Review Article

Technology for preventing work-related musculoskeletal injuries in healthcare professionals: A scoping review

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ABSTRACT

Background & Aim: This scoping review aims to identify and summarize how technology can help prevent work-related musculoskeletal injuries in healthcare professionals.

Methods & Materials: We conducted a scoping review following the steps provided by the Joanna Briggs Institute. The PRISMA® - Preferred Reporting Items for Systematic Reviews and Meta-Analyses model was used to organize the information, following the recommendations described in PRISMA-ScR (PRISMA Extension for Scoping Reviews) for the article presentation. A search of PubMed, Scopus, and CINAHL databases was conducted for all articles in December 2023.

Results: Of the 964 initial articles identified, 7 met the inclusion criteria. The reviewed studies highlight the effectiveness of various technological interventions in reducing musculoskeletal injuries among healthcare professionals. Wearable technologies, such as inertial measurement units, have been effective in promoting correct posture and reducing the risk of musculoskeletal disorders. However, the studies also identified significant challenges, including the generalizability of findings, the need for more robust empirical evidence, and issues related to the long-term sustainability and cost-effectiveness of these technologies.

Conclusion: The conclusion of this analysis highlights the need for scalable, effective, and customized therapies and calls for more study and development in gamification, wearable technologies, and tailored mobile applications.

Introduction

Musculoskeletal disorders are still the most common work-related health problem in the European Union (EU). Musculoskeletal disorders concern workers in all sectors and occupations. According to an ad hoc analysis conducted for the European Labour Force Survey under the auspices of the Directorate General Employment and Social Affairs in Brussels (1,2), a significant proportion of work-related diseases in the EU can be attributed to musculoskeletal disorders, accounting for 53% of such cases. Besides the direct effects on workers themselves, these disorders lead to high costs to enterprises and society and have a huge impact on public health (2).

A vast majority of the population claims that they did not receive proper education on pain management and, when they did, it was only when in direct contact with a health professional (3). It is clear that with the rise of world population, the existing number of health professionals specialized in musculoskeletal injuries, and the big rise in the population suffering from these disorders, there are not enough resources to have an effective prevention of these injuries live, always accompanied by a health professional in this area (4).

One of the population groups most affected by work-related musculoskeletal injuries is healthcare workers, in studies performed

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around the world, results were obtained showing a higher prevalence (35%–80%) of work-related musculoskeletal injuries in nursing workers (5-9). The most common causes of these problems are primary cause for musculoskeletal disorders in nursing is patient handling tasks such as lifting, transferring, and repositioning patients (6,8).

This exigent situation compels us to radically rethink our approach, urging us to harness the power of innovation for scalable, effective strategies to stave off work-related musculoskeletal injuries. In this landscape, the role of technology and gamification becomes particularly salient. We live in the age of a digital revolution, where technological advancements continue to redefine various facets of our lives, including healthcare (10). These advancements extend a promising pathway to radically transform the prevention, management, and treatment of work-related musculoskeletal injuries. For instance, wearable devices, armed with sensor technology, can monitor, analyze, and provide real-time feedback on body mechanics. This allows for the early detection and correction of potentially injurious behaviors, significantly minimizing the risk of Musculoskeletal disorders, in parallel, the advent of virtual and augmented reality technologies provides immersive, interactive platforms for training and rehabilitation, contributing significantly to injury prevention and recovery (11).

It is imperative to transition from our current healthcare model of disruption and correction to a model of prediction and prevention, emphasizing proactive healthcare strategies supported by technology (12). Recent research reveals that technologies and mobile applications are effective tools for knowledge transfer and decision-making in nursing or clinical education, as well as in behavior change (13), particularly around safety (14). Consequently, there has been a growing emphasis on shifting towards proactive, preventive approaches to healthcare.

The growth and popularity of technologies, driven by their ability to provide easy access to data anywhere and at any time, are significantly boosting their adoption, particularly in the realm of health and occupational safety for healthcare workers. This adoption is becoming increasingly necessary (3). Given the need for

preventive measures against work-related musculoskeletal disorders and the existing gaps in technologies specifically designed for nursing in this field, the aim of this scoping review is to identify and summarize how technology can aid in the prevention of work-related musculoskeletal injuries among healthcare professionals.

