FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

Applying Gamification to Prevent Work-related Musculoskeletal Injuries in Health Institutions

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Resumo

Na União Europeia (UE), as perturbações músculo-esqueléticas constituem uma preocupação séria e contínua de saúde ocupacional, particularmente para os profissionais de saúde. Esta dissertação desenvolve uma abordagem completa que combina tecnologia wearable, aplicações móveis e gamificação para responder à necessidade urgente de combater as lesões músculo-esqueléticas (LME). A aplicação móvel criada pretende encorajar comportamentos saudáveis e envolver os profissionais médicos na prevenção e gestão das LME através da utilização de aplicações para smartphones e da inserção de componentes de gamificação. Os dispositivos vestíveis permitem ainda a monitorização em tempo real de marcadores fisiológicos, atividade física e posturas, permitindo a deteção de riscos para a saúde e facilitando medidas preventivas.

O estudo adopta uma metodologia centrada no utilizador que inclui uma série de etapas, tais como uma análise exaustiva da literatura relevante, a obtenção de requisitos, o desenvolvimento e os testes de usabilidade, bem como a interpretação dos resultados da investigação. A solução final é criada para ser de fácil utilização, envolvente e extremamente eficaz na redução do risco de LME entre os profissionais de saúde, dando prioridade aos requisitos e preferências dos utilizadores.

É importante notar que o foco inicial do estudo era a criação de uma aplicação móvel com aspectos de gamificação para abordar as LME nos profissionais de saúde. No entanto, uma pesquisa aprofundada com os utilizadores identificou o potencial transformador da solução para a utilização de tecnologia wearable. Os wearables, a gamificação e as aplicações móveis foram, portanto, incluídos no âmbito alargado do estudo como uma estratégia integrada.

O principal objetivo desta dissertação é apresentar uma solução significativa e viável, para além de uma orientação útil para melhorias futuras. A solução proposta serve como uma intervenção robusta e duradoura que ajuda diretamente os médicos e contribui para a melhoria do sistema de saúde através da fusão de tecnologias e de uma abordagem centrada no utilizador. A incorporação de aplicações móveis, eletrónica vestível e gamificação não só aumenta os esforços de prevenção das LME, como também oferece um método prático e eficiente de reduzir os riscos de LME entre os profissionais de saúde.

Ao encorajar melhores hábitos, melhorar o bem-estar do pessoal de saúde e garantir um ambiente de trabalho mais seguro, esta investigação faz avançar significativamente a saúde no trabalho. Os resultados desta tese demonstram o potencial dos wearables e das aplicações móveis como instrumentos de mudança de paradigma para melhorar a saúde e o bem-estar no trabalho, para além de proporcionarem progressos substanciais na prevenção das LME. Apesar de algumas limitações, a solução estabelecida oferece um caminho promissor para diminuir os efeitos das LME nos profissionais de saúde, sublinhando a importância da investigação e desenvolvimento contínuos nesta área.

Abstract

In the European Union (EU), musculoskeletal disorders (MSDs) constitute a serious and continuous occupational health concern, particularly for medical professionals. This dissertation develops a complete approach that combines wearable technology, mobile applications, and gamification to meet the urgent need to battle MSDs. The created mobile application intends to encourage healthy behaviours and involve medical professionals in the prevention and management of MSDs through the use of smartphone apps and the insertion of gamification components. Wearable devices also provide real-time monitoring of physiological markers, physical activity, and postures, allowing the detection of health risks and facilitating preventative measures.

The study adopts a user-centric methodology that includes a number of steps, such as a thorough examination of the relevant literature, requirements elicitation, development, and usability testing, and interpretation of research findings. The final solution is created to be user-friendly, engaging, and extremely effective in lowering the risk of MSDs among healthcare professionals by prioritising user requirements and preferences.

It is important to note that the initial focus of the study was on the creation of a mobile app with gamification aspects to address MSDs in healthcare professionals. However, in-depth user research identified the solution's transformative potential for using wearable technology. Wearables, gamification, and mobile applications were therefore included in the extended scope of the study as an integrated strategy.

The key objective of this dissertation is to deliver a significant and workable solution in addition to helpful direction for future improvements. The proposed solution serves as a robust and long-lasting intervention that directly helps medical practitioners and contributes to the improvement of the healthcare system by fusing technologies and a user-centric approach. Incorporating mobile apps, wearable electronics, and gamification not only increases MSDs preventive efforts but also offers a practical and efficient method of reducing the risks of MSDs among healthcare professionals.

By encouraging better habits, enhancing the wellbeing of healthcare personnel, and ensuring a safer working environment, this research significantly advances occupational health. The results of this thesis show the potential of wearables and mobile applications as game-changing instruments for boosting occupational health and wellbeing in addition to providing substantial progress in the treatment of MSDs. Despite its drawbacks, the established solution offers a promising path towards lessening the effects of MSDs on medical professionals, underscoring the significance of ongoing research and development in this area.

Keywords

gamification, application, health professionals, musculoskeletal injuries, musculoskeletal disorders, work-related

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Sofia Teixeira

“Não tenhamos pressa, mas não percamos tempo.“

José Saramago

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Abbreviations and Symbols

APP	Application
BMI	Body Mass Index
MSDs	Musculoskeletal Disorders
WRMSDs	Work-related Musculoskeletal Disorders

Chapter 1

Introduction

The scope of this dissertation is presented in this chapter. The context around this dissertation's thesis, which is musculoskeletal disorders in healthcare professionals, mobile applications, and gamification, is described in section 1.1. The motivation for this work and the main goals are explained in sections 1.2 and 1.3, respectively. Finally, section 1.4 describes the format the rest of the document will follow.

1.1 Context

Musculoskeletal disorders (MSDs) is still the most common work-related health problem in the European Union (EU). MSDs concern workers in all sectors and occupations. According to an ad hoc analysis conducted for the European Labour Force Survey under the auspices of DG Employment and Social Affairs in Brussels [1], a significant proportion of work-related diseases in the EU-15 can be attributed to musculoskeletal disorders (MSDs), 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. This dissertation aims to investigate and comprehend this problem. The percentage of musculoskeletal disorders has been rising, and as a result of the aging population and the increased physical demands placed on healthcare personnel, this issue has become a public health priority.

This dissertation will explore the use of mobile apps, wearables, and gamification techniques to deal with this issue and help effectively on its prevent it. Gamification is the integration of game aspects into non-game contexts—has become a potent tool for inspiring and involving users in a variety of contexts, including marketing, education, and health. On the other side, mobile applications have completely changed how we access and consume information, opening up previously unimaginable opportunities for the healthcare industry.

Mobile apps and gamification can be combined to produce innovative, compelling, and useful solutions for the treatment and prevention of MSDs among healthcare professionals. Healthcare practitioners might adopt healthier habits thanks to the accessibility and pervasiveness of mobile applications as well as the motivational elements of gamification. [2]

Additionally, the introduction of wearable technology in healthcare opens up new opportunities for the use of these instruments. In order to warn users about potential risks, offer feedback, and promote preventive behaviors, wearables can deliver real-time data on physiological indicators, physical activity, and postures. A comprehensive solution for the management and prevention of MSDs in healthcare workers may be created by integrating these technologies.

In order to address MSDs among healthcare professionals, this research intends to build a smartphone application with integrated gamification and wearable technologies. The study will build and assess a solution that is user-friendly, entertaining, and successful in promoting healthy habits and lowering the risk of MSDs by looking into the particular needs and preferences of this group. The goal is to develop a tool that can not only directly benefit medical practitioners as a whole but also help achieve the more general objective of a better, more sustainable healthcare system.

Gamification

Gamification is the practise of incorporating game-like aspects into situations that are not games, it is used to encourage and engage people by imitating the thrill and challenges that are often found in games. Even though the term "gamification" did not become popular until 2008, the ideas it represents have been used for years in a variety of contexts, including marketing, education, and even customer and airline loyalty programmes. [3].

In essence, gamification makes use of our innate drive for contact, competitiveness, and achievement to motivate people and increase engagement. Its implementation in a variety of industries, such as marketing, education, and personal finance, among others, has demonstrated how effective it is at increasing motivation, building loyalty, and improving the user experience. It has been applied in the field of healthcare to encourage better lifestyle choices, stimulate physical activity, support medication adherence, and enhance illness management. [4].

The use of gamification concepts to combat the growth of musculoskeletal diseases (MSDs) among medical personnel has shown promise. The process of implementing healthy work practises can be made more enjoyable and engaging by the inclusion of game-like aspects. This helps with the long-term sustainability of these practises as well as increasing the possibility that healthcare providers will use preventative measures.

However, it's crucial to remember that gamification applications must be carefully considered. A focus on game-like characteristics or a disproportionate dependence on rewards may unintentionally reduce intrinsic motivation and divert attention from the main goal. Therefore, it is essential to implement gamification techniques in a smart and balanced manner, making sure the rewards provided are worthwhile and the core objective stays the main emphasis [5]. These issues are addressed by the incorporation of gamification in the suggested mobile app, which maximizes the use of game-like aspects to encourage healthcare personnel to participate in preventative actions against MSDs.

Mobile Apps in Healthcare

Mobile applications have drastically transformed the way healthcare services are delivered and have emerged as critical tools for disease management and patient health monitoring. These applications are software programs designed to run on smartphones and other mobile devices, catering to various health-related needs, such as medical reference, patient health record maintenance, hospital navigation, appointment scheduling, and remote patient monitoring [6].

Mobile apps offer healthcare professionals quick access to medical information, aiding in efficient decision-making, while for patients, these apps can improve health outcomes by fostering regular medication intake, promoting healthy lifestyles, and aiding in chronic disease management. For instance, apps can provide reminders for medication or motivate users to achieve their fitness goals through daily exercise routines and dietary advice. Additionally, to aid in the management of illnesses like anxiety and depression, mental health apps can offer cognitive-behavioral therapy and mindfulness activities [7].

However, despite the fact that mobile applications have a huge potential to advance healthcare, there are issues with data security, privacy, and the caliber of the health information offered. Ensuring that apps adhere to healthcare data standards and regulations is essential to protect patient information and provide reliable health services [8]. As these technologies continue to evolve, integrating them into healthcare effectively and safety remains a critical consideration.

Musculoskeletal Injuries in Health Professionals

Health professionals are at a heightened risk of developing musculoskeletal injuries due to the physical demands of their jobs. These injuries, often referred to as musculoskeletal disorders (MSDs), are conditions that can affect the muscles, bones, tendons, blood vessels, and nerves. MSDs are typically the result of repetitive movements, heavy lifting, or maintaining uncomfortable positions for extended periods [9].

For instance, nurses and other healthcare professionals often perform tasks such as transferring patients between beds and wheelchairs, which can lead to back injuries. Similarly, surgeons may develop MSDs due to the long hours of maintaining static postures during surgeries [10]. Moreover, the increasing use of computers in healthcare settings has led to an increased incidence of repetitive strain injuries from typing and using a mouse.

Prevention of MSDs in healthcare professionals involves a combination of training, the use of ergonomic equipment, and the implementation of safe workplace practices. However, there is also a growing recognition of the role that mobile apps and wearable devices can play in supporting these prevention efforts, which forms the focus of this dissertation.

Wearables in Healthcare

Wearable technology is designed to be worn by their users and due to its ability to collect real-time health data and provide rapid feedback accordingly, it is becoming an increasingly significant part of the healthcare field.

This technology is found in a variety of products, including smartwatches, fitness trackers, and smart clothing and they may track a lot of physiological variables like heart rate, oxygen levels, and physical activity patterns. The analysis of this real-time data can provide a thorough picture of a user's lifestyle choices, health status and help to prevent a lot of possible hazards. [11].

Wearables can assist healthcare professionals in keeping track of their physical activity, maintaining proper postures, and avoiding overexertion in the context of musculoskeletal health. For instance, for the context of this master thesis, they can be useful to identify and warn the user about bad posture or excessive physical exertion, hence reducing the risk of MSDs. [12].

Additionally, wearable technology can improve patient care. Wearables give healthcare professionals the ability to continuously monitor patient vitals, allowing them to spot aberrant changes and act quickly. By consistently and accurately giving health data, wearables can also improve the management of chronic conditions like diabetes and heart disease. [13].

Despite these advantages, a few issues need to be solved before wearables can be fully included in the healthcare system. Some challenges include wearable device accuracy, user comfort, data privacy and security, and data interpretation. [14].

In conclusion, the combination of wearable technology, gamification, and mobile apps can offer a thorough answer to the issue of MSDs among healthcare personnel. The goal of this project is to create and assess such an integrated system, offering a cutting-edge solution to this pervasive occupational health problem.

1.2 Motivation

Musculoskeletal disorders (MSDs) present prevalent and challenging issues within the healthcare industry. The impact of these conditions extends beyond mere statistics, profoundly affecting the lives of healthcare professionals and the efficiency of health systems at large.

Reviewing the existing body of research and technological solutions, a crucial gap in the market becomes evident: there are limited technical solutions designed specifically to prevent and address MSDs among healthcare workers. The field lacks innovative and effective methods for mitigating the challenges associated with MSDs, particularly those tailored to the unique needs of healthcare professionals.

This research aims to fill that gap by developing a novel solution that couples a wearable device with a gamified mobile application. This dual strategy seeks to encourage healthy work habits, promote correct ergonomics, and prevent work-related MSDs in an engaging and user-friendly way.

The concept of using gamification, in particular, holds great promise. Games, by their nature, have the power to engage and inspire users. Incorporating gamification into a program aimed at preventing MSDs could potentially revolutionize the way healthcare professionals manage their physical health and work routines.

Thus, this research is driven by the necessity for effective solutions, the potential of technology and gamification, and the opportunity to significantly contribute to enhancing the working environment for healthcare professionals, thereby making a positive impact on public health.

1.3 Goals

The primary objective of this research is to fill the evident gap in the area of WRMSD prevention and enhance the lives of healthcare professionals. The goal is to create a user-friendly smartphone application designed to encourage healthy habits and arm medical practitioners with tools to prevent MSDs.

The specific goals for this thesis are to:

- Create an effective approach to lessen the significant impact of MSDs on public health among medical personnel.
- Reduce the prevalence and effects of MSDs to promote a healthy and happier workforce.
- Provide an economically viable solution that can help to lower the high direct and indirect costs connected to these health conditions.
- Delve deeper into the challenges identified in the previous chapter and seek innovative solutions for the prevention and management of MSDs among healthcare professionals.
- Utilize technology and gamification as tools for promoting healthy work behaviors and preventing work-related MSDs.
- Explore the personalization capabilities of these interventions, extending their applicability to various groups and environments.
- Enhance the work experience and satisfaction of healthcare professionals by mitigating MSDs-related discomfort.
- Improve the cost-effectiveness and sustainability of these interventions in the long term, thereby decreasing healthcare system costs associated with MSDs.

The ultimate goal of this research is to leverage engineering knowledge to develop a tool that improves the lives and wellness of healthcare professionals while also making a significant contribution to a more efficient and long-lasting healthcare industry.

1.4 Document Structure

This chapter provides an overview of the scope of this dissertation, presenting the context, motivation, goals, methodological approach, and document structure. The remaining chapters are organized as follows:

- **Chapter 2: Literature Review**

  In this chapter, the existing research and technological solutions related to musculoskeletal disorders (MSDs), mobile applications, wearables, and gamification are reviewed. It explores the prevalence and impact of MSDs, the role of mobile apps and wearables in healthcare, and the principles and effectiveness of gamification.

- **Chapter 3: Methodology**

  The methodology employed in this research is described in this chapter. It consists of four critical phases: theoretical consultation, needs assessment, prototype development, and prototype testing. The chapter explains the purpose and process of each phase, highlighting their importance in addressing the research objectives.

- **Chapter 4: Requirements Elicitation**

  The specifications for a preventative mobile application and wearable created especially for healthcare practitioners are described in this chapter. It discusses common musculoskeletal injuries, current preventative measures, and user engagement tactics. The chapter presents the desired features of the mobile application based on interviews with healthcare professionals and addresses the challenges of musculoskeletal injury prevention in healthcare settings.

- **Chapter 5: Mobile Application Development**

  The combination of mobile apps and gamification techniques as a means to prevent and address MSDs among healthcare professionals is explored in this chapter. It discusses the benefits of mobile apps in delivering healthcare services, improving health outcomes, and supporting lifestyle changes. Additionally, it examines how gamification can be effectively applied in healthcare contexts to motivate users and promote healthier habits.

- **Chapter 6: Wearable Device Development**

  This chapter focuses on wearable technology and its potential in the management and prevention of MSDs among healthcare workers. It explains how wearables can provide real-time data on physiological indicators, physical activity, and postures to support healthcare professionals in maintaining healthy habits and avoiding overexertion. The chapter also highlights the challenges and considerations associated with the integration of wearables in healthcare.

