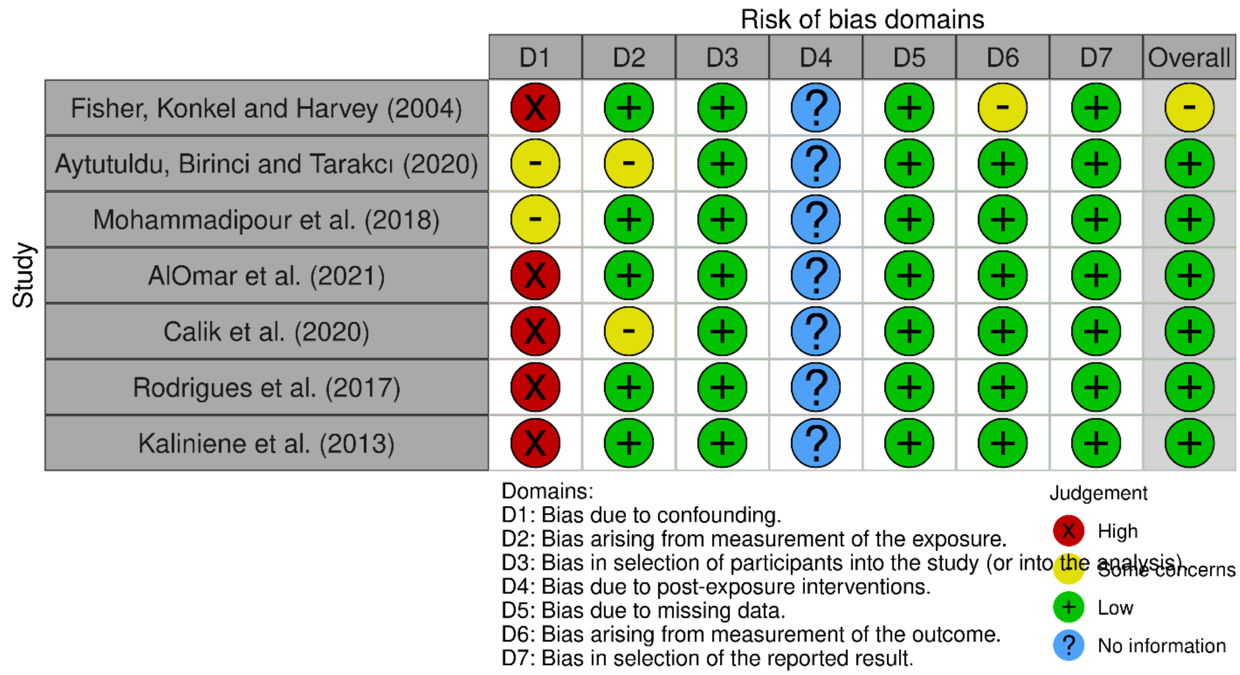

Figure- 2: Risk of Bias in the Individual Studies

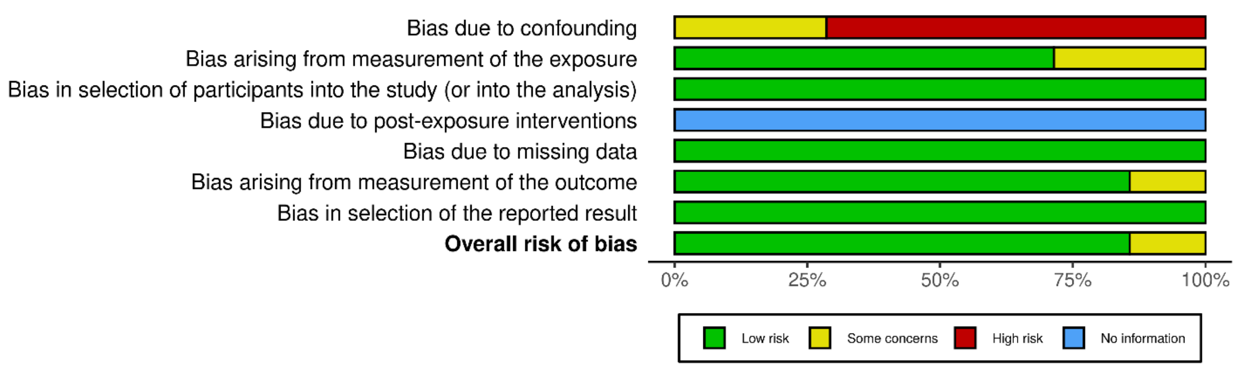

Figure- 3: Overall Risk of Bias in the Selected Studies

Existing literature has identified several confounding factors that may influence the relationship between the exposure and outcome(s) of interest in a study assessing the effects of ergonomic hazards on WRMSDs in office workers. These variables include age, gender, body mass index, physical activity levels, previous history of MSK disorders, work-related psychological factors, such as work stress, job satisfaction, etc. workstation set-up, i.e., chair height, monitor placement, etc., and working experience [98, 99, 100]. In none of the studies selected for this literature review did the researchers consider measuring and adjusting for all these confounding variables during data analysis. Due to this reason, there exist concerns regarding the distortion of the observed relationship between the exposure (ergonomic hazards) and the outcome(s) of interest (work-related musculoskeletal disorders) in all of the seven studies selected for this literature review [86, 87, 88, 89, 90, 91, 92] (See Figure- 3). However, such concerns are low in two of these studies in which the researchers utilised various methods, such as stratification [87] and statistical adjustment using multivariable regression models [88], to control for some confounding variables. Four potential confounding factors measured and adjusted in the data analysis in these studies include age [87], body mass index [87, 88], workstation set-up [87, 88], and working experience [87]. Although three studies considered the effect of workstation set-up on WRMSDs in office workers [89, 91] and working experience [92], however, lack of measurement of other potential confounding factors increased the risk of confounding bias.

Concerns regarding the appropriate measurement of the exposure (ergonomic hazards) have been observed in two of the selected studies, leading to measurement bias arising [87, 90]. In all of the remaining studies, the researchers utilised various standardised and validated tools, such as the Army Instrument [86] and ROSA (Rapid Office Strain Assessment) scale [88, 89, 91, 92], to measure ergonomic hazards. Similarly, the researchers in one of the selected studies did not use rigorous tools to measure the outcome, i.e., work-related musculoskeletal disorders in the targeted population [86]. Due to these reasons, it is impossible to determine whether the measurements performed regarding both the exposure and outcome(s) are appropriate (See Appendix- 8).