In this context, a scoping review plays a crucial role in mapping existing knowledge and identifying gaps in the current research on the use of technology for the prevention of work-related musculoskeletal injuries among healthcare professionals. By systematically examining a wide range of studies, this review will provide a comprehensive overview of the available technologies and their applications in this area, enabling the development of effective resources in subsequent phases.

Methods

We conducted a scoping review following the steps provided by the Joanna Briggs Institute (15). The PRISMA® - Preferred Reporting Items for Systematic Reviews and Meta-Analyses model was used to organize the information, following the recommendations described in PRISMA-ScR (PRISMA Extension for Scoping Reviews) for the article presentation. The protocol for this scoping review was registered and published in OSF https://doi.org/10.17605/OSF.IO/CMEQS.

Search strategy

The review began with an exploratory search of the relevant literature to identify the keywords. The main keywords were derived from the research question and synonyms were sourced from keywords identified in previous studies. To make the search as comprehensive as possible, free-text terms were used, in addition to the descriptors of each of the databases. Studies were searched in the CINAHL® (Cumulative Index to Nursing and Allied Health Literature), SCOPUS®, and PubMed®, databases. Regarding the data gathering, the following terms were searched: "game", "gamification", "electronic game", "mobile app", "mobile application web app", "video game", "web-site", "health"," injuries", "musculoskeletal", "health app", "health professionals", "nurse", "doctor",

"musculoskeletal injuries", "musculoskeletal disorders", "musculoskeletal", "work-related" and "WMSD".

These terms were combined according to the following query:

" TITLE-ABS-KEY (((("health") OR ("health professionals") OR ("nurse") OR ("doctor") OR ("Nursing Staff") OR ("Hospital")) AND (("musculoskeletal") OR ("musculoskeletal injuries") OR ("musculoskeletal disorders") OR ("work-related") OR ("WMSD") OR ("Occupational-related injuries") OR ("back injuries") OR ("lifting and transfer equipment") OR ("safe patient handling") OR ("TRANSPORTATION of patients") OR ("Ergonomics") OR ("Low Back Pain Risk Factors") OR ("Patient Positioning") OR ("Occupational Diseases")) AND (("game") OR ("gamification") OR ("mobile app") OR ("electronic game") OR ("web app") OR ("video game") OR ("gamified") OR ("game-based") OR ("mobile application") OR ("website"))) AND ((PUBYEAR >2016) AND (PUBYEAR< 2024))".

Inclusion and exclusion criteria

This study started by formulating the question, incorporating the elements of Population, Concept, and Context (PCC). In the context of the population, studies on health professionals were included. Regarding the concept, studies were included that addressed the use of Technology for preventing or reducing Work-related musculoskeletal injuries. In terms of context, publications from any context of healthcare. All types of publications were considered for inclusion, regardless of their design, in English, until December 2023. Given the up-to-dateness of technologies and for the subsequent development of a technological resource, a timeframe from 2016 to 2023 was considered. The inclusion criteria for the review were as follows: articles that address musculoskeletal work-related disorders among healthcare professionals, articles that correlate healthcare professionals' activities with the use of technology, articles that discuss technology related to healthcare professionals, and articles that focus on technologies to connect with healthcare professionals. The exclusion criteria were defined as follows: articles involving patients or e-sports players, injuries related to excessive computer usage, and articles that address other types of medical disorders). The search for additional studies was also carried out in the reference lists of all publications included in the review (''Backward citation searching'').

Review process

The result of each search was imported through the web application Rayyan QCRI® (Rayyan QCRI; https://rayyan.qcri.org/,Qatar) to facilitate systematic review. After removing all duplicates, studies were screened by two reviewers using the information in the title and abstract only to identify studies for full-text evaluation. After that, two independent reviewers conducted the selection of the studies, and the possible disagreements were resolved by consensus of a third reviewer to confirm the eligibility of the publications.