- **Chapter 7: Usability Testing**

  The usability testing results of the developed solutions are presented in this chapter. It provides an evaluation of the prototype application and examines the feedback and experiences of healthcare professionals who participated in the testing process. The chapter discusses the usability aspects, identifies areas for improvement, and provides insights for further development.

- **Chapter 8: Conclusion**

  The final chapter provides a summary and reflection of the work developed throughout the dissertation. It discusses the limitations of the research, potential future work, and the contributions made to the field. The chapter concludes by emphasizing the significance of this research in improving the lives and wellness of healthcare professionals and enhancing the healthcare industry as a whole.

Chapter 2

Literature Review

Musculoskeletal disorders (MSDs) remain the most common work-related health problem in the European Union (EU). MSDs concern workers in all sectors and occupations. The total number of cases of work-related musculoskeletal disorders in 2021/22 was 477.000 and, in the same year, 7.3 million working days were lost due to work-related musculoskeletal disorders. 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.

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 professionals. It is clear that with the rise of world population, the existing number of health professionals specialised in musculoskeletal injuries and the big rise of population suffering with these disorders, there are not enough resources to have an effective prevention of these injuries, always accompanied by a health professional in this area.

One of the population groups most affected with WRMSDs are healthcare workers. In studies performed around the world, results were obtained showing a higher prevalence of WRMSDs in nursing workers. The most common causes of these problems are primary causes for MSDs in nursing is patient handling tasks such as lifting, transferring, and repositioning of patients.

Technology is present in practically every area of our lives, at this moment, all over the world, the current number of smartphone users in the world today is 6.648 billion, meaning 86.11% of the world's population owns a smartphone. [15] It is remarkable that the various devices and software that have emerged in recent years can have a lot of positive impacts on our lives and, since the vast majority of the world's population owns a smartphone, it is the perfect opportunity to combat this problem in a global way.

One solution to this problem, to combat the lack of education on the subject, to improve awareness and to actively fight for the prevention of these disorders is the development of a gamified application.

Although the population has access to at least one mobile device capable of accessing the internet and interacting with the new technological world, this world can also be quite distracting, which makes it quite difficult to capture the attention of the general population for long periods of time. However, there is something that is able, through various highly studied techniques, to capture the attention of the general population for longer periods of time, which are: games.

It is crucial to investigate innovative prevention strategies in light of the considerable prevalence of work-related musculoskeletal diseases (WRMSDs) among healthcare professionals, the lack of suitable education in pain treatment, and the underuse of common technology. Therefore, to evaluate the potential of technology and gamification as combined therapies in the prevention of WRMSDs in healthcare professionals, this study makes use of a systematic review that adheres to PRISMA criteria [16]. This research aims to provide light on the potential roles of technology, particularly cellphones, and gamification in tackling this persistent health concern. Gamification has been shown to be effective at capturing user attention [17].

2.1 Methods

2.1.1 Research Strategy

The literature search was conducted on the Scopus and PubMed database in February 2023 in order to gather all peer-reviewed research articles are written in English language from January 2017 until February 2023. The Rayyan QCRI® platform (the Systematic Reviews web app) was used for the first data selection stages. Screening took place in February 2023.

Regarding the data gathering, the following terms were searched: “game”, “gamification”, “electronic game”, “mobile app”, “mobile application web app”, “video game”, “website”, “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))".

2.1.2 Material Selection

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 [18] [19] [20] [21] [22] [23] [24], were selected for review and detailed analysis in the next step. Figure 1 summarizes this process.

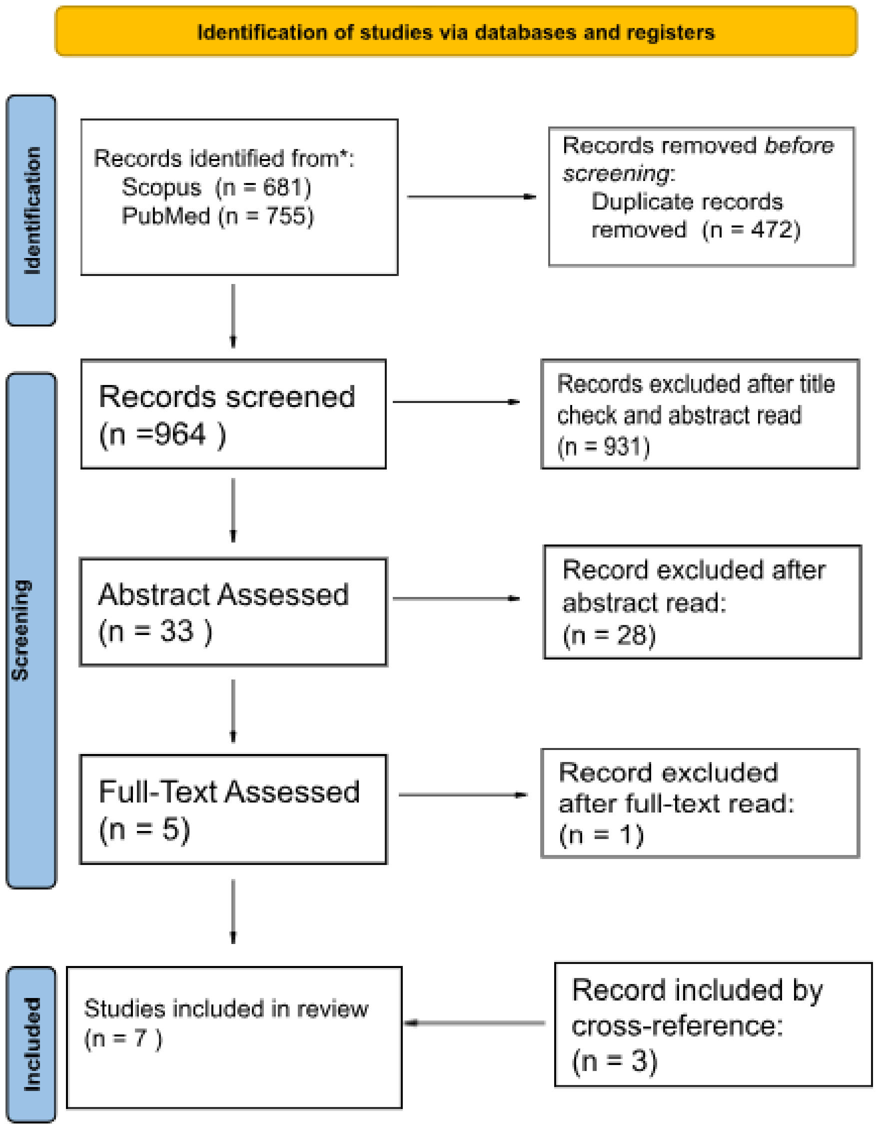

Figure 2.1: Selection process of the articles reviewed in the current study.

Table 2.1: Eligibility criteria used for the selection of the articles

Inclusion criteria	Exclusion criteria
• Articles addressing Musculoskeletal Work-related disorders on health professionals • Articles correlating health professional's activities with the use of technology • Written in English • Articles addressing technology connected with health professionals • Articles addressing gamification connected with health professionals	• Articles that did not address musculoskeletal work-related disorders • Did not target primarily musculoskeletal disorders • Involved patients/e-sports players • Injuries connected with excessive computer usage • Articles addressing other types of medical disorders • Not written in English

2.2 Results

This section, describes the main achieved results, regarding the formal characteristics of the selected articles, and the category identification and relationships between determinants.

Table 2.2: Results of literature review

ID	Authors, (year), Country	Methodology	Aim	Participants	Limitations
[18] A1	Linda Nice Gama, Cláudia Mara de Melo Tavares (2019), Brazil	Technological production study, following the phases of software engineering	Develop a multi-platform application for the prevention of musculoskeletal risk factors related to nursing work in a hospital unit and to evaluate the usability criteria with nurses and computer professionals.	Eight nurses and two information technology professionals participated in the study	Data such as images and videos require a greater consumption of data and devices, and may cause difficulties in the application.
[19]A2	José Nunes da Silva Filho, Jonas Lírio Gurgel, Flávia Porto (2020), Brazil	This is a randomized controlled parallel experiment	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.

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Table 2.2 Continued from previous page

ID	Authors, (Year), Country	Methodology	Aim	Participants	Limitations
[20]A3	Pront, Leeanne; Müller, Amanda; Koschade, Adam; Hutton, Alison (2018), Australia	A comprehensive search of electronic databases was conducted, followed by a thematic analysis of the literature.	N/A: Literature Review	The aim of this research was to investigate video game-based learning in nursing education and establish how video games are currently employed and how they link to the development of decision-making, motivation, and other benefits.	Many of the reviewed studies had limited samples and were contextually specific, limiting their generalizability. The majority of research was conducted in affluent countries, hindering its relevance to low-income settings. Furthermore, different definitions of gaming, combined with a diverse range of game types, complicated comparisons across studies, thus inhibiting conclusive determinations on the efficacy of educational gaming for nursing students' benefit.

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Table 2.2 Continued from previous page

ID	Authors, (Year), Country	Methodology	Aim	Participants	Limitations
[21]A4	Maria Sisto, Mohsen Zare, Nabil Ouerhani, Christophe Bolinhas, Margaux Divernois, Bernard Mignot, Jean-Claude Sagot, and Stéphane Gobron1 (2018), France	The methodology is a combination of the development of an app and evaluation.	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.	The participants in this study were 20 healthy adults who were recruited from a university community. The participants were required to have no history of MSDs and no current physical limitations that would prevent them from using the VR equipment for this purpose.	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 MSD prevention.

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Table 2.2 Continued from previous page

ID	Authors, (Year), Country	Methodology	Aim	Participants	Limitations
[22]A5	Anastasios Petropoulos, Dimitrios Sikeridis and Theodore Anton-akopoulos (2020), Greece	Development of a wearable device that incorporates IMU sensors and testing it on a group of participants to evaluate its effectiveness in detecting and correcting poor posture.	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 in real-time.	10 adults between the ages of 18 and 50 from a university community. The participants wore the wearable device for a period of time and were evaluated on their posture and the accuracy of the device.	It's highlighted three limitations of this study. First a small sample size, secondly a limited population of healthy adults, and, finally, a short evaluation period. These limitations make it difficult to draw definitive conclusions about the device's effectiveness in detecting and correcting poor posture, particularly in populations with pre-existing musculoskeletal conditions or over a longer period of time.

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Table 2.2 Continued from previous page

ID	Authors, (Year), Country	Methodology	Aim	Participants	Limitations
[23]A6	Andrea Ferrone, Christopher Napier and Carlo Menon (2021), Canada	Online survey of healthcare workers with low back pain. The survey collected data on the participants' demographics, work history, pain level, and technology use.	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, including nurses, physicians, and therapists. The participants ranged in age from 20 to 65 years old and had a mix of acute and chronic low back pain.	The limitations of this study include the reliance on self-reported data, limited generalizability to other populations with low back pain, and a lack of evaluation of specific wearable technologies. Additionally, potential barriers to the adoption of wearable technology among healthcare workers were not addressed.

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Table 2.2 Continued from previous page

ID	Authors, (Year), Country	Methodology	Aim	Participants	Limitations
[24] A7	Armando David Sousa, Cristina Lavareda Baixinho, Maria Helena Presado, Maria Adriana Henriques (2023), Portugal	Systematic review of 12 studies	Examine the effectiveness of interventions in preventing musculoskeletal injuries related to nursing work	N/A: Literature Review	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.

2.2.1 Outcomes

Adding to this general description of each one of the articles selected, I would like to highlight the outcomes of each one.

- A1: The application was developed based on scientific evidence and was designed to help nursing professionals prevent musculoskeletal risks through self-monitoring, education, and the provision of ergonomic guidelines. The evaluation of the application's effectiveness involved a randomized controlled trial with 30 nursing professionals, which showed significant improvement in the intervention group in terms of pain intensity, disability, and quality of life, as compared to the control group. The study suggests that the mobile application could be an effective tool for preventing musculoskeletal risks in nursing work.

- A2: Study showed that there was a significant reduction in musculoskeletal pain in the experimental group that performed stretching exercises compared to the control group. The study suggests that incorporating stretching exercises as a routine practice in the work environment can help prevent and reduce musculoskeletal pain in nursing professionals. Stretching exercises can be an effective and low-cost intervention to prevent and reduce musculoskeletal pain in healthcare workers.

- A3: In recent years, making use of gaming to augment nursing education has garnered rising interest from educators, who are looking for more means to heighten the learning atmosphere and better prepare scholars for clinical practices that take place outside the classroom. This text aims to provide a comprehensive insight on the current studies revolving around gaming in nursing instruction and determining the potential pros and opportunities connected to its activation. The examination ascertained that gaming can vigorously boost nursing pedagogy by establishing an uncritical and fascinating learning atmosphere allowing learners to rehearse clinical aptitudes through processes such as serious or educational games and virtual patient models which can be particularly beneficial when crafting reasoning abilities. Additionally, game-based training bolsters interprofessional communication and collaboration among health discipline students. Nevertheless, while employing gaming into nursing instruction demands intense contemplation of functionality, availability and pedagogic worthiness of specific games ensuring they're available regardless of pupils technology backgrounds or capacities. Consequently, this texts proposes that gaming can certainly fortify nursing tuition offering an exciting and particular learning opportunity. However, further investigations need to take place to completely fathom the consequence of gaming in nursing guidance and recognize the most ideal methods for putting it into action. It is only with scrupulous organization in addition to consideration that gaming can turn out to be a precious asset for nursing teachers when getting ready for the succeeding healthcare generation.

- A4: The article discusses the creation and assessment of a virtual reality serious game intended to reduce the risk of musculoskeletal illnesses (MSDs) at work. In many industries, especially those that require repetitive or difficult actions, MSDs are a widespread and expensive problem. The prevention game was created as a low-cost and entertaining approach to MSD prevention. The game simulates work-related duties and movements that can result in MSDs by utilizing virtual reality technology. Motion-sensing controllers are used by players to complete activities while receiving feedback on their posture and movements. The game encourages players to develop healthy work habits and provides instructional material on MSD prevention. The paper details the game's evaluation with 35 players representing a range of sectors. In order to gauge the players' understanding of MSD prevention and their opinions on the game, pre- and post-game surveys were administered to them before and after the 30-minute game. The evaluation revealed that the game was successful in raising players' awareness of MSD prevention and in encouraging favorable attitudes toward establishing healthy work practices. Participants said they would be willing to play the game again since it was interesting and fun. The authors come to the conclusion that further research should be done on virtual reality serious games as a low-cost and efficient method of MSD prevention in the workplace. Overall, the study shows how virtual reality serious games can be used as a technique to reduce musculoskeletal diseases at work. It was discovered that the "Preventure" game was fun to play, useful for enhancing knowledge, and helpful for fostering favorable attitudes toward healthy work practices. According to the findings, MSD prevention programs across multiple industries may benefit from the inclusion of virtual reality serious games.

- A5: The creation and assessment of a wearable smart health adviser using inertial measurement units (IMUs) to track posture and give users feedback are discussed in the study. Poor posture is a prevalent issue that can result in a number of health concerns, such as respiratory conditions and musculoskeletal ailments. The wearable device seeks to offer a cheap and practical alternative for posture correction and monitoring. The system is made up of a number of IMUs that are fastened to the user's body in order to track the orientation and movement of various body parts. A microcontroller processes the IMU data before sending it to a smartphone application that gives the user feedback on their posture and movement habits. Overall, the study shows how wearable smart health advisors can encourage good behavior and guard against problems with posture-related health. The IMU-enabled posture monitor was found to be successful in raising participants' levels of posture awareness and encouraging healthy modifications to their movement and posture patterns. The results imply that wearable gadgets that make use of IMUs might be a useful addition to programs for posture monitoring and correction.

- A6: In order to determine their technology requirements for the prevention and management of low back pain, a survey of healthcare professionals was undertaken, the findings of which are presented in this study. Since healthcare professionals are frequently required to perform physically demanding tasks, low back pain is a common issue for them. Wearable technology has the ability to help people become more aware of their own posture and movement patterns as well as give them advice on how to avoid and treat low back pain. 134 healthcare professionals, including nurses, physical therapists, and other specialists, responded to the poll. The participants were questioned regarding their knowledge of wearable technology for posture monitoring, their awareness of low back discomfort, and their preferences for a wearable device's characteristics. According to the poll, 69% of healthcare workers reported having low back discomfort at some point in the past or present. 80% of the participants said they would be interested in utilizing a wearable device for posture monitoring, showing that most of them were aware of the potential advantages of wearable technology for this purpose. The wearable technology that offers input on posture and movement habits, is easy to wear, and has a long battery life is preferred by the participants. They also stressed the significance of wearable technology's data security and privacy. The authors draw the conclusion that wearable technology has enormous potential for raising low back pain awareness among healthcare professionals and encouraging good exercise habits.