Considering the overall risk of bias being 'low' in the selected studies (See Figure- 2), it can be inferred that these studies provide moderate-to-high methodological quality evidence.

Combining results of risk of bias assessment and critical appraisal of studies performed via the Mixed Methods Appraisal tool version 2018, three of the studies were rated as of 'moderate' or 'acceptable' quality (< 85% criteria met) [86, 87, 90], while, four studies were categorised as 'high' quality studies (> 85% criteria met) [88, 89, 91, 92].

3.4. Data Synthesis

Five of the selected studies reported the prevalence rates of development of work-related musculoskeletal disorders in study participants owing to ergonomic risk factors, i.e., improper usage position of mouse and keyboard, and curved alignment of wrists, etc. [87, 88, 89, 90, 92]. Out of four of the studies reporting incidence rates of WRMSDs in the back [87, 88, 89, 90], the lower back was identified as the most common site of musculoskeletal pain in two studies (MSP) [88, 89]. The incidence rates of lower back MSP in both of these studies were comparable, recorded at: 72.4% and 73.1%, respectively [88, 89]. Contrarily, in one of the selected studies, the incidence of upper back pain (69.6%) was slightly higher than the prevalence rates recorded for lower back pain (64.1%) [90]. similarly, in one study, the prevalence rates of lower back pain were the lowest (27%) [87]. However, these surpassed the corresponding prevalence rates of neck pain (18.4%) within the study population [87]. The second most common work-related musculoskeletal disorder reported by four studies selected for the review was neck pain [87, 88, 90, and 92]. In this context, three of these studies indicated the highest incidence rates of neck pain, recorded at 55.2%, 65.2%, and 65.7%, respectively [88, 90, 92]. The lowest rate of neck pain measured in one study was 18.4% [87]. Among the selected studies, the prevalence rate of upper extremity pain, reported exclusively in one study, was 39.5% [87]. Related to the incidence of WRMSDs, one of the selected studies reported that the percentages of participants who experienced the symptoms of musculoskeletal pain during the past year and those who experienced disabling WRMSDs in the past year were 84.5% and 52.3%, respectively. Nevertheless, the findings of majority of the studies indicate that the most common WRMSD reported in office workers is lower back pain, followed by neck pain.