Data extraction and analysis

For the data extraction and analysis, a systematic approach was adopted to ensure the accuracy and relevance of the selected studies. Key information from each article—such as study design, population, interventions, outcomes, and noted limitations—was meticulously gathered during the data extraction phase. This data was then synthesized into a narrative format. The results were subsequently organized into a structured table (Table 1), highlighting the characteristics and outcomes of each study. This approach facilitated a clear and concise analysis of the evidence on the use of technology in preventing work-related musculoskeletal injuries among healthcare professionals. The results are presented in distinct subsections that detail the characteristics of the included studies, participants, and digital technologies employed, as well as the outcomes of the interventions.

Table 1. Studies included in this review

(Year), Country	Methodology	Aim	Participants	Limitations
(2019), Brazil (3)	Prototype development	Develop a multi-platform application for the prevention of musculoskeletal risk factors related to nursing work in a hospital unit and evaluate the usability criteria with nurses and computer professionals.	8 nurses and 2 information technology professionals	Data such as images and videos require greater consumption of data and devices and may cause difficulties in the application.
(2020), Brazil (16)	Randomized controlled Trial	To analyze the effects of muscle stretching exercises (MSE) on pain among Nursing Professionals	Nursing professionals	Unpredictability of the possible placebo effect that the intervention may have had on volunteers should be considered.
(2023), Czech Republic (17)	Systematic review	The study presents the most widely used methods for assessing the ergonomics of work positions using motion capture technology, their advantages, and disadvantages.	Included Nursing and health professionals	The most commonly used ergonomics assessment methods are not complex enough to be effectively combined with motion capture, indicating a need for integration. This technology has become highly significant in the field of ergonomic evaluation of work postures. However, the evaluation systems still have errors and require ongoing improvement.
(2018), France (11)	Prototype development	Investigate the technology needs of healthcare workers with low back pain and explore the potential use of wearable technology to increase their self-awareness of this condition	20 healthy adults who were recruited from a university community	This study has essentially three limitations: small sample size and limited population, evaluation limited to a single session, and the lack of comparison with alternative methods of musculoskeletal disorders prevention.
(2020), Greece (18)	Prototype development	Present the development and evaluation of a wearable smart health advisor that uses inertial measurement unit (IMU) sensors to monitor and provide feedback on users' posture when seated in real-time. The goal is to improve sitting habits.	10 adults between the ages of 18 and 50 from a university community	First, a small sample size, second a limited population of healthy adults, and, finally, a short evaluation period. These make it difficult to draw definitive conclusions about the effectiveness of detecting and correcting posture, particularly in populations with pre-existing musculoskeletal conditions or over a longer period of time.
(2021), Canada (19)	Descriptive study	Investigate the technology needs of healthcare workers with low back pain and explore the potential use of wearable technology to increase their self-awareness of this condition	136 healthcare workers with low back pain. Participants from a variety of healthcare settings and professions. The ages ranged from 20 to 65 years old.	First, a small sample size, second a limited population of healthy adults, and, finally, a short evaluation period. These make it difficult to draw definitive conclusions about the effectiveness of detecting and correcting posture, particularly in populations with pre-existing musculoskeletal conditions or over a longer period of time.
(2023), Portugal (20)	Systematic review	Examine the effectiveness of interventions in preventing musculoskeletal injuries related to nursing work		Given the various limitations present, such as disparate interventions and outcome measures used in studies conducted primarily within high-income countries, along with a lack of reporting on whether interventions are both cost-effective and sustainable over extended periods of time, the generalizability and application of any findings may be impacted.