However, the creation of wearable technology that satisfies the requirements and tastes of healthcare professionals necessitates careful consideration of elements like comfort, battery life, and privacy. Overall, the paper emphasizes the potential of wearable technology for healthcare workers to prevent and treat low back pain. According to the survey, low back discomfort is very common among healthcare professionals, and they are usually aware of the potential advantages of wearable technology for posture monitoring. The results imply that wearable gadgets that are secure, pleasant, and provide input on posture and movement patterns could be an important improvement in low back pain prevention and management programs in the healthcare industry.

- A7: The outcomes of the study demonstrated that interventions such as exercise programs, education and training, ergonomic interventions, and organizational changes can be effective in preventing or reducing musculoskeletal injuries related to nursing work.The study also highlighted the importance of a multidisciplinary approach to preventing musculoskeletal injuries, recognizing that interventions need to involve different healthcare professionals such as occupational therapists, physiotherapists, and ergonomic experts. Furthermore, the study emphasized the need to tailor interventions to the specific needs of different nursing specialties, acknowledging that nursing work can vary across different settings and specialties. In conclusion that interventions can be effective in preventing musculoskeletal injuries related to nursing work, but more research is needed to determine the optimal intervention strategies for different nursing specialties and settings. The heterogeneity of the interventions and outcome measures across the studies was recognized as a limitation, making it challenging to compare the results. Nevertheless, the study's findings are relevant for healthcare professionals and organizations to implement effective interventions to prevent and reduce musculoskeletal injuries related to nursing work, improving the health and well-being of nursing professionals.

2.3 Discussion

This systematic review aimed to explore the prevalence of musculoskeletal disorders in healthcare professionals, 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.

2.3.1 Effectiveness

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 [18] 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 [19] as a regular practice in the workplace is a cheap and efficient strategy for nursing workers to lessen musculoskeletal pain.

The application of instructional games to nursing instruction is another potential strategy. According to the review, using different game formats can help practice clinical skills in interesting learning contexts. It has been demonstrated that this game-based training enhances interprofessional communication and cooperation. [20]

In addition, virtual reality serious games, like the prevention game [21], have shown promise as a cheap and efficient way to prevent MSDs in the workplace. These games can increase players' understanding of MSD prevention and build good attitudes toward healthy work practices by imitating work-related tasks and movements that can cause MSDs.

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 (IMUs)[22]. These gadgets can be useful tools for enhancing musculoskeletal health by increasing users' awareness of their posture and encouraging beneficial alterations to their movement and posture patterns. Wearable technology has been found to provide benefits in the treatment of low back pain.

Wearable technology has been highlighted as having potential advantages for medical professionals in the setting of low back pain. [23] According to the survey's findings, medical practitioners 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. [24] Those strategies can be integrated into a mobile app.

2.3.2 Challenges and limitations

The challenges and limitations in preventing work-related musculoskeletal disorders (WMSDs) in health professionals and the effectiveness of using mobile apps with gamification can be further elaborated as follows:

a) Data consumption and device compatibility [18]: Mobile applications that use images and videos to demonstrate physical exercises can require advanced devices with more data than accessibility allows. To cater to users of varying capabilities and data plans, optimizing app content delivery becomes necessary.

b) Placebo effect [19]: The placebo effect, for example, in stretching exercises [19] is unpredictable, it poses a challenge in concluding their effectiveness in reducing musculoskeletal pain. Effective control groups and blinding procedures in intervention studies play an important role in overcoming this limitation.

c) Generalizability [20] [21] [22] [23] [24]: Several studies reviewed were limited in sample size, conducted in affluent countries or within specific contexts, undermining generalizability.

Moreover, factors like different game types, discordant outcome measures, and intervention measures create further comparison complexities. A need for research in diverse settings with standardized definitions and larger sample sizes arises to properly assess interventions that counter WMSDs among health professionals.

d) Lack of Comparison [21] [22]: With certain virtual reality gaming interventions being evaluated with either a small population or during single sessions, questions arise on its extended effectiveness over long periods or if used by patients with existing bone-muscle problems. In certain cases where alternative preventive methods to tackle WMSDs are not compared effectively, more research into comparisons between intervention strategies must occur.

e) Self-Reported Data [23] and Barriers to Adoption: Biases may emerge as self-reported data was given credibility in some studies pertaining to wearable technology adoption and its relation to healthcare workers. Possible hindrances towards accommodating wearables in posture monitoring projects or enacting programmes against low back pain- such as privacy issues, feasibility concerns or expenses- did not come under scrutiny but should be included in all future evaluations relating to these matters.

f) Cost-Effectiveness and Sustainability [24]: Studies discussed were not thorough enough regarding cost-effectiveness or sustainability judgments related to said interventions taken over longer time frames. These findings may not be applicable for real-world settings since institutions of medical care must evolve from informed decisions regarding WMSDs prevention resources. Hence, more extensive studies measuring long-term cost-efficiency should occur for curbing nursing work-related musculoskeletal injuries.

2.3.3 Potential

The various strategies covered in the papers chosen for the systematic review illustrate the broad potential of technology in preventing musculoskeletal injuries among healthcare personnel. Each intervention has special benefits that, when combined, customised 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 [18] redefine how nursing professionals approach the prevention of musculoskeletal problems. In addition, wearable technologies with an emphasis on preventing low back pain [23] and IMUs [22] 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 [21] and educational gaming [20] 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, VR serious 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.

Stretching exercises [19] are a straightforward intervention that can effectively treat musculoskeletal pain for a minimal cost. This intervention has the potential to be widely used in a variety of healthcare settings and can be tailored to the needs of healthcare professionals with various expertise and backgrounds. 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 [24] 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.

2.3.4 Further research and development

The systematic 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.

Investigating the incorporation of more individualised features in mobile applications, such as specialised 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 [18]. 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 gaming [20] and virtual reality serious games [21]. 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 behaviour 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 IMUs [22] or aimed at preventing back pain [23]. 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 [19], 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, additional studies should concentrate on developing and assessing multidisciplinary approaches [24] to prevent musculoskeletal injuries, including figuring out the best mix of interventions for various nursing specialties and settings as well as evaluating their cost-effectiveness and sustainability over time.

The prevention and treatment of musculoskeletal injuries among healthcare professionals could be revolutionized by upcoming research and development in gamification, wearables, mobile applications, and other technology areas. Future research can pave the way for more efficient, accessible, and individualised therapies that cater to the distinct needs of healthcare professionals across various specialisations and contexts by combining and building upon the findings of the selected publications in this systematic review.

2.4 Summary

The systematic review's conclusion emphasises how critical it is to address the widespread problem of musculoskeletal disorders (MSDs) among healthcare professionals. Despite considerable progress in the field of digital health solutions, the challenge of MSDs remains widespread and critical. These problems must be prevented and managed in a novel, multidisciplinary manner beyond conventional practises.

The panorama of digital health solutions now on the market offers a variety of promising tactics. Self-monitoring, ergonomic guidance, and mobile informational applications have been shown to enhance quality of life and reduce pain levels among medical workers. Adding regular stretching exercises to the workplace has also been found to be a cheap, efficient strategy to lessen musculoskeletal discomfort. By fostering a better awareness of and encouraging safe work practises, serious games have also been proven to be good tools for preventing musculoskeletal injuries.

In addition, wearable technology that encourages good posture provides a workable option for in-the-moment posture monitoring and correction, making a substantial contribution to preventing low back pain, one of the common problems afflicting healthcare workers. While these existing solutions have shown promise, the review also reveals several difficulties and restrictions that warrant further exploration.

Current challenges include issues with data consumption, device compatibility, the generalizability of outcomes, the placebo effect, motivation, biases in self-reported data, and long-term cost-effectiveness. The ability of these interventions to offer personalised capabilities, applicability across various groups and environments, comfort, and data security are areas that require more focus. In addition, determining the most effective combination of interventions for various nursing specialties remains an open question.

Future research and development should concentrate on addressing these challenges. Efforts must be put into carrying out exhaustive, sizable studies that can attest to the treatments' durability, scalability, cost-effectiveness, and sustainability. A few of the issues that need to be addressed include enhancing the personalised features of mobile applications, expanding the applicability of game-based learning to different groups and environments, improving the comfort and data security of wearable devices, and determining the ideal combination of interventions for different nursing specialties.

Finally, the adoption and continuous use of these technologies in the healthcare industry present substantial prospects for the rapid, simple, and tailored management of musculoskeletal issues among healthcare practitioners. The results of this systematic study significantly support the expansion of these techniques to provide a risk-free and healthy working environment for our vital healthcare workers.

Chapter 3

Methodology

The approach taken for addressing the challenges in musculoskeletal disorder (MSD) prevention is described in this chapter. A user-centric strategy was used, concentrating on the requirements and practical knowledge of healthcare professionals, as shown in Figure 3.1 literature review, requirements elicitation, iterative development, usability testing, and discussion of the research findings and the possibility for future developments in MSDs prevention were all part of the process. The goal was to develop a useful tool that lowers MSDs among healthcare workers by incorporating user feedback and continuously refining the solution.

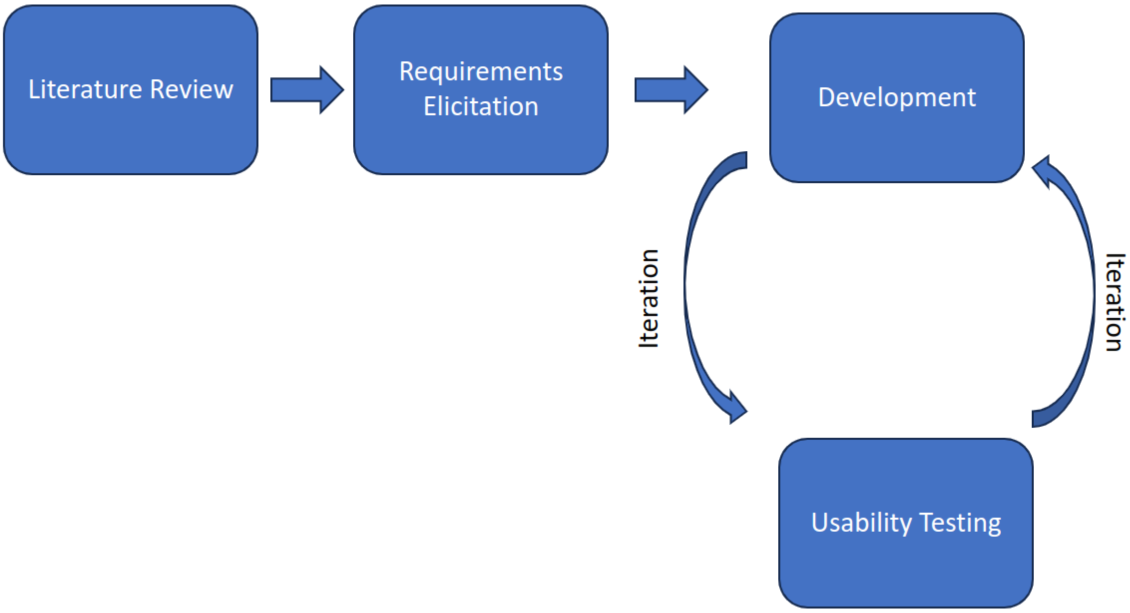

Figure 3.1: User-centred methodology used.

This methodology was chosen because it places a strong emphasis on the end user's needs, behaviours, and experiences—all of which are essential to the creation of an efficient and useful solution.

The users of the proposed mobile application and wearable device are healthcare professionals, who encounter particular obstacles and limitations at work. A user-centric approach to product development makes the development process sympathetic to these unique situations, resulting in a finished product that is suited to their needs, simple to use, and successful in reducing musculoskeletal disorders (MSDs).

This methodology also enables iterative design and enhancements depending on input from and experiences with users. This iterative cycle aids in continuously improving the solution and ensuring that it is in line with user requirements and expectations. The usefulness and acceptance rate of the suggested solutions might be considerably increased by this continuous feedback loop, which would increase their potential influence on lowering MSDs among healthcare professionals.

By including users in the development process, ensuring that their needs are satisfied, and eventually creating a solution that is more likely to be adopted and effectively used over time.

3.1 Literature Review

As a vital first step in this study, a systematic review was undertaken to evaluate completely what is known about musculoskeletal diseases (MSDs) among healthcare professionals. The systematic review sought to glean important information regarding the prevalence of MSDs, current preventive methods, and the contribution of digital health solutions to these issues.

A thorough search of pertinent literature from reliable databases and journals was part of the systematic review's strict methodology. The main goal was to develop a thorough understanding of the complex nature of MSDs in the healthcare sector and to spot any gaps or chances for novel solutions.

The conclusion of the systematic review underscored the critical importance of addressing the widespread problem of MSDs among healthcare professionals. Despite advancements in digital health solutions, the challenge of MSDs remains pervasive and demands novel, multidisciplinary approaches beyond conventional practices.

The systematic review served as a foundation for understanding the broader context and laying the groundwork for this study. By comprehensively analyzing existing research, it provided valuable insights into the user's needs, behaviours, and experiences in relation to MSDs prevention and management.

The following steps of the research process, such as user research, ideation, tool and architecture selection, iterative development, and usability testing, were guided by the findings from the systematic review. This study utilised a user-centric approach by incorporating the knowledge from the literature review, ensuring that the solutions developed meet the unique needs of healthcare professionals.

Overall, the systematic review was essential in influencing this study's methodology and strategy. It gave a thorough awareness of the current situation and acted as a springboard for the creation of creative ideas to lessen the effect of MSDs on healthcare personnel.

3.2 Requirements Elicitation

An important part of this study's user research phase aims to identify the unique requirements of healthcare professionals in the prevention of musculoskeletal disorders (MSDs). Adding to the previous step of the systematic review, through structured one-on-one interviews, important information was gleaned about the current preventive measures taken by healthcare professionals, the difficulties they faced, the prevalence of MSDs cases, and the potential use of technology to address these issues. The interviews, which the researcher personally conducted, enabled a thorough examination of participants' experiences and viewpoints, assuring consistency and usefulness in data gathering.

A thorough analysis of the data revealed common themes and important discoveries that helped to deepen the awareness of the demands and difficulties faced by healthcare professionals in the field of MSDs prevention.

The results of the interviews offered insightful information about the demands and difficulties facing medical practitioners in MSDs prevention. The aim was to find creative responses that may successfully meet these needs, in order to produce ideas and concepts that could align with the determined requirements. With this information, the requirements for the mobile application development were defined.

In addition, the interviews revealed a distinct demand for real-time position monitoring that had not been thought of before. As a result, the requirements elicitation phase was extended to encompass the investigation of the feasibility of incorporating real-time position tracking technology in the wearable device proof of concept.

Technical viability, practicality, and connection with the study objectives were taken into account throughout the requirements elicitation phase. The emphasis was on defining the requirements that would address the needs of the users and guide the development process.

The established criteria and requirements played a crucial role in directing the development process' later stages. They provided a framework for the implementation, design, and assessment of the concept.

The results of the interviews and the requirements elicitation process will be thoroughly discussed and analysed in Chapter 4, providing insight into how they may affect the creation of the wearable technology and mobile application. The research aims to deliver targeted and efficient solutions in MSDs prevention, thereby boosting healthcare professionals' well-being and quality of life by embracing their viewpoints and experiences.

3.3 Development

Choosing the right tools and creating a sturdy architecture are essential factors to consider while creating a mobile application and the proof of concept of the wearable device. The procedure used to select the best tools and establish the architecture for these solutions is described in this subsection.

A thorough assessment of the available tools and technologies was carried out to guarantee the mobile application's effective creation and best performance. During this selection process, factors like usability, performance, scalability, and compatibility with the planned functionalities were carefully considered. The tools picked were meant to facilitate a smooth user experience while allowing for future maintenance and enhancements.

Likewise, a careful assessment of tools and technologies was made for the proof-of-concept wearable device. Compatibility with the intended functionalities, implementation viability, and possibility for integration with the mobile application was given priority in the selection process. The main objective was to find tools and technologies to efficiently support the real-time position tracking functionality and fit the project's goals and available resources.

Both the mobile application and the wearable device were developed with efficiency, scalability, and the potential for future improvements by carefully choosing the right tools and creating a solid architecture. The implementation and assessment of these solutions will be covered in more detail in Chapter 5 and Chapter 6, respectively, showing how the chosen architecture and tools aided in achieving the thesis' goals.