All selected studies reported the statistical association between inappropriate postures and the occurrence of work-related musculoskeletal disorders in office workers [86, 87, 88, 89, 90, 91, 92]. In all of these studies, the relationship between the exposure (ergonomic hazards) and the outcome(s) (WRMSDs) was found to be statistically significant, i.e., $p > 0.05$. For instance, the findings of three of the selected studies indicated a statistically significant association between awkward postures while using keyboards and WRMSDs [86, 88, 90]. Two of these studies reported a statistically significant relationship ($p > 0.05$) between ergonomic risk factors, i.e., inappropriate working postures on computers and WRMSDs, including pain in the neck, back, and upper extremities [86, 89]. Another study demonstrated a statistically significant association ($p < 0.002$) between awkward postures and pain in the neck and lower back [88]. Similarly, the statistically significant ($p < 0.001$) correlation between the usage of computers in inappropriate postures and neck and back pain was observed in a study [90]. In one study in which the study population was divided into two subgroups (subgroup 1, comprising N= 17 workers with work-related musculoskeletal pain (WMSP), and subgroup 2, consisting of N= 18 workers without WRMSK pain (WOMSP)), study participants in sub-group 1 demonstrated significantly higher average values in the ROSA score (WMSP: 6.60 [CI 95%:6.21–7.11] and WOMSP: 5.89 [CI 95%:5.30–6.31], $p = 0.001$) [91]. Nevertheless, a positive moderate correlation was reported between RULA and ROSA scores ($p < 0.001$) [91]. Lastly, one of the selected studies observed a statistically significant association ($p = 0.02$) between ROSA scores and neck pain [92].

Four of the selected studies provided research on the influence of various confounding factors while assessing the effect of ergonomic hazards on work-related musculoskeletal disorders in office workers [87, 88, 91, 92]. Firstly, evidence related to the effect of the age of the study population on WRMSDs in office workers was provided in one of these studies [87]. The findings of this study indicate that the probability of experiencing WRMSDs in various age groups is as follows: 50-70 years age group – 1.94 times (95% CI: 1.10-3.64)> 40-49 years age group – 2.44 times (95% CI: 1.26-4.45)> 23-29 years old. These findings suggest that compared to young adults, office workers of the age group 50-70 years are the most susceptible to developing WRMSDs [87]. Two of the selected studies reported the impact of body weight or mean body mass index on WRMSDs in office workers [87, 88]. In this context, one study demonstrated a statistically significant correlation ($p = 0.014$) between mean BMI and Q-DASH score [87]. Similarly, normal body weight was linked with a significant reduction (OR = 0.10, 95% CI = 0.05–0.18) in the risk of developing WRMSDs in the study population in the other article [88]. Two out of seven selected studies provided evidence related to the effect of working experience with computers on the risk of developing WRMSDs [87, 92]. In one of these studies, a statistical association between working years and the risk of WRMSDs was reported by calculating the ODI and Q-DASH scores. Both of these associations were statistically significant: $p = 0.041$ and $p = 0.043$, respectively [87]. Similarly, this study reported a statistically significant correlation between working hours and the NDI score ($p = 0.003$) [87]. Findings of another study indicated the association between working experience and the risk of developing WRMSDs as follows: employees with 16-35 years of work experience– 2.42 times (95% CI: 1.41-4.22) > employees with 6-15 years of work experience – 2.26 times (95% CI: 1.45-3.50) > employees with 1-5 years of experience [92]. Thus, the findings of both of these studies indicate that the probability of acquiring WRMSDs in office workers enhanced with an increase in the number of years of experience. Workstation analysis performed by the researchers in two of the selected studies yielded comparable results [87, 88]. The findings of these studies indicate that office workers who were at a medium risk level of development of WRMSDs equated to 55.2% and 53.1%, respectively. Similarly, the percentages of office workers at a high-risk level of development of WRMSDs were reported to be 27.6% and 28.2%, respectively [87, 88]. These findings are slightly comparable to the results of the workstation analysis of another study, in which, regardless of the ROSA ergonomic index scale, participants categorised as high-risk equated to 33.7% [89]. Findings of another study, which provided research evidence related to the influence of workstation set-up on WRMSDs in office workers, suggest that the subgroup-1 (workers with musculoskeletal pain) demonstrated higher mean scores in the chair section of the ROSA scale, upper limb RULA scale, and workstation section of MUEQ-Br revised. Additional findings of this study indicate that the armrest and chair height sections from the ROSA scale demonstrated higher average values in subgroup-1 workers than subgroup-2 workers [91]. Out of the studies reporting the impact of workstation set-up on WRMSDs [87, 88, 89, 91], findings of one study indicated the percentage (68.8%) of participants who needed to modify their posture and percentage (27.6%) of participants who needed to modify their posture soon [88].