Results

Figure 1 shows the process of identifying and including articles presented through PRISMA® (Preferred Reporting Items for Systematic Reviews and Meta-Analyzes). In the first stage, the duplicate records were removed, after this process, we had 964 records. The gathered records were checked by reading the title; after checking all titles, 931 records were excluded. In stage two, the remaining 33 articles were screened by reading the abstract, with 28 articles being excluded at this stage. In stage three, the remaining 5 articles were screened by reading the full text. In the last stage, a cross-referencing of the 4 selected articles was conducted, and 3 additional articles were included after full-text analysis. Hence, after the selection process, a total of 7 articles, corresponding to references (3,11,16-20) were selected for review and detailed analysis in the next step. Figure 1 summarizes this process.
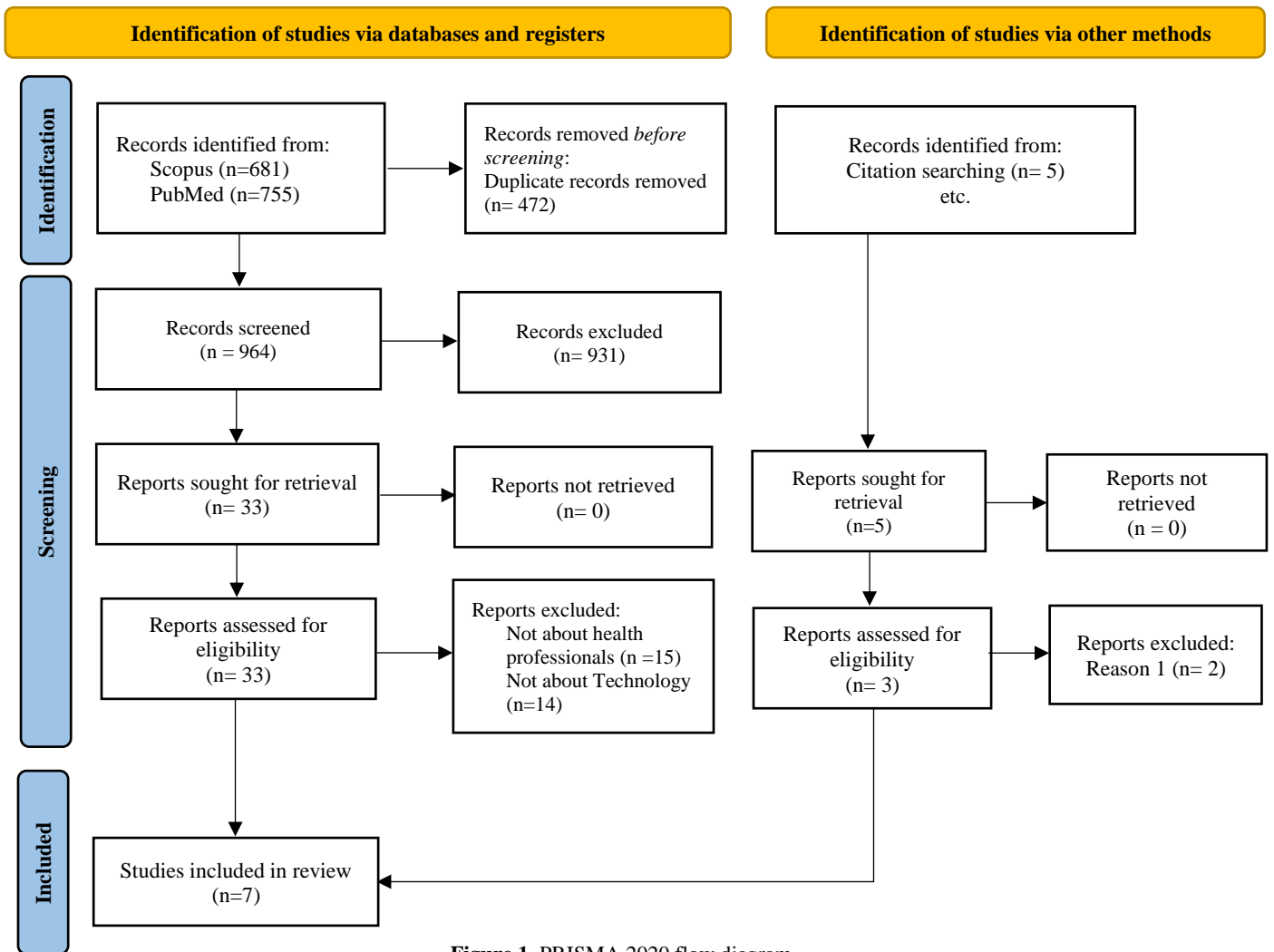
Figure 1. PRISMA 2020 flow diagram