Mobile Application

A tailored development process was used to create this mobile application. Due to the individualized nature of the project, a modified Agile approach was used to support the development process and fit with the goals of this master thesis.

The chosen approach embraced adaptability, incremental growth, and continuous improvement, which also made the required modifications to fit this environment. Due to this, several Agile techniques, such as stand-ups and sprint review meetings, were not relevant; nonetheless, the core ideas of Agile were still applied to improve the development process.

The methodology emphasized iterative development, combining feedback loops and regular self-evaluation to promote ongoing mobile app improvement. The development process was divided into several iterations, each with a specific time limit and focused on a particular set of goals and deliverables. These iterations served as checkpoints to monitor development and guarantee a well-organized workflow.

To acquire insightful information and guarantee alignment with user needs, constant communication and engagement with domain experts, like my supervisors and healthcare professionals, were maintained throughout the development process. These inputs were vital in helping to prioritize features that addressed their particular problems with preventing musculoskeletal injuries and informing development decisions.

A flexible strategy was also used to respond to changing requirements and incorporate improvements based on user and professional feedback. This made it possible for the application to advance and get better with each iteration.

Wearable Device

The wearable device was developed as a proof of concept to provide real-time posture tracking. The development process involved careful considerations at both the hardware and algorithmic levels.

A microcontroller with integrated WiFi was selected for the hardware layer since it was compatible with the needed sensors and could enable real-time data transmission. This hardware was chosen with consideration for variables including adaptability, power effectiveness, and connectivity possibilities.

Planning and design, coding and implementation, testing and improvement were all parts of the development process. The project scope and system architecture were developed during the planning and design phase. Programming the hardware and developing the required features for the mobile application were tasks of the coding and implementation phase. Testing and improvement were carried out to guarantee the reliability of posture detection and the wearable device's overall functionality.

The creation of the wearable device demonstrated the feasibility of real-time posture tracking as a proof of concept. It paved the way for upcoming advancements and improvements while offering insightful information on the demands of medical professionals.

3.4 Usability Testing

A key phase in the creation of the mobile application was usability testing, which evaluated the app's functionality and user experience. A panel of medical experts, including physiotherapists and nurses, took part in the testing procedure to offer insightful feedback.

Participants interacted with the mobile application during the testing process and undertook a series of tasks that covered various features and functionalities. These tasks were thoughtfully created to reflect common user challenges and circumstances. The app's features were made available to participants so they could explore them.

Participants were invited to think aloud, express their opinions, and discuss any challenges they had while completing the activities throughout the testing sessions. This made it possible to receive real-time feedback and gave crucial information about the application's usability and user experience.

A more quantitative part of the exam was created by asking participants to rate how simple they thought each task was to complete. From the participants' point of view, this metric gave an overall evaluation of the application's utility.

The testing procedure produced valuable qualitative and quantitative data, and Chapter 7 will give a more thorough and complete examination of the usability testing procedure, participant feedback, and the findings attained. This chapter will go into the particular conclusions, highlight significant observations, and offer practical advice for enhancing and honing the mobile application.

3.5 Discussion

An extensive examination and explanation of the research findings are provided in the discussion section. The key conclusions are outlined, along with the study's advantages and disadvantages, and some future research topics are suggested. The purpose of this section is to give a thorough knowledge of the ramifications and importance of the project's results. The discussion portion advances current research in the field and lays the way for additional progress by critically analysing the findings and taking their wider implications into account.

3.6 Summary

The methodology section of this thesis describes a user-centric strategy to solve the issues with MSDs prevention. A customised solution was created after user research revealed the particular requirements of healthcare workers. Real-time position monitoring was one of the creative thoughts that emerged from the ideation phase. To enable the successful development of the wearable gadget and mobile application, tools and architecture were carefully chosen. Following an iterative methodology, domain experts were included in the development process and their feedback was taken into consideration. The usability testing produced insightful recommendations for ways to improve the solution. Overall, this approach lays the groundwork for developing solutions that significantly lower MSDs among medical personnel.

Chapter 4

Requirements Elicitation

The specifications for a preventative mobile application and wearable created especially for healthcare practitioners are described in this chapter. The findings are based on discussions with eleven healthcare workers with varied degrees of expertise, and they offer important new information about the standards for musculoskeletal injury prevention in healthcare settings.

The most common musculoskeletal injuries and their causes are covered first, and then the issues and current preventative measures used in healthcare settings are explored. After examining potential user engagement tactics and overcoming any adoption barriers, we then go into the desired features of the mobile application.

An overview of the interview results is given, and solutions to these issues are suggested. By using a user-centric approach and taking healthcare professionals' demands into account, the mobile application and wearable device's efficacy and usability are intended to be improved.

It is ensured that the expectations of healthcare professionals are met and that the difficulties of musculoskeletal injury prevention in healthcare settings are successfully handled in the final solution by using this structured approach and taking into account their observations.

4.1 Interviews

In order to obtain thorough and detailed information from a varied set of healthcare professionals, including nurses and physiotherapists, structured interviewing techniques were used. For the purpose of reducing work-related musculoskeletal injuries, 11 participants who met the criteria to be potential users of the mobile application participated in the interviews. This diversified group brought with them a range of years of expertise in their different fields, offering insightful information about the demands and difficulties involved with musculoskeletal injury prevention in healthcare settings (the interview questions are in Appendix A.1).

The interviews were held both physically and remotely through the use of *Google Meets*, enabling simple and adaptable participation regardless of participants' availability or location. These interviews' audio sessions were taped to make transcribing and analysis easier.

Participants had plenty of time to voice their ideas and elaborate on their experiences throughout the 30-minute interview sessions, which were usual. To ensure a thorough grasp of the challenges they confront with musculoskeletal injuries in their work environment, participants were urged to submit honest and thorough remarks.

These interviews provided a priceless chance to gather qualitative information and fully comprehend the participants' experiences. In order to ensure that the final solution takes into account the particular needs and preferences of healthcare professionals in preventing work-related musculoskeletal disorders (WRMSDs), the information gathered from these interviews served as a foundation for developing the specifications for the mobile application and wearable device.

4.2 Participants Characterization

The participants in the interviews included nurses and physiotherapists with varying years of experience in their respective fields. Table 4.1 provides an overview of the participants' characteristics.

Table 4.1: Interview Participants' Characteristics

Participant	Age (years)	Years of Experience	Profession
1	65	44	Nurse
2	22	1	Nurse
3	28	6	Nurse
4	42	19	Nurse
5	38	16	Nurse
6	37	15	Nurse
7	32	9	Nurse
8	29	7	Nurse
9	30	8	Nurse
10	24	1	Physiotherapist
11	24	3	Physiotherapist

4.3 Analysis and Discussion

4.3.1 Problem Identification

The participants were asked about the most common musculoskeletal injuries they or their colleagues experience in their work environment. The reported injuries included low back pain, cervical pain, spinal injuries, wrist and hand injuries and contractures. These injuries were reported with a frequency rating of to 10 on a scale of 1-10, indicating a significant occurrence in the healthcare professionals' daily work routines.

Figure 4.1 presents a pie chart illustrating the distribution of reported musculoskeletal injuries.

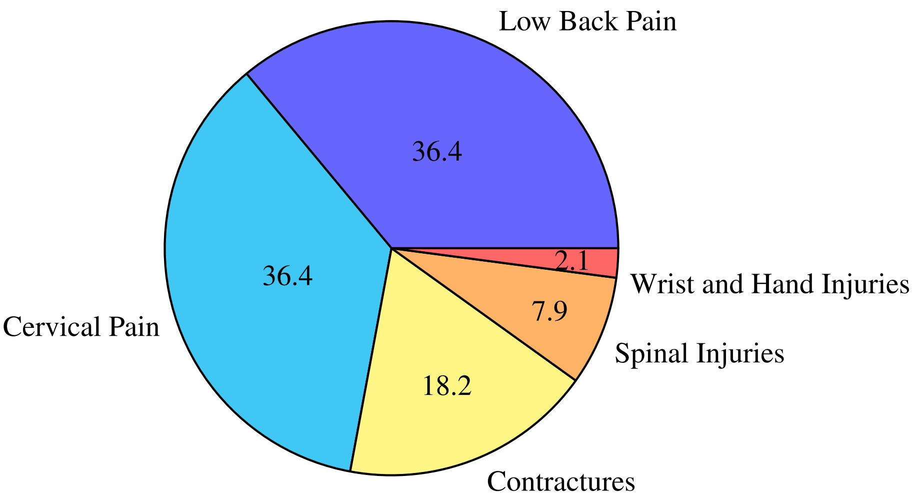

Figure 4.1: Distribution of reported musculoskeletal injuries.

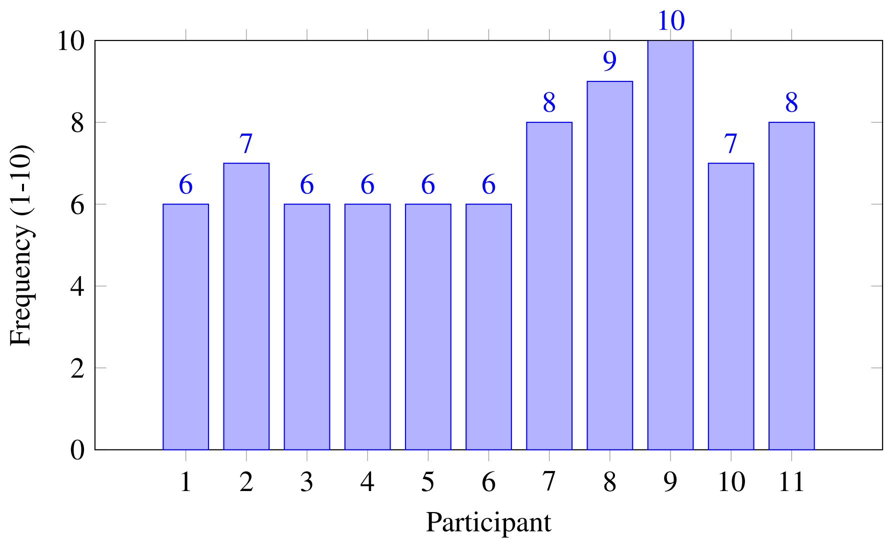

Figure 4.2: Frequency of musculoskeletal injuries reported by participants.

Participants identified several factors when discussing the reasons behind the high frequency of these injuries. One common reason was the lack of proper warnings or reminders about maintaining correct posture and ergonomics during work-related tasks. Participants emphasized that the absence of timely alerts or notifications regarding incorrect postures and movements contributes to the occurrence of musculoskeletal injuries.

Furthermore, participants highlighted that excessive workload and a lack of sufficient human resources in the healthcare setting further exacerbate the risk of musculoskeletal injuries. The demanding nature of their work, including frequent patient transfers and performing tasks that require physical exertion, contributes to an increased likelihood of developing these injuries. Additionally, participants expressed a need for more extensive ergonomic training and education to improve their awareness and knowledge about injury prevention techniques.

In conclusion, the interviews revealed that healthcare professionals face various musculoskeletal injuries, including low back pain, cervical pain, spinal injuries, and contractures, with a significant frequency. The primary factors contributing to these injuries were the lack of warnings, insufficient resources (human and material), and lack of frequent ergonomic training. Addressing these problems and implementing effective preventive measures can significantly reduce the risk of musculoskeletal injuries among healthcare professionals.

Current Techniques

Participants were questioned about their present methods to get insight into the tactics used by health professionals to prevent musculoskeletal injuries in their working environments. The responses from the participants are described in the next section:

Participants disclosed using a range of methods and tactics to avoid musculoskeletal injuries. Among these tactics were:

- **Posture and Positioning**: Many participants emphasized the importance of maintaining correct posture and positioning during their work activities. They consciously tried to avoid improper lifting techniques, use supportive equipment, and position themselves ergonomically.
- **Physical Conditioning**: Several participants mentioned engaging in regular physical conditioning exercises. These exercises aim to strengthen their muscles, improve flexibility, and enhance overall physical fitness. Examples of activities include stretching, strength training, and cardiovascular exercises. Some of the participants also mentioned that they often go to osteopaths.
- **Education and Training**: Some participants mentioned receiving education and training on musculoskeletal injury prevention. They highlighted the value of understanding proper body mechanics, ergonomics, and safe work practices. Such training gave them the knowledge to make informed decisions and minimize injury risks.

The preventive measures healthcare practitioners take to reduce the risk of musculoskeletal injuries are reflected in the present procedures. However, participants also noted difficulties in putting these techniques into practice. These difficulties included a lack of resources, a high workload, and the requirement for ongoing reinforcement of appropriate methods and procedures.

The participant responses' insights offer important information for creating the wearable device and mobile application. The suggested approach can improve the prevention of musculoskeletal injuries among health professionals by resolving the stated obstacles and considering the participants' requirements.

Barriers to Self-Care

The participants offered insightful information about the challenges they encounter in putting self-care practises into practice. Their comments are summarised as follows:

1. Lack of awareness and reminders:
   - Increased knowledge and reminders regarding musculoskeletal injury prevention and excellent posture were mentioned by participants 1, 2, 3, 4, 5, and 7. Due to the pressures of their jobs, they said that health professionals frequently fail to maintain appropriate posture and advised that regular reminders or alerts would be helpful.
2. Limited resources and equipment:
   - Concerns were raised by participants 2, 3, 5, and 9 about the lack of tools and resources to support self-care habits. They stressed the need for ergonomic tools, adjustable furniture, and other supportive equipment to guarantee appropriate posture and avoid accidents.
3. Excessive workloads and time constraints:
   - Participants 1, 4, 5, 6, 7 and 8 reported time constraints and heavy workloads as major obstacles to self-care. They talked about how challenging it was to find dedicated time for breaks, workouts, or posture adjustment amidst the pressures of their line of work.
4. Lack of training and knowledge:
   - Participants 2, 3, 5, and 6 highlighted the demand for more education and training in ergonomics and good posture. They believed that medical practitioners frequently lacked the knowledge and abilities needed to maintain proper posture and avoid musculoskeletal injuries.
5. Convenience and forgetfulness:
   - Participants 6 and 8 brought up the propensity of health practitioners to ignore appropriate posture in favour of convenience. They recommended that a solution should be simple to use, incorporated into their daily routine, and offer prompt reminders to support people in regularly maintaining excellent posture.
6. Complexity and lack of motivation:
   - Participants 7, 8, and 11 expressed concern about a potential solution's complexity and likely opposition from medical experts to new technologies. They emphasised the significance of ease of use and simplicity to promote adoption and long-term motivation.
7. Absence of feedback and evaluation:
   - Participants 4 and 11 made particular note of the value of getting feedback and assessments of their posture and progress. They recommended adding gamification components, vibration feedback, and real-time notifications to the self-care system to boost motivation and promote frequent use.

By considering these identified barriers, the mobile application and wearable device development can address these challenges and provide effective solutions to support health professionals in practising self-care, maintaining proper posture, and preventing musculoskeletal injuries.

4.3.2 Mobile App Information Gathering

Motivation and Willingness to Use

The replies from the participants shed light on the variables affecting willingness and motivation to adopt a self-care solution in a healthcare context. These observations offer helpful guidance for developing an intervention that meets the requirements and preferences of healthcare professionals.

The participants emphasised the need for incentives and motivation to promote involvement with a self-care solution. They emphasised the requirement for unequivocal proof that the proposed remedy may effectively lower injuries and advance general understanding in the field of prevention. As a potential motivator, linking the self-care solution to the annual evaluation procedure for healthcare personnel was suggested because it might favourably affect career advancement within the healthcare facility.

The participants emphasised the necessity for broader availability of the self-care solution across multiple healthcare services regarding practical implementation. They proposed that easy access and utilisation would be facilitated by a comprehensive catalogue of available materials and resources. Furthermore, it was vital that the solution fit easily into the practice of healthcare professionals. Real-time alerts, feedback, and vibration-based reminders were proposed as motivating elements that could improve user comfort and convenience.

For maintaining engagement with the self-care solution, ongoing training and consistent reinforcement of correct posture and ergonomics were considered vital. In order to accommodate the hectic schedules of healthcare workers, the participants emphasised the importance of regular reminders and the necessity to maximise resource utilisation.

It was thought crucial to address potential adoption hindrances such aversion to new technologies and time restraints. The participants suggested a simple approach along with thorough training courses to address any potential difficulties. The solution should be simple to use and simple to incorporate into the daily activities of healthcare workers without introducing needless complexity or laborious duties.