Four of the selected studies provided research data on work-related musculoskeletal disorders' effect on working efficiency or job performances [86, 88, 87] and activities of daily living in office workers [90]. In this context, a major limitation of these studies is that the researchers did not utilise standardised outcome measures or scales to ensure objective measurement of these outcome(s), i.e., working efficiency and activities of daily living. Nevertheless, three of the selected studies reported a negative effect of WRMSDs on the working efficiency or job performances of the targeted population, and this effect was found to be statistically significant ($p < 0.05$) [86, 88, 89]. Furthermore, neck pain was reported to restrict activities of daily living in 22.9% of office workers in one study [90].

Appendix- 9 summarises the results of the studies selected for the literature review.

3. Discussion

This review aimed to gather and synthesise research evidence to identify the effects of ergonomic hazards on work-related musculoskeletal disorders (WRMSDs) in office workers. In this study, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2009 guidelines [52] were employed to conduct and report research findings. Using these guidelines enhanced the transparency and reproducibility of the review by ensuring that the screening process is conducted systematically and unbiasedly. A thorough literature search strategy was employed to identify and select potentially relevant research articles. Subsequently, seven studies that fulfilled the predetermined inclusion criteria were chosen to examine the research evidence on the review topic. Research data from the selected studies was gathered by utilising a tool that was adapted and piloted from two tools: Cochrane Collaboration [75] and Garrard (2007) [76] data extraction tools. Research studies included in the review were assessed for risk of bias and rated for methodological evidence quality. Out of the ten studies reviewed, three were assessed to have a rating of 'moderate' or 'acceptable' quality, while the remaining four were classified as 'high' quality. Narrative synthesis was employed to present the findings of the studies.

The total number of participants in the selected studies included N= 1811. The drop-out rate was low as only one research participant left before collecting complete cross-sectional data. This factor significantly increased the internal validity of the current literature review due to minimising the potential for attrition bias or the risk of missing data [101]. Secondly, the majority of the selected studies had large sample sizes. Due to this reason, the findings can be speculated to be representative of the target population, hence, enhancing the generalisability and external validity of the results.

The selected studies reported an average work duration of 30.78 hours per week across the study populations. This is in line with the recent Office for National Statistics data, which highlights that as of April 2023, full-time workers in the United Kingdom typically worked an average of 31.7 hours per week [102]. Thus, the current literature review's findings apply to local populations of office workers in the UK.

The selected cross-sectional studies were homogeneous. They were generally similar in terms of the nature of work, scales utilised for ergonomic risk factor assessment, and outcome measures. Most of the selected studies utilised Rapid Office Strain Assessment (ROSA) scale to assess ergonomic risk factors via direct observation of participants' postures. It is, hereby, important to underpin that in the existing literature, this scale has demonstrated moderate-to-high construct validity (ICC = 0.668-0.866) [103] and high intra- and inter-rater reliability (ICCs of 0.92 and 0.89, respectively) [104].

The selected studies utilised highly valid and reliable outcome measures, such as the Nordic musculoskeletal questionnaire (NMQ), Rapid Upper Limb Assessment (RULA) scale, etc., to assess work-related musculoskeletal disorders in the targeted population. A study found the test-retest reliability of NMQ to be equivalent to 80-90% [105]. Another study computed the observer's reliability of the RULA scale in the study population of office workers and found it reliable (Pearson's r = 0.97, $p = 0.031$) [106].

This review reported a direct causal relationship between ergonomic hazards and work-related musculoskeletal disorders in office workers. These findings are supported by a systematic review, which established a direct association between awkward postures and WRMSDs in software professionals [107]. The current literature review indicates that lower back pain (LBP) is the most common musculoskeletal pain reported among office workers. These findings are comparable to the results of a recently-published systematic review of longitudinal studies, which highlight that LBP is the most commonly reported MSK disorder experienced by office workers [108].

The current study reported a statistically significant association ($p < 0.05$) between the occurrence of work-related musculoskeletal disorders in office workers and their working efficiency or job performance. These findings align with the results of a recent systematic review and meta-analysis, which demonstrated significant impairments in the working efficiency of office workers owing to pain secondary to WRMSDs [109]. These results relevant to the negative impact of WRMSDs on the work productivity of office workers have also been supported by findings of two cross-sectional studies [110, 111].

4.1. Strengths and Limitations

Applying the AMSTAR checklist, a critical appraisal tool for systematic reviews, the current study provides moderate quality methodological evidence [112]. The present study possesses several strengths. Firstly, implementing a systematic and comprehensive search strategy helped reduce bias in the literature review process by ensuring the inclusion of all relevant studies. Moreover, this approach enhanced the transparency and reproducibility of the review. Secondly, using the Population, Exposure, and Outcome (PEO) tool to formulate research questions and establish inclusion criteria is another strength of the current literature review. This systematic approach enhances the rigor and credibility of the literature review by minimising the risk of overlooking pertinent studies and ensuring that the inclusion criteria align with the research objectives. Thirdly, the utilisation of the Mixed Methods Appraisal Tool, version 2018, and ROBVIS-E tool to perform a critical appraisal and assess the risk of bias in the selected studies, respectively, is another strength of the current study. This systematic assessment enabled the researcher to evaluate the internal validity of the literature review. This significantly enhanced the transparency and robustness of the study.