Characteristics of the included studies

The selected studies (N= 7) span from 2018 to 2023, reflecting a global perspective with contributions from Brazil (3,16), the Czech Republic (17), France (11), Greece (18), Canada (19), and Portugal (20). The studies utilized a range of methodological approaches, including prototype development (3,11,18), randomized controlled trials (16), systematic reviews (17,20), and descriptive studies (19) Three of the studies focused on developing prototypes aimed at innovating tools and interventions that leverage technology for preventing musculoskeletal injuries. These prototypes included mobile applications (3), wearable smart health advisors utilizing inertial measurement unit sensors (18), and virtual reality games designed for educational and preventive purposes (11). The studies employed diverse designs, with some relying on subjective, self-reported measures, while others incorporated objective data gathered through technological means (3,16,19). The interventions varied in duration, frequency, and intensity, targeting different aspects of musculoskeletal health, including posture correction (18), pain management (16,19), and educational improvements through gamification (11, 17).

Characteristics of the participants

Most of the studies (3,16,17) specifically involved nursing professionals, reflecting the targeted focus on musculoskeletal health within this group. However, in some cases, broader populations were included for testing purposes. For instance, one study (11) involved 20 healthy adults from a university community to explore the potential of wearable technology. Similarly, another study (18) included 10 adults from a

university community. Another study (19) involved 136 healthcare professionals with low back pain, with participants drawn from various healthcare settings and professions. Despite the use of diverse populations for testing, most of the research remained focused on interventions specifically relevant to nursing professionals.

Characteristics of digital technology

The various interventions included the use of mobile applications (3), exercise programs (16), virtual reality (11), and wearable technology (17,18,19). These technologies were designed not only to address physical health issues, such as posture correction and pain management but also to enhance the educational experiences of healthcare professionals through interactive and engaging platforms.

These innovations aimed to empower nurses in their daily work routines, improve their physical health, and strengthen the educational framework within which they operate (3,16,19). The studies frequently utilized technologies with capabilities for real-time monitoring, feedback, or interactive learning (3,17,18), fostering active involvement from nursing professionals in managing their health and enhancing their educational outcomes (11).

Outcomes

The collection of articles presents various methodologies and technologies developed to assist nursing professionals in mitigating musculoskeletal injuries. One study (3) introduces a mobile application that utilizes scientific data, self-monitoring tools, learning materials, and ergonomic recommendations. The study supports its efficacy by demonstrating improved musculoskeletal health among nurses who used the application.

Taking an innovative approach, Brazilian researchers (16) conducted a study on the effectiveness of stretching exercises. This simple, affordable, and accessible method was found to promote musculoskeletal health among nursing professionals by reducing discomfort related to their physically demanding roles.

A series of studies reviewed (17) presents the most widely used methods for assessing the ergonomics of work positions using motion capture technology. The review discusses the advantages and disadvantages of these methods, highlighting the need for their integration with motion capture to improve ergonomic evaluations in nursing and healthcare settings.

Building on the technological theme, another study (11) introduces a virtual reality game designed to reduce musculoskeletal illnesses at work. This innovative approach uses simulation to raise awareness and instill healthy work habits, demonstrating how the immersive world of virtual reality can be harnessed for health education.

Wearable technology is also featured in these discussions. One study (18) showcases a wearable smart health advisor that uses inertial measurement to monitor posture when seated and provides feedback to users. This device offers a practical solution for tracking and improving posture-related health issues.

Similarly, another study (19) explores wearable technology further by conducting a survey to assess healthcare professionals' needs for such devices in preventing and treating low back pain. The findings suggest that wearable gadgets providing feedback on posture and movement patterns could be crucial additions to low back pain prevention and management programs.

Finally, a systematic review (20) emphasizes the importance of a comprehensive, multidisciplinary approach to preventing and reducing musculoskeletal injuries associated with nursing. This approach includes a combination of organizational changes, ergonomic treatments, education, training, and exercise programs, underscoring the need for tailored, multipronged interventions across different nursing specialties."

Discussion

This review aimed to identify and summarize how Technology can help in the prevention of work-related Musculoskeletal Injuries of healthcare professionals, the efficiency of the use of technologies allied with gamification to prevent this type of problems and the reality already existing in the field of digital health related to these disorders. The discussion is divided into four subsections— Technologies, Challenges and Limitations, Potential, and Further Research and Development—to allow a systematic and thorough analysis.