The participants recommended adding gamification components to the self-care solution to boost motivation. To enhance the experience and make it more exciting and fun, this could include elements like levels, points, and awards. Furthermore, disseminating statistical data on the frequency and effects of injuries in the healthcare industry should promote awareness and emphasise the significance of self-care practices.

In conclusion, establishing an effective self-care programme for healthcare professionals necessitates careful consideration of several variables. Clear evidence of success, smooth integration into processes, workable implementation tactics, and adding gamification components can all boost motivation. Healthcare personnel are more likely to engage with the self-care solution and prioritise their well-being while providing high-quality treatment to patients if adoption barriers are addressed and ongoing training and reinforcement are provided.

Practicability

The practicability of the self-care solution was a fundamental aspect of this study, taking into consideration not only how the app and wearable device could be integrated into the daily routine of healthcare professionals but also the time commitment they could afford.

As depicted in Figure 4.3, the time participants were willing to allocate for the app ranged from 10 to 30 minutes daily. The majority of participants stated they could commit approximately 10 minutes daily. This time commitment variability highlights the importance of the app's design to be flexible and adaptive to accommodate different schedules and usage patterns among healthcare professionals.

Delving deeper into the results from Question 11, the participants indicated essential characteristics for the app to be practical. Real-time, non-disruptive feedback was emphasised, emphasising the necessity for the app to run in the background without interfering with users' work processes. Participants emphasised the significance of an easy-to-use interface that would enable them to interact with the app and comprehend the facts being displayed.

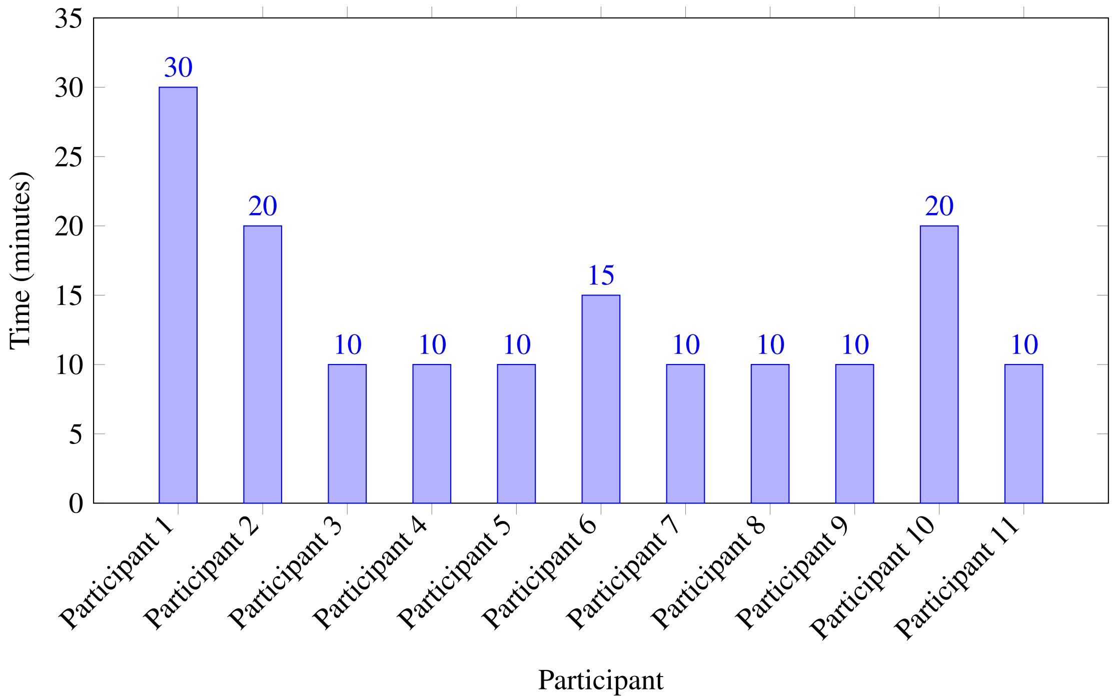

Figure 4.3: Time able to spend on the application per 8h shift.

Impediments to the Use of the Application

The participants mentioned potential barriers to using a mobile application during their work shift. When creating the app and guaranteeing its proper implementation, it is imperative to take these obstacles into account. The following provides a summary of the obstacles found and the solutions they brought about:

- **Lack of time**: Participants 2, 3, 5, 6, 7, 9, and 11 emphasised that not having enough time is a major barrier to using mobile applications. Their busy job schedules and responsibilities frequently leave little time for extracurricular activities. The app should be created with quick exercises and reminders that may be readily incorporated into users' everyday routines in order to overcome this difficulty.

- **Resistance to new technology**: Concerns regarding possible opposition to new technologies among healthcare workers were stated by participants 7, 8, and 10. To get over this problem, the app needs to have an easy-to-use user interface that makes it usable even for people who are not knowledgeable about technology.

- **Lack of internet access**: Participant 11 mentioned the lack of internet access in their work environment as a potential barrier to using a mobile application. To address this issue, the app should have offline functionality, allowing users to access and use it even without an internet connection. Data synchronization can be performed when an internet connection is available.

- **Complexity**: Concerns were raised by participants 6 and 8 regarding a mobile app's complexity and potential usage effects. The software should be made to be simple to use, with clear instructions and intuitive features, in order to allay this worry. Simpler interactions and a user-friendly design can promote adoption and regular use.

- **Lack of motivation**: Using a mobile app for self-care requires motivation, according to participants 7, 8, and 11. The software should include motivating features like gamification, prizes, and progress tracking to alleviate this problem. These features can add to the app's appeal and encourage users to continue using it frequently.

The mobile application can remove usage obstacles and encourage broad adoption among healthcare professionals by addressing these noted constraints and adopting the suggested remedies.

4.4 Requirements Definition

Based on the interviews conducted with healthcare professionals and the analysis of their responses, the following requirements are identified for the preventative mobile application and wearable device:

1. **Posture and Ergonomics Guidance**: The application should offer real-time guidance on maintaining correct posture and ergonomics during work-related tasks. It should provide visual and audio cues to alert users when their posture is incorrect and suggest corrective actions.

2. **Education and Training**: The application should incorporate educational materials and training modules on musculoskeletal injury prevention. It should provide healthcare professionals with the necessary knowledge and skills to maintain proper posture and perform tasks safely.

3. **Reminders and Alerts**: The application should send timely reminders and alerts to healthcare professionals to encourage them to practice self-care and maintain good posture throughout their work shifts. These reminders should be non-disruptive.

4. **Gamification and Motivation**: The application should incorporate gamification elements to make self-care activities engaging and motivating. This can include rewards, challenges, and progress tracking to encourage regular use and adherence to injury prevention practices.

5. **Offline Functionality**: The application should have offline functionalities to enable usage in environments with limited or no internet access. Data synchronization should occur when an internet connection is available.

6. **Simple and Intuitive User Interface**: The application should have a user-friendly interface that is easy to navigate and understand, even for users with limited technological proficiency. Clear instructions and intuitive features should be incorporated to facilitate ease of use.

7. **Compatibility with Wearable Device**: The application should be compatible with the wearable device to gather data on movement, posture, and physical activity. The wearable device should seamlessly integrate with the mobile application and provide accurate and real-time data.

8. **Posture Monitoring**: The application should provide the ability to monitor and report musculoskeletal injuries in real time. This includes capturing data on the type and severity of injuries, as well as the frequency of occurrence.

9. **Continuous Improvement and Updates**: The application should allow for continuous improvement and updates based on user feedback and evolving best practices. Regular updates should be provided to address any identified issues, enhance functionality, and incorporate new features.

By incorporating these requirements into the design and development of the mobile application and wearable device, healthcare professionals can benefit from an effective tool to prevent work-related musculoskeletal injuries and promote their overall well-being.

Chapter 5

Mobile App Development

This chapter starts with Section 5.1, which elicits and explains which tools were selected for this development process. All the processes related to the user interface design were given in Section 5.3. The developed interfaces and their functionalities are shown and described in Section 5.4. The final section, 5.5, gives an overview of all the tools used to maintain and ensure the quality of the user-experience.

5.1 Tools

Throughout the development process, various technologies were used to boost productivity and encourage quality control. Here are a few of the essential tools:

- **Visual Studio Code**: The coding was done using Visual Studio Code, an open-source code editor created by Microsoft. A number of languages are supported by it, including JavaScript, which was used to create the app with React Native. It had functions that greatly increased development efficiency, including code navigation, syntax highlighting, auto-completion, and debugging. Additionally, the abundance of extensions offered by Visual Studio Code enabled the editor to be customized for a more convenient programming experience.

- **React Native**: The mobile application was created using React Native, a JavaScript technology created by Facebook. It lowers the cost and duration of development by enabling developers to create applications for both iOS and Android using a single codebase.

- **Firebase**: The mobile application's backend was built using Google's Backend-as-a-Service Firebase technology. The real-time database, authentication, and cloud storage that were necessary for the mobile application are all provided.

- **Expo**: To improve the development procedure, Expo, a free and open-source toolset for React Native, was employed. It offers an abstraction layer on top of React Native that makes developing, testing, and deploying mobile applications easier.

- **Git and GitHub**: Git, a distributed version control system, and GitHub, a web-based hosting service for Git repositories, were used for version control and source code management. They helped keep track of code changes and enabled collaborative development.

- **Figma**: The user interface design of the mobile application was created using Figma, a web-based UI design and prototyping tool. Because of its collaborative capabilities, it was especially helpful for creating user interface prototypes for various application screens.

- **Jest**: The code for the application was tested using Jest, a JavaScript testing framework. It guarantees the consistency and accuracy of the code, avoiding any potential flaws or abnormalities.

5.2 Architecture

The mobile application's system architecture is based on a reliable and scalable design pattern. The architecture uses a client-server approach and combines well-known frameworks, database technologies, and design principles in order to provide a cross-platform, high-performance application that can scale to accommodate an increasing user base.

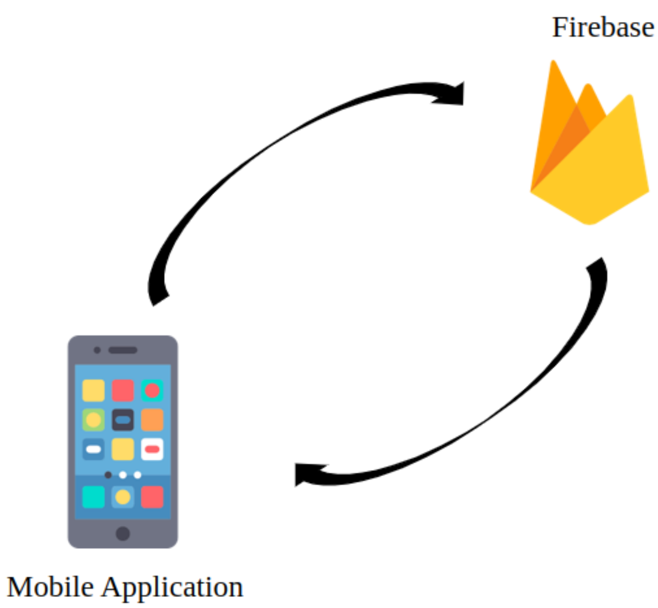

Figure 5.1: Architecture of the mobile application.

Mobile Application

React Native, a JavaScript-based framework that enables cross-platform app development, is the foundation of the strategy for creating this mobile application. This decision was made taking into account the following framework's main benefits:

- **Platform compatibility:** With a single codebase, React Native facilitates the development of apps for both iOS and Android, which significantly cuts down both the time and expense of development.
- **Native performance:** React Native's ability to utilize native components ensures improved performance, delivering a seamless and engaging user experience.
- **Developer-friendly:** Given the popularity of JavaScript, the primary language of React Native, there is an extensive ecosystem of tools, resources, and a large talent pool of skilled developers available, simplifying the development process.

Backend

The architecture employs a client-server model, using Firebase as the backend database, while the client operates on the user's mobile device. The choice of Firebase was motivated by several factors:

- **Intuitive interface:** Firebase provides a user-friendly interface that significantly lowers the learning curve for developers compared to alternatives like AWS, leading to faster development and deployment.
- **Scalability:** Firebase Firestore, a flexible NoSQL cloud database, offers automatic scalability, dynamically adjusting the database infrastructure as the user base expands.
- **Real-time data synchronization:** Firestore ensures real-time data synchronization across all user devices, a critical requirement for our app's instant data change and synchronization needs. Furthermore, Firebase's serverless cloud functions are utilized, eliminating the need for manual server management and scaling. The architecture is designed to automatically respond to changes in demand, which ensures sustained performance even under varying load conditions.
- **Cost-Effective Solution:** Firebase offers an economically viable solution for startups and small-scale applications. Its extensive free plan offers a range of services without any upfront costs, enabling the app to start on a small scale and scale up as the user base grows.
- **Privacy Regulations:** Firebase prioritises security and privacy, and it offers tools to assist developers comply with privacy laws. It provides solutions for controlling user permission, safeguarding sensitive data storage, and adhering to privacy laws including the General Data Protection Regulation (GDPR) and the California Consumer Privacy Act (CCPA). We can make sure that our application handles user data in a way that complies with privacy laws by utilising Firebase's built-in privacy capabilities.
- **Authentication Advantages:**Firebase offers a robust authentication system, allowing us to easily implement user authentication and authorization in our app. With Firebase Authentication, we can support various authentication methods. This simplifies the development

process and enhances the security of our app by handling user authentication securely and reliably.

- **Caching strategies:**To ensure quick and easy access to frequently queried data and to minimize costly database operations, the architecture employs advanced caching techniques. Firebase's Firestore benefits from a layered caching architecture, enabling efficient data retrieval and aiding application scalability in response to an expanding user base.

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5.3 User Interface Design

In order to create an aesthetically pleasing and user-friendly interface, the mobile app's user interface design adheres to accepted design standards and takes user experience into account. The following design principles and user experience criteria affected the UI design:

- Easy to Understand Navigation: The app's navigation is made to be simple to use and understand. With the aid of well-known patterns like buttons or bottom navigation bars, users can rapidly switch between screens. To guarantee seamless navigation, the positioning and labeling of navigation items adhere to best standards.

- Responsive Design: The UI design adjusts to various screen sizes and orientations. This guarantees a constant and perfect user experience on all kinds of gadgets, like smartphones and tablets. Adaptive layouts, scalable visuals, and adaptable UI components are examples of responsive design elements.

- Visual Hierarchy: To direct users' attention and prioritize information, the UI design uses visual hierarchy strategies. To capture users' attention and make it easier for them to do tasks, crucial features like call-to-action buttons, notifications, and critical material are visually accentuated.

- Minimalism & Simplicity [25]: The UI design uses a minimalist aesthetic, emphasizing clarity and simplicity. It avoids unnecessary visual clutter and gives priority to actions and information that are most important. With this simplicity, usability is improved and users' cognitive load is decreased.

- Consistency and Branding: The UI design upholds consistency throughout the app, making sure that the visual components, fonts, colors, and layout are in line with the branding and general aesthetic of the app. Consistent design components promote a consistent and recognizable user experience.

The user interface (UI) and user experience (UX) components are designed and implemented throughout the front-end development phase. For the app's users, the emphasis is on designing visually appealing interfaces, simple navigation, and frictionless interactions. The UI design is done in this React Native-based mobile application utilising JavaScript and JSX syntax, enabling cross-platform development.

The code snippet included in Appendix B demonstrates an example of how the UI components are implemented using React Native.

In the code, various React Native components such as `View`, `Text`, `Image`, `TouchableOpacity`, `CountdownCircleTimer`, and `Swiper` are utilized to create the desired user interface. The styles for each component are defined using the `StyleSheet.create` function to ensure consistent and cohesive styling.

Efforts were made during the development process to ensure that the UI design is adjustable to every screen using React Native's responsive design capabilities. React Native provides built-in features and techniques to achieve responsiveness that were used in this development, such as:

- Flexbox Layout: React Native utilizes a flexbox layout system, similar to CSS flexbox, to create flexible and responsive UI designs. It allows components to automatically adjust their sizes and positions based on available space.

- Percentage-based Sizing: React Native supports specifying dimensions using percentages, allowing components to scale proportionally to the screen size. This enables the UI to adapt seamlessly to different screen sizes and orientations.

- Device-specific Styling: React Native provides access to device-specific information, such as screen dimensions and pixel density, allowing developers to customize the UI based on the specific device being used. This ensures optimal rendering and usability on various devices.

By leveraging React Native's component library and the provided styling capabilities, it was possible to create a visually appealing and responsive user interface for the mobile application.

Brand Identity

Application Name and Logo

The application name and logo are fundamental elements of the brand identity. They serve as the first point of contact for users and play a significant role in shaping their perception of the mobile application.