Applying the AMSTAR checklist, this systematic review has certain limitations. One limitation of the study is the use of a language limiter owing to the lack of external funding sources, which restricted the inclusion of studies published only in English. This decision introduced a potential language bias by excluding relevant research in other languages. Consequently, the search might not have captured the full scope of available literature on the topic, potentially leading to incomplete coverage. As a result, the findings of the current review may only partially represent the breadth and depth of the existing research in this field. Secondly, the generalisability of the study findings may be limited due to the selection of studies involving office workers who primarily worked via using computers. Another limitation of the study is the presence of heterogeneity in the outcome measures utilised across the selected studies. This made direct comparisons across the studies difficult. The involvement of a single researcher in the data extraction process is also a potential limitation of the current study, which might have increased the risk of bias due to subjective data interpretation errors. In this context, the lack of involvement of a second reviewer to independently review the extracted data also decreased data extraction reliability.

4.2. Implications for Practice and Future Research

The results of this review emphasise the importance of addressing the high prevalence rates of work-related musculoskeletal disorders (WMSDs) among office workers via effective screening and intervention strategies. Particular consideration should be directed towards individuals who belong to older age groups, have extensive work experience, and engage in prolonged working hours, as these populations exhibit heightened vulnerability to developing these disorders in the selected studies. In this context, annual check-ups by occupational physicians are recommended. The current study's findings highlight the significant negative effect of inappropriate postures and workstation set-ups on the risk of WRMSDs in office workers. Hence, it is recommended that the organisation of education and training programmes targeting office workers mitigate ergonomic risk factors and prevent WRMSDs by providing guidance on proper postures and workstation set-ups. Such programmes can serve as valuable tools in promoting awareness and equipping individuals with the knowledge and skills necessary to create ergonomically supportive work environments.

The findings of the current study identify potential areas for future research. In the current study, the selection of studies with cross-sectional study designs enabled the researcher to collect outcome data over a specific point in time. In this context, additional longitudinal research data is needed to determine the effects of ergonomics-led WRMSDs on overall health-related quality of life in office workers. Secondly, studies highlighting ergonomic hazards' effect on musculoskeletal pain were included in the current review. To investigate the effects of ergonomic risk factors on functional limitations, i.e., range of motion in office workers with WRMSDs, is an area of potential future research. Thirdly, the studies selected for the current review did not explore the effects of various confounding factors, i.e., gender, prior history of musculoskeletal disorders, and work-related psychological factors, such as work stress, job satisfaction, etc. while exploring the relationship between ergonomic risk factors and WRMSDs in office workers. This is an additional area of future research.

4. Conclusion

In conclusion, this review provides valuable insights into the effects of ergonomic hazards on work-related musculoskeletal disorders (WRMSDs) in office workers. The study adhered to the

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, ensuring transparency and reproducibility in the research process. Including seven studies with a total of 1,811 participants strengthened the internal validity and generalisability of the findings. The selected studies consistently reported a causal relationship between ergonomic hazards and WRMSDs, particularly lower back pain (LBP), which aligns with previous research in this area.

The review highlighted the significance of the association between WRMSDs and working efficiency or job performance, emphasising the negative impact of these disorders on office workers' productivity. This finding underscores the need for effective screening and intervention strategies to mitigate ergonomic risk factors and prevent WRMSDs. Recommendations include annual check-ups by occupational physicians and education and training programmes targeting office workers to promote proper postures and workstation set-ups.

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6. Appendices

Appendix- 1: Key Words and Medical Subject Headings (MeSH)

PEO Framework	Key Words	Justification
Population	office workers OR desk workers OR office employees OR staff OR workforce **AND**	Encompass individuals who work in an office setting are likely to be exposed to ergonomic hazards or adopt various work postures. Including these terms ensures that the search focuses on the specific population of interest.
Exposure	ergonomic hazards OR ergonomics OR poor postures OR inappropriate postures OR work postures **AND**	Capture the concept of unfavorable or incorrect body positions or movements that can contribute to the development of musculoskeletal disorders.
Outcome(s)	work-related musculoskeletal disorders OR WRMSDs OR musculoskeletal disorders OR MSDs OR chronic MSDs OR musculoskeletal conditions OR back pain OR chronic back pain OR upper back pain OR chronic upper back pain OR chronic lower back pain or chronic low back pain OR neck pain OR pain in neck OR upper extremity pain OR upper limb pain OR upper limb disorders	**Work-related musculoskeletal disorders (WRMSDs), musculoskeletal disorders (MSDs), chronic MSDs, musculoskeletal conditions:** These terms encompass a range of musculoskeletal disorders and conditions that are relevant to the research question. They include conditions such as back pain, neck pain, and upper limb disorders that are associated with office work and ergonomic hazards.