Technologies

A systematic evaluation of the chosen publications showed how successful various strategies involving technology are at preventing or reducing musculoskeletal hazards among healthcare practitioners. One such intervention was a mobile app (3) that offered self-monitoring, information, and ergonomic guidelines and improved nursing professionals' pain levels, level of handicap, and quality of life. Additionally, it has been discovered that including stretching exercises[16] as a regular practice in the workplace is a cheap and efficient strategy for nursing workers to lessen musculoskeletal pain.

In addition, virtual reality games, like prevention games (11), have shown promise as a cheap and efficient way to prevent work-related musculoskeletal injuries in the workplace. These games can increase players' understanding of work-related musculoskeletal injury prevention and build good attitudes toward healthy work practices by imitating work-related tasks and movements that can cause work-related musculoskeletal injuries.

The promotion of healthy posture habits and the prevention of posture-related health problems have both been demonstrated by wearable technology, such as those utilizing inertial measurement units (17,18). By promoting positive changes to users' movement and posture patterns and raising users' awareness of their posture, these devices can be effective aids for improving musculoskeletal health. It was proven that wearable technologies would highly benefit the Low back pain treatment.

Wearable technology has been highlighted as having potential advantages for Health professionals in the setting of low back pain (19). According to the survey's findings, health professionals are largely aware of these advantages and have voiced a desire to use such devices for posture monitoring. Last but not least, research on a variety of therapies, including fitness regimens, education and training, ergonomic interventions, and organizational changes, has highlighted the significance of a multidisciplinary approach and adapting interventions to particular nursing specialties and situations (20). Those strategies can be integrated into a mobile app.

Challenges and limitations

The challenges in preventing work-related musculoskeletal disorders among healthcare professionals, particularly with technology use, can be summarized as follows. Mobile apps for physical exercises often demand advanced devices and high data usage, requiring optimization for broader accessibility (16). The placebo effect in interventions like stretching complicates effectiveness assessments, necessitating robust control measures in studies (3,16). Many studies face limitations in sample size and context, reducing generalizability, and highlighting the need for research in diverse settings with standardized methods (11,17,20). Additionally, biases from self-reported data and barriers like privacy concerns and costs in wearable tech adoption need a more thorough examination (19). Lastly, the long-term cost-effectiveness and sustainability of these interventions remain underexplored, warranting further research (20).

Potential

The various strategies covered in the papers chosen for the scoping review illustrate the broad potential of technology in preventing musculoskeletal injuries among healthcare personnel. Each intervention has special benefits that, when combined, customized to particular requirements, or used in different healthcare settings, can have a major influence on the management and prevention of these injuries. By combining scientific data, self-monitoring, education, and ergonomic principles into an approachable platform, mobile applications (3) redefine how nursing professionals approach the prevention of musculoskeletal problems. In addition, wearable technologies with an emphasis on preventing low back pain (19) and inertial measurement units (18) provide potential options for real-time posture monitoring and correction.

These gadgets can be tailored to match the unique tastes and needs of healthcare practitioners as technology develops, making these treatments both practical and efficient.

The engaging aspect of games is used by serious virtual reality games (11) to improve learning experiences and raise awareness of

musculoskeletal injury prevention. Gaming has the potential to improve clinical skill development, interdisciplinary communication, and teamwork, better preparing healthcare practitioners for situations they would face in the real world. Likewise, virtual reality games have the ability to influence behavior, promote a good mindset about musculoskeletal health, and be applied to a variety of businesses outside of healthcare.

Exercises that stretch the muscles and joints (16) are a simple intervention that effectively treats musculoskeletal discomfort for a low cost. This intervention can be adjusted to the demands of healthcare professionals with different specialties and backgrounds, and it has the potential to be extensively employed in a range of healthcare settings. These strategies can be easily implemented in a gamified mobile app to increase prevention efficacy.

Last but not least, the potential of a multidisciplinary approach (20) emphasizes the value of teamwork among medical experts and specialists in treating musculoskeletal ailments. These cooperative efforts can result in more efficient and long-lasting preventative methods by adjusting interventions to the particular demands of various nursing specialties and contexts.