The application name, *BodyBoost*, embodies the core purpose of the app: empowering health professionals to prevent musculoskeletal injuries and enhance their well-being. The name is concise, and conveys the app's focus on physical health and improvement.

Figure 5.2: *BodyBoost* logo.

The logo, as depicted in Figure 5.2, was created using Adobe Illustrator. It was carefully designed to visually represent the essence of BodyBoost, incorporating elements that symbolize strength, movement, and the musculoskeletal system. The use of Adobe Illustrator allowed for precise control over the design elements and ensured a high-quality and professional logo.

When using the logo, ensure that it is displayed prominently in the app's interface, marketing materials, and any other relevant touchpoints. Consistency in logo usage helps to establish brand recognition and reinforce the app's identity.

By combining the powerful application name, BodyBoost, with a visually appealing and professionally designed logo, you create a strong brand identity that reflects the app's purpose and resonates with health professionals.

Color Scheme

The chosen colour scheme for your mobile app consists of four main colours: blue, teal, crimson, and F6B04B. Each colour serves a specific purpose in conveying your app's brand identity and creating a visually appealing user interface.

- **Primary Color: Blue (5E8FBF)**

  Blue is a calming colour often associated with trust, dependability, and reliability. It has a soothing effect on users and can create a sense of security and comfort. In the context of a healthcare app, the colour blue is commonly used to convey professionalism and trustworthiness. By using blue as the primary colour, you establish a foundation of reliability and reliability for your app.

- **Secondary Color: Teal (5EBFBF)**

  Teal is a calming and refreshing colour that evokes feelings of balance, stability, and harmony. It complements the primary blue colour and adds a touch of vibrancy to the app's colour palette. Teal can help create a visually engaging and harmonious user interface. Its calming properties can also contribute to a sense of tranquillity and well-being for app users.

- **Accent Color: Crimson (C94277)**

  Crimson is an energetic and attention-grabbing colour that can be used sparingly as an accent colour within the app. As an accent colour, crimson draws attention to important elements or actions, creating visual interest and guiding users' focus. The use of crimson strategically can help highlight key features or calls-to-action, enhancing user engagement and interaction.

- **Additional Accent Color: Yellow Orange (F6B04B**

  Yellow Orange is a warm and vibrant colour that can be used as an additional accent colour within the app. It adds a pop of energy and excitement to the colour scheme, providing versatility and visual interest. This colour can be used to draw attention to specific elements or create visual contrast in the user interface.

By combining these colours, you may produce a vibrant and visually appealing colour scheme that strikes a balance between components that inspire confidence, tranquillity, brightness, and attention. This colour scheme creates a visually appealing and harmonious user experience and is in line with the goal of your programme. To retain a consistent and recognisable brand identity throughout your app's design aspects, keep in mind to use these hues consistently.

5.4 Features and Functionality

Onboarding

The onboarding screen sets the tone and piques the user's attention as their first encounter with the mobile app. Users are guided through the main features and advantages of the software through a carousel function that displays various panels during the onboarding process for emphBody-Boost. Users can become familiar with the operation of the app by seeing each screen in the carousel, which offers a visually appealing experience and precise information. Healthcare professionals can learn more about *BodyBoost* benefits for preventing musculoskeletal problems on each carousel screen. The different onboarding process screens are shown by the images in Figures 5.3, 5.4 and 5.5. It has a friendly greeting, pertinent images, instructive text, and call-to-action buttons, the "Login" and "Sign Up" buttons. These buttons smoothly direct users to the necessary screens for account creation or login, allowing users to continue.

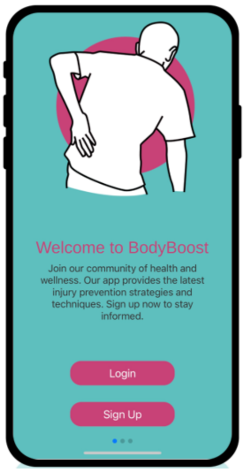

Figure 5.3: Onboarding screen: Welcome.

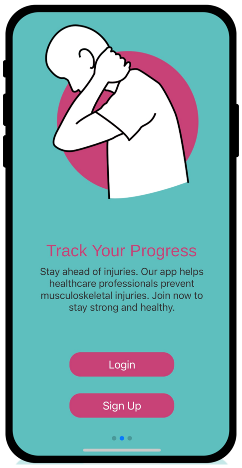

Figure 5.4: Onboarding screen: Progress.

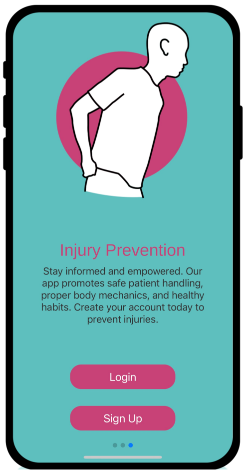

Figure 5.5: Onboarding screen: Prevention.

Login

Users reach the login screen, a crucial entry point to the app's resources, after seeing the onboarding screen. The login screen, shown in Figure 5.6, has two crucial text input fields: one for the user's email and one for their password. It is simple and user-friendly in design. Visually highlighting the functions of each field, representative icons are used in each field.

Figure 5.6: Login screen.

Sign Up

Another essential component of *BodyBoost* is the sign-up page. It is where new users register and submit their necessary information, enabling customization and individualized service. This screen, shown in Figure 5.7, has a number of text input areas and menus, each serving a particular function.

’Username’ is the first field on the form and is accompanied by an icon. ’Email’ and ’Password’ are the next fields. Users enter these details while creating an account to log in later and verify their identity.

The user’s physical characteristics, "Weight" and "Height," are requested in the following set of inputs. The accuracy of the app’s fitness advice and progress-tracking features depends on these numerical inputs.

Users can choose their current degree of physical activity using the ’Activity degree’ menu, which has options ranging from ’Low’ to ’Very High’. This information enables the app’s functionality to be tailored to the user’s lifestyle.

Users can choose whether or not to smoke on the ’Smoking’ menu, which is a binary option. This function is crucial because it enables the app to account for lifestyle elements that might affect fitness and health outcomes.

Users can also select the service that they work in on the "Service" menu, which includes choices like "Surgery," "Pediatric," and "Internal Medicine."

At the end of the registration procedure, there are two call-to-action buttons. The ’Sign Up’ button on the main page is used to submit the form and set up the user’s account. A brief toast notification that the account was established and forwarded to the login page follows a successful registration.

The ’Already have an account? Users can also use the login option with an account to return to the login page.

During the sign-up process, the app ensures the security of user accounts. If users encounter an error when defining their password, a pop-up message alerts them to the issue, providing guidance on password requirements or any other relevant error details. This ensures that users can create strong and secure passwords for their accounts. An example of such a pop-up message is depicted in Figure 5.8.

Like the rest of the application, the sign-up page was designed with user-friendliness in mind. Colour coding and typographic cues direct the user’s attention and interaction, while iconography clearly identifies each input field’s function.

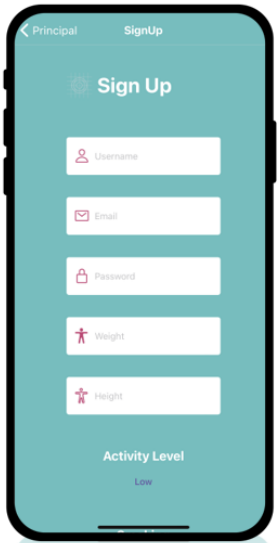

Figure 5.7: Sign-up screen.

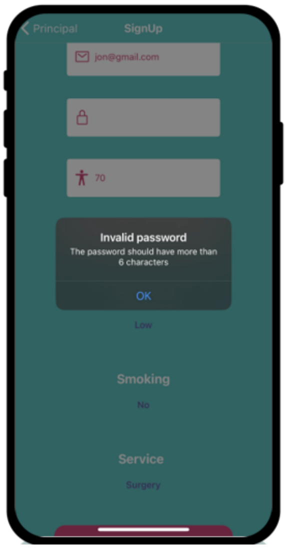

Figure 5.8: Pop-up message: Password error.

HomePage

The *BodyBoost* application's home screen serves as its focal point and gives users a comprehensive overview of all of its features. The layout of the home screen is shown in Figure 5.9.

The *BodyBoost* logo at the top of the screen grounds the user's experience in the brand identity.

After then, the screen is split up into a number of parts, each of which is devoted to a crucial aspect of the app's functionality: Practice, Assessment, and Posture. One or more touch-sensitive buttons are used to symbolize each part and serve as the user interface for navigating. Pressing a button directs the user to the app's relevant screen or function. For instance, the "Exercises" button beneath the Practice section directs users to the "ExerciseScreen" page.

A fixed navigation bar with a number of icon-based buttons is located at the bottom of the home screen. These buttons correspond to the app's Dashboard, Exercises, Leaderboard, and Profile screens, each of which represents a different essential feature. The usage of instantly recognizable icons makes it easier for the user to go quickly to the appropriate area of the program.

Quick access to the key components of the BodyBoost program is made possible by the home screen's user-centered design and simple navigation. Its user-friendly design encourages users to explore the app and take full use of all of its functions in order to improve their physical well-being.

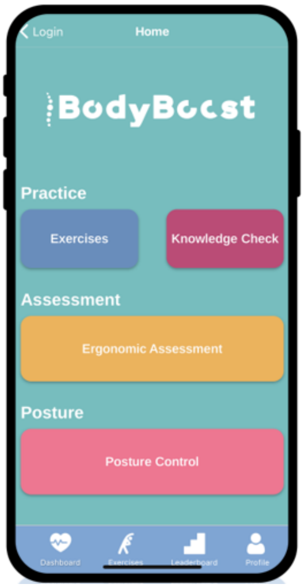

Figure 5.9: Homepage screen.

Trivia

The Trivia screen, shown in Figure 5.10, is a fun component, game-like, created to inform users about musculoskeletal health and preventative measures through entertaining questions.

There are a number of prepared questions about the health of the musculoskeletal system, each with multiple-choice answers. The heart of this feature presents the user with each question in turn. A timer of 15 seconds is displayed for each question to encourage quick thinking and engagement. If the user doesn't choose an answer within the allotted time, the program automatically advances to the next question.

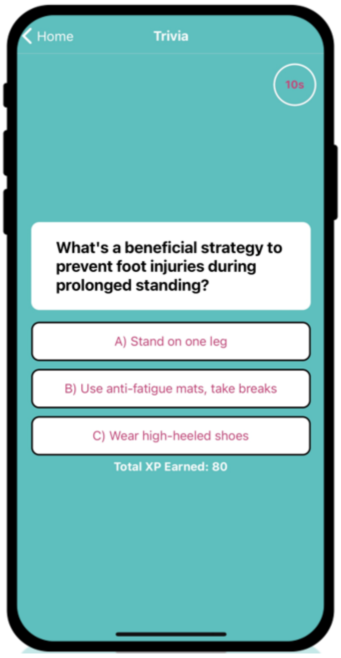

Figure 5.10: Trivia screen.

When the user selects an answer, the chosen response is cross-verified with the correct response. If the user's choice was accurate, a visual indication, as shown in Figure 5.11, is displayed, and the user's experience points (XP) are increased by 10. On the other hand, if the user selects the wrong answer, a different visual indication, as shown in Figure 5.12, provides immediate feedback on the incorrect response.

Thanks to the Firebase integration, experience points are retrieved and updated for logged-in users in real time. This gamified approach encourages user interaction with the content and fosters ongoing learning about musculoskeletal health.

Additionally, the Trivia screen displays the total amount of XP earned, giving the user immediate feedback and a sense of accomplishment. This system not only rewards user participation but also creates a user-friendly learning environment by merging educational information with a UI that resembles a video game.

By incorporating the Trivia feature, *BodyBoost* provides an enjoyable way for users to expand their knowledge about musculoskeletal health while keeping them engaged and motivated to learn more.

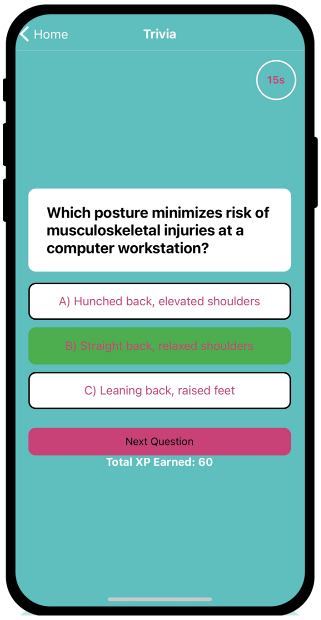

Figure 5.11: Visual indication of a correct answer.

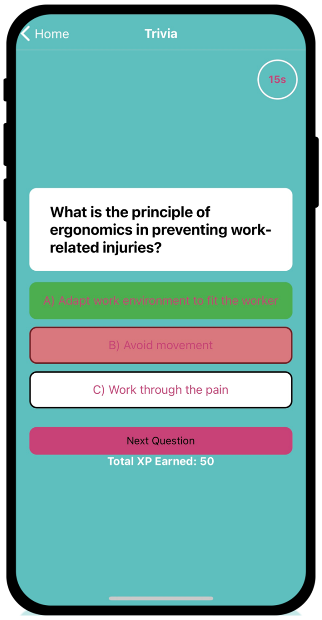

Figure 5.12: Visual indication of a wrong answer.

Leaderboard

By visualizing user performance, the Leaderboard panel in Figure 5.13 introduces a competitive element to the BodyBoost application. The screen shows a list of users arranged according to their level, giving users a concrete indicator of their progress and an incentive to use the app's services more frequently. The user information is retrieved from the Firestore database's by the 'level' attribute present in each user registered in the app. The Leaderboard screen automatically updates whenever the data referring to 'level' attribute is modified, guaranteeing that the ranks are always accurate. The screen incorporates a loading state that shows a 'Loading...' text while the user data is being fetched. If an error arises during this procedure, it is detected and displayed on the screen, improving the app's ability to handle errors. When the data is successfully fetched, the username, service, and level of each user are dis- played in the list item that serves as their representation. The username and level are prominently shown, highlighting the leaderboard's competitive nature. The service is offered as a description, giving the user's level context. Additionally, each list item has a thumbnail image that is drawn from the user's profile picture and shown to the left of the list item. This improves the leaderboard's aesthetic appeal and makes it simpler for users to recognize other users. The designs of the leaderboard screen have an emphasis on visibility and readability, making the information obvious with bold fonts and contrasting colours. The list items' white colour creates a high-contrast background for the text and photographs, but the background colour of the screen is consistent with the app's general concept. The user experience is enhanced by the spacing between the elements, the usage of margins for easier reading, and the application of shadows for a depth effect. This screen utilizes the social component of fitness and health improvement by creating a sense of community among the app users in addition to acting as an interactive tool for user engagement.

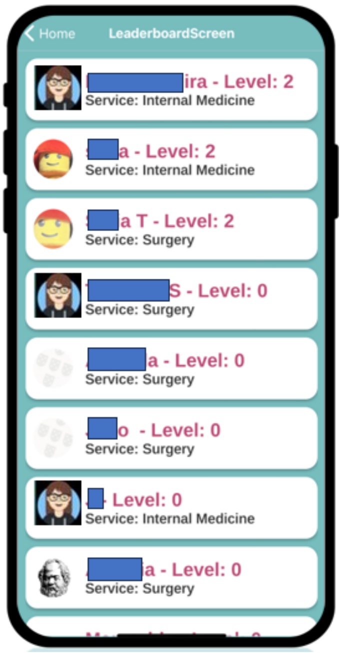

Figure 5.13: Leaderboard screen.

Profile

Figure 5.14 shows that the Profile page is a crucial interface for the *BodyBoost* application. By showing a profile photo, individual health data, and the service of choice, it provides a personalized user experience. The screen's top portion prominently displays the user's profile photo, adding a personal touch. Below is a clear display of personal health information, such as height, weight, exercise level, and smoking status. Users can track their fitness journey dynamically by updating these fields. The circular progress bar is one of the screen's distinctive features. This dynamic element helps to gamify the experience by visualizing the user's level and experience points (XP). Additionally, the selected service is shown, providing transparency and the option to change services if fitness objectives change. The Profile screen's visual style complements that of the BodyBoost app as a whole. It provides a structured layout with a focus on readability and usability. It is interesting and visually appealing because of the profile image and circular progress bar, which serve as its main visual components. Users receive an extensive overview of their fitness journey and personal information management on the Profile page, which effectively acts as a personalized centre.