		Chronic back pain, upper back pain, chronic upper back pain, chronic lower back pain, chronic low back pain, neck pain, pain in neck, upper extremity pain, upper limb pain: These terms capture the concept of specific types of pain or discomfort experienced by individuals with musculoskeletal disorders. Including these terms ensures that the search captures relevant studies that address the various pain symptoms associated with work-related musculoskeletal disorders.

Appendix- 2: Eligibility Criteria

PEO(S) Tool	Inclusion Criteria	Exclusion Criteria
Population	• Studies involving office workers	• Studies involving occupational workers other than office or desk workers
Exposure	• Studies assessing effect of ergonomic hazards	• Studies assessing effect of environmental factors, such as heat, noise, excessive lights etc. • Studies assessing impact of ergonomic hazards other than inappropriate postures i.e., lifting heavy loads, repetitive tasks etc.

Outcome(s)	• Research studies in which primary outcome is work-related musculoskeletal disorders	• Studies not determining the effect of exposure on WRMSDs
Study Design	• Primary studies based on observational/ quantitative research designs, such as cross-sectional studies, longitudinal studies etc.	• Secondary studies, such as literature reviews and meta-analyses • Qualitative studies

Appendix- 3: Database Search Results

Database: AMED - The Allied and Complementary Medicine Database	Search Results
office workers OR desk workers OR office employees AND ergonomic hazards OR ergonomics AND work-related musculoskeletal disorders OR WRMSDs OR musculoskeletal disorders or MSDs or chronic MSDs or musculoskeletal conditions	15
Limiters: • **Studies published between 2000 and 2023** • **Studies published in the "English language only"** • **"Free Full Text" articles** • **Scholarly articles**	15 15 9 9
Total Studies Retrieved	1

Database: MEDLINE	Search Results
office workers OR desk workers OR office employees AND ergonomic hazards OR ergonomics AND work-related musculoskeletal disorders OR WRMSDs OR musculoskeletal disorders or MSDs or chronic MSDs or musculoskeletal conditions	181
Limiters: • **Studies published between 2000 and 2023** • **Studies published in the "English language only"** • **"Free Full Text" articles** • **Scholarly articles**	172 169 61 61
Total Studies Retrieved	61

Database: CINAHL Ultimate	Search Results
office workers OR desk workers OR office employees AND ergonomic hazards OR ergonomics AND work-related musculoskeletal disorders OR WRMSDs OR musculoskeletal disorders or MSDs or chronic MSDs or musculoskeletal conditions	91

Limiters: • **Studies published between 2000 and 2023** • **Studies published in the "English language only"** • **"Free Full Text" articles** • **Scholarly articles**	90 49 49 48
Total Studies Retrieved	48

Appendix- 4: Summary of Study Characteristics and Main Findings

Authors	Country	Study Design	Sample Size (N)	Mean age (Years)	Nature of Work	Exposure Assessed	Outcome measures	Findings
Fisher, Konkel and Harvey (2004) [86]	Kentucky, United States of America	Cross-sectional study	N= 50 Males= 10 Females= 40	55.2 ± 5.3	University staff (N= 17) and faculty members (N= 33)	Army Instrument relevant to awkward postures	-	- Association between: 1. Working postures and WRMSDs= $p > 0.05$ 2. Working efficiency and WRMSDs= $p < 0.05$
Aytutuldu, Birinci and Tarakcı (2020) [87]	Turkey	Cross-sectional study	N= 150 Males= 70 Females= 80	31.95 ± 8.45	Computer-based office work	Inappropriate postures	- Nordic musculoskeletal questionnaire - ODI - Q-DASH - NDI	Association between working postures and WRMSDs= $p > 0.05$
Mohammadipour et al. (2018) [88]	Iran	Cross-sectional study	N= 250 Males= 121 Females= 129	30.2 ± 10.1	Computer-based office work	ROSA scale	- Nordic musculoskeletal questionnaire - RULA scale	Association between working postures and WRMSDs= $p < 0.002$
AlOmar et al. (2021) [89]	Saudi Arabia	Cross-sectional study	N= 451 Males= 252 Females= 199	38.63 ± 8.5	Computer-based office work	ROSA scale	Nordic musculoskeletal questionnaire	Association between working postures and WRMSDs= $p > 0.05$
Calik et al. (2020) [90]	Turkey	Cross-sectional study	N= 362 Males= 183	37.35 ± 8.43	Computer-based	Inappropriate postures	Visual analogue scale	Association between working postures and