Further research and development

The scoping review identifies various areas for more study and advancement in the use of technology among healthcare professionals to avoid musculoskeletal injuries, particularly in the areas of gamification, wearable technology, and mobile applications. Considering the growing relevance of information and communication technologies in healthcare, it is very important to merge different ideas of how technology should be designed in terms of technical aspects (21-23).

Investigating the incorporation of more individualized features in mobile applications, such as specialized ergonomic guidelines and recommendations based on a person's working environment or particular nursing specialty, may provide insightful information about their efficacy in a range of healthcare settings (16). A fuller knowledge of the impact of mobile application treatments would also result from looking into their long-term consequences and possible scalability.

To evaluate the effectiveness of various game kinds and designs, particularly their accessibility and relevance in low-income or under-resourced situations, further study is required in the fields of educational serious games (11). It will be easier to find best practices and increase the generalizability of game-based learning if the study's scope is broadened to encompass a variety of groups and environments. A more thorough understanding of gaming's function in reducing musculoskeletal injuries will also come from looking at how it affects long-term knowledge retention, skill development, and behavior change.

Future studies might examine the development of more cozy, user-friendly wearables with longer battery life and improved data security and privacy, such as those that use inertial measurement units (18) or aimed at preventing back pain (19). It will be possible to assess these devices' full potential for the prevention and treatment of musculoskeletal problems by looking at how well they perform in bigger, more diverse populations over longer periods of time.

The creation and execution of future interventions may be influenced by learning about potential obstacles to the adoption of wearable technology among healthcare professionals.

Stretching exercises (16), which are straightforward and inexpensive, also call for additional investigation in terms of the ideal frequency, length, and exercise kinds best suited for various healthcare settings and specialties. Understanding these therapies' long-term impacts will help us better grasp their advantages.

Last but not least, more research should focus on creating and analyzing multidisciplinary strategies (20) to prevent musculoskeletal injuries, including selecting the optimal combination of interventions for different nursing specialties and settings and assessing their cost-effectiveness and long-term viability.

Future advancements in gamification, wearable technology, mobile applications, and other technological areas may alter how healthcare professionals are prevented from and treated for musculoskeletal injuries. It can pave the way for more efficient, accessible, and individualized therapies that cater to the distinct needs of

healthcare professionals across various specializations and contexts by combining and building upon the findings of the selected publications in this systematic review.

Limitations of this study

This literature review has only considered papers published in the English language and is limited to 2016 and 2023, however, the authors' assumption was that most significant publications would be found within this language. Grey literature such as reports from organizations, etc. are not included.

Conclusion

This scoping review provides an in-depth analysis of the role technology plays in managing musculoskeletal illnesses, highlighting effective strategies. Various interventions include the use of mobile apps, exercise programs, virtual reality, and wearable technology. These tools aim not only to address physical health issues, such as posture and pain management but also to enhance healthcare professional training through interactive platforms. Mobile applications are particularly effective, offering self-monitoring, essential information provision, and ergonomic guidance.

Similarly, wearable devices like inertial measurement units can offer real-time posture adjustments and monitoring, significantly improving musculoskeletal health. However, the review also identifies several challenges and limitations that need addressing. These include potential placebo effects, the generalizability of results, the absence of control groups, reliance on self-reported data, and concerns regarding the cost-effectiveness and sustainability of these interventions. Issues such as data usage and device compatibility also pose challenges. The need for broader research in diverse environments with larger populations and standardized criteria is emphasized to better assess interventions aimed at preventing work-related musculoskeletal injuries among health professionals. Given these obstacles, the review advocates for further research and development in various areas, including more personalized features in mobile applications, enhanced accessibility, and the relevance of educational gaming and virtual reality serious games, particularly in low-resource settings.

The future of preventing and treating work-related musculoskeletal injuries lies in utilizing these insights to develop tailored interventions for healthcare professionals in various specialties and contexts. These advancements could fundamentally change the approach to musculoskeletal disorders, greatly benefiting the health and well-being of healthcare workers globally.

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Conflicts of Interest

The authors declare no conflict of interest.

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