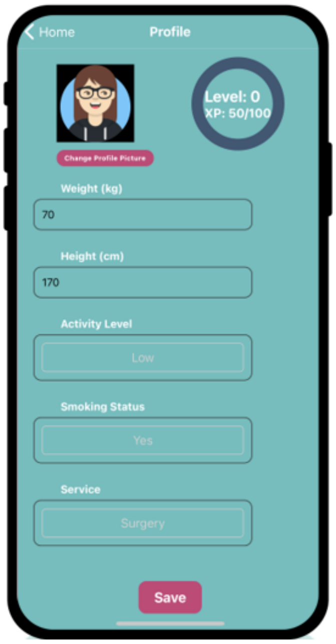

Figure 5.14: Profile screen

Exercise Screen Training Slides

The Exercise Screen, which serves as the centre for choosing and carrying out physical training programs, is a crucial component of the *BodyBoost* application. Users can interact with the selection of exercises offered by the program through this screen, as shown in Figure 5.15 Mobile App BodyBoost The title "Select Training" is prominently displayed on the screen. Users can better grasp how to use this screen's main feature, which is to select a training regimen, with the help of this instructional directive. A collection of rectangular cards representing various training regimens kept in the exercise sets data object is constantly added to the exercise screen. The title of the training routine is included on each card, and users can click it to start that particular training set. The interface changes into a carousel of exercise slides produced as soon as a user enters a training set, as shown in Figure 5.16 Every exercise in the chosen training set is displayed as a slide with a sizable graphic illustrative of the exercise and a countdown timer to monitor the exercise's duration. The countdown timer works as a visual cue as well as a reference for the exercise's duration. Below the image and timer are exercise instructions that make it very obvious how to carry out the activity. Once the current exercise is completed, the timer will automatically go on to the following one. Users have the option to pause the timer if a break is necessary, giving them a choice over how quickly they train. The Exercise Screen blends usability and functionality to make it simple for users to interact with the app's exercise features. Its straightforward design makes it easy for users to go through their training sessions, encouraging continued use and fostering a positive user experience.

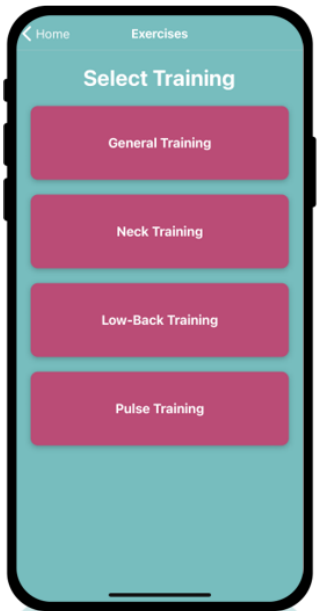

Figure 5.15: Application's profile screen.

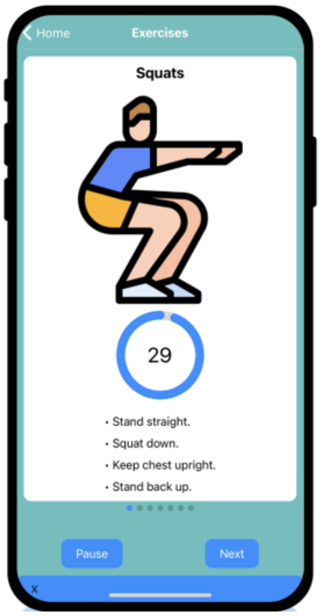

Figure 5.16: Application's game screen.

Posture Control

Posture control is a crucial feature of the *BodyBoost* application that allows users to monitor and improve their posture. By leveraging a wearable device, the app tracks and detects instances of bad posture throughout the day, providing valuable insights for users to make posture adjustments.

The Posture Log screen, illustrated in Figure 5.17, presents a visual representation of the user's posture history. The screen displays a bar chart that showcases the number of instances of bad posture detected for the past four days. The x-axis represents the dates, while the y-axis indicates the count of bad posture detections.

The values shown in the chart are derived from the user's posture data captured by the wearable device. The wearable device continuously tracks the user's posture and sends the collected data to the *BodyBoost* app for analysis and visualization.

Figure 5.17: Posture control screen.

In addition to the bar chart, the Posture Log screen also provides a log of posture detections for each day. This log includes the date and timestamps when bad posture was detected. By reviewing the log, users can identify specific instances and patterns of poor posture throughout their daily routines.

By leveraging the capabilities of wearable technology, the *BodyBoost* app offers users a valuable tool to monitor and enhance their posture, ultimately contributing to their overall well-being.

Ergonomic Assessment Screen

An ergonomic assessment function in the *BodyBoost* app allows users to assess their risk of musculoskeletal injuries and receive advice on how to improve their ergonomic habits. Users can evaluate the effect of their work-related activities on their physical well-being using the ergonomic evaluation screen, and they can also get suggestions for improving their ergonomic habits.

A series of questions are asked on the ergonomic assessment screen about physical demands, instruction in safe patient handling methods, accessibility to ergonomic equipment, discomfort or pain experienced during or after work, and how frequently you stretch. By choosing the relevant alternatives, users can express their opinions.

The software generates customised recommendations to address particular areas of concern based on the user's responses. These suggestions direct users to the section of the application that provide the exercises, methods, and tools they need to enhance their ergonomic practises.

The app's training section offers a range of exercises designed to strengthen specific muscle groups, improve posture, and promote overall physical well-being. Users can explore the exercises that are relevant to their needs and follow guided instructions to perform them correctly.

In addition, the trivia game provides educational resources, tips, and techniques for maintaining good posture during work-related activities. Users can learn about proper ergonomics, body mechanics, and techniques to minimize muscle and joint strain while performing their tasks.

The ergonomic assessment tool of *BodyBoost*, is shown in Figures 5.18 and 5.19, and it enables users to become more aware of their musculoskeletal health, make educated decisions to improve their ergonomic practises, and have access to the resources they need to improve their well-being. It is an effective instrument for fostering ergonomic awareness and assisting in adopting healthier work practices.

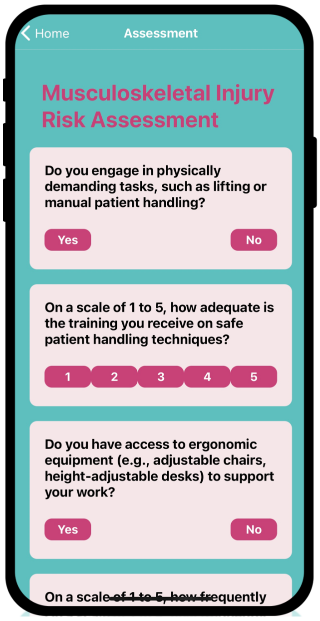

Figure 5.18: Application's profile screen.

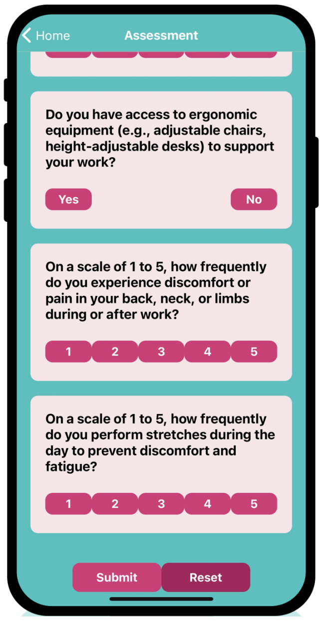

Figure 5.19: Application's game screen.

Notifications

Users need notifications in order to stay interested in and informed about their fitness journey. The *BodyBoost* app uses notifications to deliver sensible reminders and tailored criticism.

Users can opt to get notifications that gently prompt them to stretch. Maintaining flexibility, avoiding injuries, and enhancing overall muscle health all depend on regular stretching. BodyBoost periodically notifies users to take a break and perform stretching exercises in order to promote healthy behaviours. These alerts are meant to encourage better posture, ease tension in the muscles, and improve general well-being. Figure 5.20 depicts an illustration of one such notification.

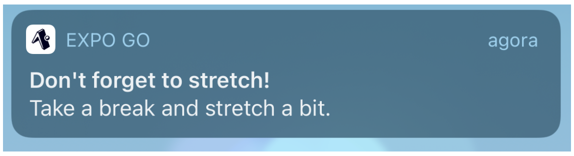

Figure 5.20: Notification: "Don't forget to stretch".

Additionally, thanks to the smooth interaction with the created wearable gadget, *BodyBoost* is able to track posture all day long. The user's mobile device receives an instant notification whenever the wearable device notices improper posture. These posture notifications serve as real-time feedback, encouraging users to improve their posture and maintain a healthy alignment based on the information gathered by our wearable gadget. BodyBoost's cutting-edge technology enables users to take charge of their posture and proactively avoid musculoskeletal problems. Figure 5.21 shows an illustration of a posture notification.

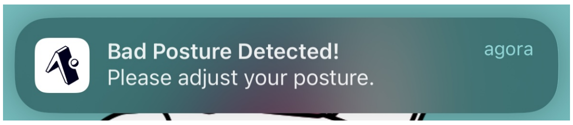

Figure 5.21: Notification: Detected bad posture.

5.5 Testing and Quality Assurance

During the creation of the mobile app, ensuring high standards and a bug-free user experience was a top focus. To achieve this goal, several tactics were used.

- **Unit Testing**: To confirm its functionality, each part of the software has undergone independent testing. Unit tests were written and managed with the aid of Jest, a JavaScript testing framework. It made it easier to test the reasoning behind functions, how components looked, and how well user input was handled.

- **Integration Testing**: Integration testing was done to ensure that the app's many components function effectively together after individual component functioning was confirmed. This involved testing the data transfer across various screens, the accuracy of the navigation, and how the app interacted with the backend.

- **Functional Testing**: To ensure that each feature functioned as planned, the app underwent user testing. To ensure that user tasks and workflows could be accomplished without problems, this involved performing them.

- **Usability Testing**: Usability testing was used to assess the user interface and overall user experience of the app. It made sure the app was simple to use, intuitive, and satisfied the needs and expectations of its target audience. A group of the intended users used the app during this testing and gave their opinions on it.

Chapter 6

Wearable Device Development

In this chapter, we delve into the heart of our real-time posture tracking system, focusing on the real-time detection algorithm. The dynamic posture detection and feedback mechanism in our system is powered by this algorithm, which forms the basis of its functionality. This algorithm was created in the Arduino environment and was specifically designed to work with the ESP32 FireBeetle board and LSM9DS0 sensor, analyzing their data streams, identifying potentially dangerous postures, and providing real-time feedback to the user.

We will go over the algorithm's four main phases: posture detection, roll, pitch, and yaw transformation, data collecting, and sensor configuration. We will examine how each of these stages affects the posture tracking and feedback systems because they are all essential to the system's efficient operation.

The accelerometer, magnetometer, and gyroscope are adjusted in the sensor configuration stage to better suit the system's requirements for accurate posture detection. Raw sensor data is gathered during the data gathering phase, which is subsequently processed to remove noise and bias in preparation for further analysis. To better comprehend the user's position, the raw sensor data is subsequently converted into roll, pitch, and yaw measurements. The posture detection process, which uses the roll, pitch, and yaw to detect and warn of any improper postures, is finally explained.

Understanding these processes will give a thorough understanding of how the posture monitoring system works at its core. through give the user real-time feedback and enable prompt repair of posture-related difficulties, a complex process from sensor setup through posture recognition is necessary. This in-depth examination of the detection method will help to advance knowledge of sensor-based posture detection and the integration of hardware and software elements to produce a comprehensive, successful solution.

6.1 Design and Components

In this section, we'll talk about the structure and parts of the wearable device that tracks healthcare workers' positions in real time and looks for awkward postures.

The wearable device is made to precisely track healthcare workers' positions and movements in real time with the goal of spotting awkward postures and issuing alerts as needed. The ESP32 FireBeetle microcontroller and the LSM9DS0 sensor are its two main parts.

ESP32 FireBeetle

The choice of the ESP32 FireBeetle microcontroller was made based on several factors:

The ESP32 FireBeetle microcontroller was selected based on a number of considerations, including:

- Wireless Communication: The ESP32 FireBeetle has integrated Bluetooth and Wi-Fi features that enable smooth wireless communication with other devices. As a result, real-time data transmission to the mobile application is made possible, and data storage in a remote database is made easier.
- Processing power: The ESP32 FireBeetle has a potent dual-core processor that has enough power to handle simultaneous data collection, analysis, and wireless communication tasks. This guarantees the wearable device's effective and dependable operation.
- Platform that is Developer-Friendly: The ESP32 FireBeetle is supported by a robust development ecosystem that provides a range of libraries, tools, and resources for quick prototyping and development. This makes it easier to implement complex functionalities and makes it easier to integrate the microcontroller into the wearable device.

At first, there was an attempt to make the wearable gadget with an Arduino Nano. However, a more reliable connectivity solution was required because it was necessary to store data on Firebase for later retrieval. Since the Arduino Nano lacks integrated wireless capabilities, connecting directly to Firebase without a separate module is difficult. The switch to the ESP32 FireBeetle was made to benefit from its built-in Wi-Fi capabilities, which make data storage easier without the need for additional hardware.

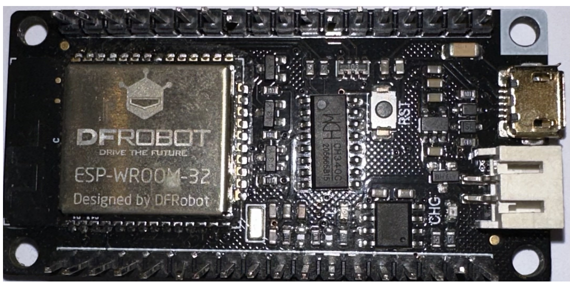

Figure 6.1: ESP32 FireBeetle.

LSM9SD0

The acceleration, rotation, and magnetic field are the three crucial components of movement and orientation that the LSM9DS0 sensor encompasses in its nine degrees of freedom. This compact multi-axis sensor module combines a 3-axis accelerometer, 3-axis gyroscope, and 3-axis magnetometer to provide comprehensive data for tracking the position and movements of the wearable device.

The X, Y, and Z axes are three perpendicular axes along which the 3-axis accelerometer measures acceleration. This enables the sensor to record velocity changes and recognize quick movements or position changes. The wearable device can spot instances of potentially awkward postures, like sudden jerks or quick changes in orientation, by tracking acceleration data.

The gyroscope, which also has three axes of operation, gauges rotational motion. It offers details on the angular velocity and orientation changes of the wearable device. The device can identify subtle posture changes, such as tilting or bending, which may help identify awkward postures, by monitoring the gyroscope data.

The magnetic field's strength and direction are measured by the magnetometer. The sensor helps ascertain the wearable device's exact orientation by using the Earth's magnetic field as a reference. This makes it possible to provide precise positioning information, improving the accuracy of posture detection and guaranteeing accurate movement tracking for the healthcare professional.

The LSM9DS0 sensor is a good option for the wearable device's design because of its 9 degrees of freedom, small size, and compatibility with the selected microcontroller (ESP32 FireBeetle). The sensor's high accuracy and resolution help to ensure accurate data collection and analysis for the safety and well-being of the healthcare professional.

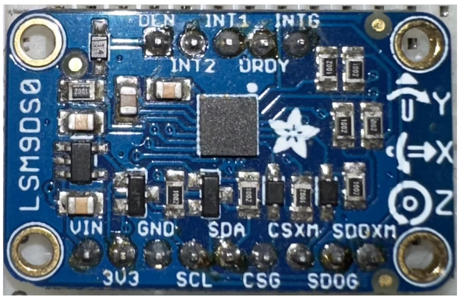

Figure 6.2: LSM9SD0 sensor.

Wearable Device over a Phone

While a smartphone could potentially be used for posture detection, a dedicated wearable device was chosen for several reasons. First off, a wearable device like the one created for this thesis can be better adapted to the medical requirements of professionals. Unlike a phone, whose position may change depending on how it is held, it may be precisely positioned and adjusted to meet the monitoring requirements.

Secondly, there are many different sensors and configurations on cellphones, so a solution that works well on one model might not work as well on another. The performance is consistent for all users thanks to the development of a specific wearable.

Last but not least, utilizing a smartphone for continuous posture detection may severely deplete its battery. The wearable gadget, on the other hand, can be made to be energy-efficient and have a battery life that enables extended use between charges.

These factors influenced the decision to design a wearable device rather than rely on a smartphone, along with the chance to gain practical experience in creating a hardware solution.

6.2 Tools

The usage of various hardware and software tools aided in the creation and deployment of the posture tracking system.

Software Tools

The software tools employed can be divided into development tools and cloud services.

Development Tools:

1. **Arduino IDE:** This was used for programming the ESP32 FireBeetle Board. Due to its simplicity, usability, and extensive support for numerous microcontrollers, including ESP32, the Arduino IDE was chosen. Additionally, it has a sizable user population that offers a wealth of resources and troubleshooting assistance.