			Females= 179		office work			WRMSDs= $p < 0.001$
Rodrigues et al. (2017) [91]	Brazil	Cross-sectional study	N= 35 Males= 19 Females= 16	25.6 ± 5.7	Computer-based office work	ROSA scale	- RULA - MUEQ-Br revised	Association between inappropriate working postures and WRMSDs in subgroup-1 (workers with musculoskeletal pain): $p = 0.001$
Fisher, Konkel and Harvey (2004) [86]	Lithuania, Eastern Europe	Cross-sectional study	N= 513 Males= 266 Females= 247	35.7 ± 10.7	Public service work	ROSA scale	Nordic musculoskeletal questionnaire	Association between ROSA scores and neck pain: $p = 0.02$

Appendix- 5: Characteristics of Study Participants

Study	Sample Size (N)	Male Population (N)	Female Population (N)	Mean age (years)	Nature of Work	Mean Body Mass Index
Fisher, Konkel and Harvey (2004) [86]	50	10	40	55.2 ± 5.3	University staff (N= 17) and faculty members (N= 33)	-
Aytutuldu, Birinci and Tarakcı (2020) [87]	150	70	80	31.95 ± 8.45	Computer-based office work	24.35 ± 4.13
Mohammadipour et al. (2018) [88]	250	121	129	30.2 ± 10.1	Computer-based office work	25.77

AlOmar et al. (2021) [89]	451	252	199	38.63 ± 8.5	Computer-based office work	-
Calik et al. (2020) [90]	362	183	179	37.35 ± 8.43	Computer-based office work	-
Rodrigues et al. (2017) [91]	35	19	16	25.6 ± 5.7	Computer-based office work	-
Kaliniene et al. (2013) [92]	513	266	247	35.7 ± 10.7	Public service workers	-

Appendix- 6: Exposure Characteristics

Study	Average Work Duration (Hours per Week)	Mean Years of Experience (Years)	Instruments Utilised for Ergonomic Risk Assessment
Fisher, Konkel and Harvey (2004) [86]	35	-	Items on the Army Instrument relevant to awkward postures
Aytutuldu, Birinci and Tarakcı (2020) [87]	34.05	1	-
Mohammadipour et al. (2018) [88]	35	1	ROSA: via direct observation of postures of participants
AlOmar et al. (2021) [89]	-	11.95 ± 8.3	ROSA checklist
Calik et al. (2020) [90]	19.06	10.08 ± 6.27	-
Rodrigues et al. (2017) [91]	-	1	ROSA checklist
Kaliniene et al. (2013) [92]	-	-	ROSA checklist

Appendix- 7: Characteristics of Outcome(s)

Study	Outcome(s) Assessed	Scales Utilised
Fisher, Konkel and Harvey (2004) [86]	Musculoskeletal pain in: 1. Upper extremity	-

	2. Neck 3. Back	
Aytutuldu, Birinci and Tarakcı (2020) [87]	Musculoskeletal pain in: 1. Upper extremity 2. Neck 3. Back	- Nordic musculoskeletal questionnaire - Oswestry disability index (ODI) - Disabilities of the arm, shoulder, and hand questionnaire short-form (Q-DASH) - Neck disability index (NDI)
Mohammadipour et al. (2018) [88]	Musculoskeletal pain in: 1. Upper extremity 2. Neck 3. Back	- Nordic musculoskeletal questionnaire - Rapid Upper Limb Assessment (RULA) scale
AlOmar et al. (2021) [89]	Musculoskeletal pain in: 1. Upper extremity 2. Neck 3. Back	- Nordic musculoskeletal questionnaire
Calik et al. (2020) [90]	Musculoskeletal pain in: 1. Upper extremity 2. Neck 3. Back	- Visual analogue scale
Rodrigues et al. (2017) [91]	Musculoskeletal pain in: 1. Upper extremity 2. Neck 3. Back	- Rapid Upper Limb Assessment (RULA) scale - Maastricht Upper Extremity Questionnaire revised Brazilian Portuguese version (MUEQ-Br revised)
Kaliniene et al. (2013) [92]	Neck musculoskeletal disorders	- Nordic musculoskeletal questionnaire

Appendix- 8: Critical Appraisal: Mixed Methods Appraisal Tool, Version 2018

Methodological Quality Criteria for Quantitative Non-Randomised Study Designs: Mixed Methods Appraisal Tool, version 2018	Fisher, Konkel and Harvey (2004) [86]	Aytutuldu, Birinci and Tarakcı (2020) [87]	Mohammadipour et al. (2018) [88]	AlOmar et al. (2021) [89]	Calik et al. (2020) [90]	Rodrigues et al. (2017) [91]	Kaliniene et al. (2013) [92]
S1: Are the research questions clear?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
S2: Does the collected data facilitate in effectively answering the research questions?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3.1: Do study participants represent the targeted population?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3.2: Are the measurements performed	Can't tell	Can't tell	Yes	Yes	Can't tell	Yes	Yes

regarding both the exposure and outcome(s) appropriate?							
3.3: Is the outcome data complete?	Can’t tell	Yes	Yes	Yes	Yes	Yes	Yes
3.4: Are the confounding factors accounted for in the design and data analysis?	No	Can’t tell	Can’t tell	No	No	No	No
3.5: During the study period, was the exposure delivered as intended?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Overall Score: Quality of Evidence	Score: 4/7 (57%) Quality: Moderate	Score: 5/7 (71%) Quality: Moderate	Score: 6/7 (86%) Quality: High	Score: 6/7 (86%) Quality: High	Score: 5/7 (71%) Quality: Moderate	Score: 6/7 (86%) Quality: High	Score: 6/7 (86%) Quality: High

Appendix- 9: Summary of Results

Study	Back Pain	Neck Pain	Upper Extremity Pain	Statistical Association between Ergonomic Risk Factors and WRMSDs	Influence of Confounding Factors	Association between WRMSDs and Working Efficiency/ Activities of Daily Living
Fisher, Konkel and Harvey (2004) [86]	-	-	39.5%	Statistically significant ($p > 0.05$)	-	Working Efficiency: Statistically significant ($p < 0.05$)
Aytutuldu, Birinci and Tarakcı (2020) [87]	Lower back pain: 27%	18.4%	-	Statistically significant ($p > 0.05$)	**- Probability of WRMSDs in various age groups:** 50-70 years age group – 1.94 times (95% CI: 1.10-3.64)> 40-49 years age group – 2.44 times (95% CI: 1.26-4.45)> 23-29 years old **- Statistical Correlation between Mean BMI and Q-DASH Score:** Statistically significant ($p = 0.014$) **- Statistical Association between Working Years and the Risk of WRMSDs:**	

					1. ODI score: $p = 0.041$ 2. Q-DASH score: $p = 0.043$ **Workstation Analysis – Risk of Development of WRMSDs:** 1. Medium-risk level: 55.2% 2. High-risk level: 27.6%	
Mohammadipour et al. (2018) [88]	Lower back pain: 72.4%	55.2%	-	Statistically significant ($p < 0.002$)	**Normal Body Weight:** Significant reduction in the risk of developing WRMSDs (OR = 0.10, 95% CI = 0.05–0.18) **- Workstation analysis – Risk of Development of WRMSDs:** 1. Medium-risk level: 53.1% 2. High-risk level: 28.2%	Working Efficiency: Statistically significant ($p < 0.05$)
AlOmar et al. (2021) [89]	Lower back pain: 73.1%	-	-	Statistically significant ($p > 0.05$)	**- Workstation Analysis – Risk of Development of WRMSDs:** 1. High-risk level: 33.7%	Working Efficiency: Statistically significant ($p < 0.05$)
Calik et al. (2020) [90]	Upper back pain: 69.6%	65.2%	-	Statistically significant ($p < 0.001$)	-	Neck pain restricted ADLs: 22.9% of office workers

	Lower back pain: 64.1%					
Rodrigues et al. (2017) [91]	-	-	-	Statistically significant (*p* = 0.001) in subgroup-1 (workers with musculoskeletal pain)	Mean scores on MUEQ-Br revised – in the chair section of the ROSA scale, upper limb RULA scale, and workstation section: subgroup-1>>> sub-group-2	-
Kaliniene et al. (2013) [92]	-	65.7%	-	Statistically significant (*p* = 0.02) between ROSA scores and neck pain	**Association between Working Experience and the Risk of Developing WRMSDs:** Employees with 16-35 years of work experience– 2.42 times (95% CI: 1.41-4.22) > employees with 6-15 years of work experience – 2.26 times (95% CI: 1.45-3.50) > employees with 1-5 years of experience	-