2. **Visual Studio Code:** The sophisticated productivity-enhancing capabilities of Visual Studio Code (VS Code), like debugging tools and built-in Git commands, were what made it suitable to use for developing the code parts associated with the React Native application, like fetching data from the database. Additionally, it offers a wide range of extensions, which speeds up the development process even more.

Cloud Services:

1. **Firebase:** Firebase, as a cloud service, was chosen for its real-time capabilities, ease of use, scalability, and integration support for various platforms, including React Native.

   - **Firebase Realtime Database:** Used for real-time data transfer from the ESP32 to the mobile application. It was chosen for its capability to handle and sync data in real-time across all connected devices.

   - **Firebase Firestore:** Used for long-term storage of posture data along with timestamp for future reference. Firestore, a flexible, scalable NoSQL cloud database, allows for easy querying and data retrieval, which complements the limitations of the Realtime Database.

In conclusion, the choice of tools was largely dictated by the requirements of real-time tracking, data syncing, ease of use, scalability, and cross-platform compatibility. Each tool was selected for its specific advantages and its capacity to meet the demands of the project.

6.3 System Architecture

The hardware layer and the software layer are the two separate levels that make up the system's architecture.

Starting with the hardware layer, the ESP32 FireBeetle, a flexible microcontroller with built-in WiFi capabilities, serves as the wearable device's "brains". It has the LSM9DS0 sensor, which consists of a 3D digital linear acceleration sensor, a 3D digital angular rate sensor, and a 3D digital magnetic sensor. The LSM9DS0 sensor's raw data is interpreted by the ESP32 software, which then transforms it into measurements of roll, pitch, and yaw orientation. Real-time processing ensures that the data is up to date and prepared for WiFi transmission to Firebase Realtime Database.

The smartphone application and the wearable gadget are connected by Firebase. The Realtime Database is updated by Firebase after receiving the orientation data from the ESP32 over WiFi.

The mobile application then downloads data from the Firebase Realtime Database once every second and then uploads the data into a Firestore database collection called "sensorData" after retrieving it. This information is timestamped and saved for further study and reference. This transfer from Realtime Database to Firestore has been implemented to bypass the limitations of the free tier of Firebase, which does not allow for long-term storage and retrieval of data in the Realtime Database. Therefore, by moving data to Firestore, the system ensures that the posture information is timestamped and stored for further study and reference. It's important to note here that this is a workaround due to budget constraints. With a larger budget, a more efficient method of long-term data storage could be utilized, which would further enhance the application's functionality.

Reviewing the logged posture data is a secondary feature of the mobile application. Users can do this to track and examine their posture over time, providing insights and chances for posture development.

In conclusion, the system's architecture shows a streamlined, effective flow of real-time data, from initial LSM9DS0 sensor capture through user-facing presentation within the React Native mobile application *BodyBoost*.

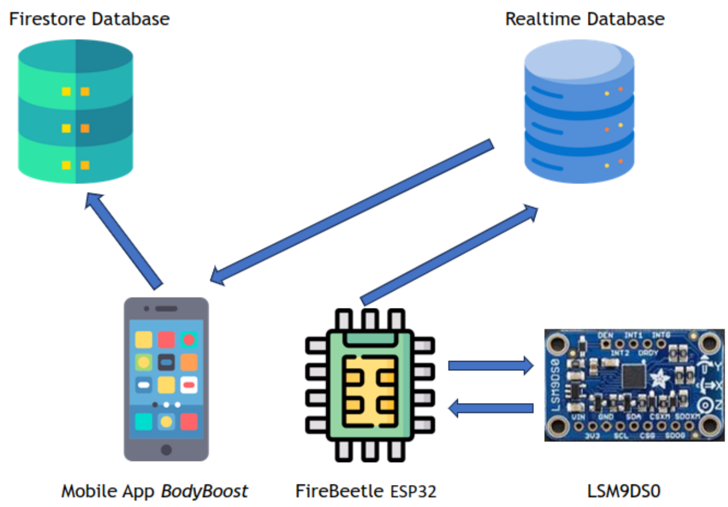

Figure 6.3: Architecture of the proposed solution.

6.4 Development and Implementation

The real-time posture tracking system was developed through a series of steps, including planning and design, coding and implementation, testing and improvement.

Planning

The project's scope was established, the essential equipment was gathered, and the system architecture was designed during the initial planning and design stage. The Arduino Nano was the initial piece of hardware chosen because of its small size and ability to work with the LSM9DS0 sensor. After considering various data transmission techniques, the FireBeetle ESP32 board will be used instead.

Instead of the Bluetooth connection that would have been made with the Arduino Nano, the FireBeetle ESP32's Wi-Fi capabilities allowed for an indirect connection to the mobile application via the Firebase Realtime Database. This modification had several benefits, including centralized sensor data storage that could be accessed from various devices, simpler system scaling in the event that more wearables were added, and the ability to remotely monitor posture data.

Because it can instantly update data, which is essential for the real-time feedback system, Firebase was chosen as the real-time database.

The system's architecture ensured that the software and hardware parts could cooperate. User experience was prioritized, and it was made sure that the application was easy to use and that the feedback was accurate and quick.

Real-time Detection Algorithm

After providing a general description of the system, we focus on a particular aspect of the project called the real-time posture detection method. This algorithm is created in the Arduino environment and is specifically designed for the ESP32 FireBeetle board and LSM9DS0 sensor. Its primary job is to assess sensor signals, spot difficult postures in real time, and lay the groundwork for the feedback mechanism of the system.

The initial sensor design, data collecting, and posture detection are the three key stages of this algorithm. The LSM9DS0 sensor's signals from an accelerometer, a magnetometer, and a gyroscope are largely used in these stages to establish the wearable device's three-dimensional orientation. The parts that follow go into greater detail on each stage, clarifying their specific functions and contributions to the system's overall performance.

Sensor Configuration and Calibration

The process of sensor initialization involves fine-tuning the accelerometer, magnetometer, and gyroscope. The magnetometer gain is adjusted to 2 (mT), the gyroscope scale is established at 245 degrees per second, and the accelerometer range is defined as 19.6 (m/s^2). These configurations optimize the system for effective posture detection within the scope of this application.

The sensitivity of the magnetometer is set to 2 mT, an appropriate level for detecting the Earth's magnetic field, which is integral to determining the yaw of the instrument. The strength of the Earth's magnetic field is latitude-dependent, generally fluctuating around 25 to 65 (μT). Thus, a 2 mT range ensures sufficient sensitivity, while mitigating the risk of oversaturation by stronger magnetic fields.

The gyroscope sensitivity is set to 245 degrees per second, a value standardly used for tracking human motion and chosen taking into consideration, typical range of human limb movements during normal activities.[26] This setup aids in capturing swift movements while minimizing the chances of sensor overload due to sudden, high-speed movements. Given that the limbs — the fastest moving parts of the human body — typically do not exceed this speed during normal movement, this configuration is optimal.

Parallel to this, the range of the accelerometer is configured to 19.6 m/s^2. Given that humans exist in a gravitational field of 9.8 m/s^2, the chosen value for the accelerometer was twice this value, and most routine actions result in accelerations less than this, the chosen range effectively covers most human activities, such as running, jumping, or walking. These settings can be adjusted to cater to specific requirements, such as high-intensity activities or environments with strong magnetic fields.

The performance of the system for accurate posture detection within the parameters of this application has been shown to be optimised by these values, which were discovered through experimentation and testing.

Data Acquisition

Raw sensor data is read from the LSM9DS0 sensor during data acquisition. This unprocessed data represents angular velocity from the gyroscope, magnetic fields from the magnetometer, and linear acceleration from the accelerometer. But before further analysis, these data must be corrected for various types of errors, such as noise and bias.

This problem is solved during calibration by running a median filter through the raw sensor data. The accuracy of posture detection is improved by this filter's assistance in smoothing out sensor readings and reducing the impact of random noise and outliers.

Transformation to Roll, Pitch, Yaw

Following calibration, raw sensor readings reflect the device's movement and orientation within three dimensions but across various frames of reference. To simplify interpretation and make it applicable for posture detection, these readings are transformed into roll, pitch, and yaw angles.

In electrotechnical engineering, pitch, yaw, and roll are the three angles employed to depict a device's orientation in three dimensions: pitch refers to rotation around the horizontal axis, yaw refers to rotation around the vertical axis, and roll pertains to rotation around the longitudinal axis.

Traditionally, these angles were computed as follows:

- Roll was determined by the ratio of the accelerometer readings on the Y-axis and Z-axis.
- Pitch was calculated using the magnitude of the Y-axis and Z-axis readings, coupled with the X-axis accelerometer readings.
- Yaw was evaluated by the arctangent of the ratio between the Y-axis and X-axis magnetometer readings.

However, these calculations did not consider the gyroscope readings. To rectify this, a sensor fusion technique is now employed in the application to achieve a more accurate portrayal of the device's orientation. Orientation filters like the Kalman filter, used in this application, are common sensor fusion methods for IMUs, and they allow for an optimal combination of data from multiple sensors, thereby improving accuracy and reliability.

This advancement enables the integration of gyroscope data into the pitch, roll, and yaw calculations, yielding enhanced accuracy in dynamic scenarios where the device is rapidly moved or experiences vibrational disturbances. The gyroscopes provide the rate of rotation, assisting in determining the device's orientation more accurately when used in combination with accelerometer and magnetometer readings.

Post-calibration, the sensor data undergoes a processing pipeline that includes three stages, seamlessly transitioning from one to the next. The initial stage involves taking and storing sensor readings. Once this primary data is gathered, the system moves to the second stage which focuses on calculating offsets. A running median filter is employed in this stage to evade bias and minimize noise in the data. The median of the last 15 readings serves as the offset, ensuring a reliable benchmark.

As the system enters the final stage, offset-corrected accelerometer data is subjected to a Kalman filter. The parameters for the filter were chosen based on performance metrics that resulted in the most accurate posture detection in tests. This stage is crucial for further noise reduction and delivering smooth sensor readings.

With these processes complete, the system is able to accurately compute the roll, pitch, and yaw angles based on the filtered accelerometer and magnetometer readings. These angles are then employed to detect poor posture conditions. A particular instance of this would be the system flagging a bad posture when the roll angle exceeds 120 degrees.

The entire process, right from the computed angles to the condition of the posture, is periodically uploaded to Firebase at 2-second intervals. This allows for further analysis and enables real-time monitoring of the data.

The application code employed for this process includes libraries and commands to initialize the sensor, connect to the Wi-Fi, set up Firebase, read sensor data, calculate offsets, apply the Kalman filter, compute roll, pitch, and yaw, and flag poor posture. The calculated angles and sensor data are then periodically updated on Firebase.

Posture Detection

This wearable serves as a proof of concept, with the current posture detection algorithm primarily focusing on the roll angle. An awkward posture is identified when the roll angle exceeds a threshold of 170 degrees, a value that was established through rigorous testing. Upon detection, an alert is promptly generated.

The purpose of this proof of concept is to demonstrate the system's potential in real-world applications, especially in its early stage of detecting a specific type of poor posture. This fundamental concept, along with the employed techniques, lays a solid foundation for subsequent developments and advancements.

Moreover, the proof of concept illustrates the inherent adaptability of the algorithm. It is designed to incorporate new detection rules and modifications, meeting specific application requirements, and setting the stage for future enhancements. This includes the capacity to detect more complex postures and dynamic movements, thereby boosting the system's potential as a beneficial tool for posture monitoring and correction.

Understanding the complexity of human postures and movements, it is acknowledged that a combination of roll, pitch, and yaw angles may be necessary for precise posture detection in future iterations. Therefore, the adaptability of the algorithm allows for the inclusion of new detection rules and modifications as per the application's requirements. With its ability to identify a broader range of awkward postures and movements, the system further augments its potential health benefits.

6.5 Prototype

A wearable device physical prototype was made as part of the development process to show off its use and viability. The LSM9DS0 sensor and the ESP32 FireBeetle microcontroller made up the prototype, which was put together on a breadboard.

The hardware setup of the prototype can be seen in Figure 6.4. It demonstrates how the LSM9DS0 sensor is connected to the ESP32 FireBeetle microcontroller. The breadboard made it simple and adaptable to connect the components, facilitating the collection and processing of data for posture tracking.

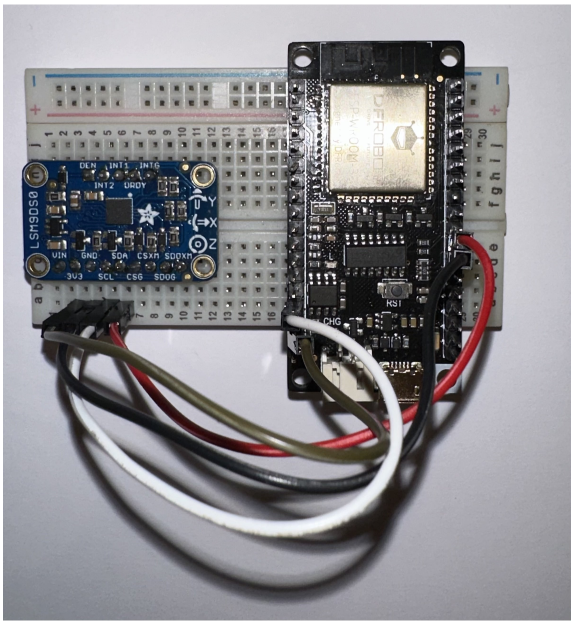

Figure 6.4: Hardware setup.

The prototype was worn by a user during testing to replicate real-world situations and gather information on posture and movement. The prototype was fastened to the user's body using improvised straps and mounting options, as seen in Figure 6.5 It's vital to remember that this configuration wasn't meant for regular use and was only meant to be temporary. The real-time posture detection algorithm's functionality and efficacy were mainly assessed and validated during the testing.

Figure 6.5: Prototype in use.

Although the prototype's appearance in use may seem unsuitable for ordinary use, it provided valuable information about the algorithm's performance. The prototype was worn by the user as they engaged in a variety of motions and positions, and the sensor continuously recorded data. The system then used this data to find and assess posture-related information.

It is important to note that the prototype's current configuration is not meant to serve as the final product. Future revisions should aim to create a wearable technology that is more cosy, discrete, and easy to incorporate into daily life. The wearable device can become a useful and unobtrusive solution for posture monitoring in healthcare settings by putting the user's comfort and convenience first.

A computer-generated image of a potential future design for the wearable device was produced as part of the design process, it can be seen in Figure 6.6 This illustration can assist in putting the possible aesthetic and usability enhancements into perspective. It's crucial to remember that this computer-generated image is merely conceptual at this point and does not reflect the prototype's current status.

Figure 6.6: Potential future design.

6.6 Testing and Refinement

The system performed a series of tests following its initial implementation to confirm the precision of the posture detection, the promptness of the real-time feedback given by the mobile application, and the consistency of the data saved in Firestore.

To increase the effectiveness and dependability of the system, several iterations of testing and improvement were carried out. These testing assisted in identifying possible areas for enhancement, such as real-time detection algorithm optimization for quicker and more precise detection of difficult postures. The system was improved using the feedback from these testing to create the finished product.

In conclusion, a thorough process from planning and design, through coding and implementation, to rigorous testing and refining, went into the development and execution of this system. This iterative procedure made sure that the real-time posture tracking system was dependable, accurate, and effective.

Chapter 7

Usability Testing

To ensure optimal performance, a positive user experience, and overall user happiness, rigorous testing and validation are crucial phases in the creation of mobile applications. In light of this, this chapter will examine in depth the insightful input gathered from a selected group of healthcare professionals who participated in assessing the mobile application that was developed.

A thorough description of the broad participant pool, which includes healthcare professionals selected to evaluate the usability of the mobile application, is first laid out in this chapter. The process os task evaluation, a method that enables participants to interact with the application and provide immediate feedback, is then explained.

The System Usability Scale (SUS), a powerful tool for this particular application, is then explained. It acts as a quantitative indicator of the application's perceived usefulness following task execution.

The method for obtaining open-ended input is revealed in the final section. In addition to the SUS data, this component includes qualitative user experience information.

7.1 Participants Characterization

The usability of the mobile application was evaluated by a diverse group of healthcare professionals, consisting of physiotherapists and nurses. These individuals have direct experience in addressing musculoskeletal health issues, making them ideal evaluators for an application focused on posture and musculoskeletal health.

Table 7.1 provides a summary of the demographic information and professional background of the participants. This includes their age, years of professional experience, and profession.

The participants' ages range from 24 to 42, reflecting a mix of relatively recent graduates and seasoned professionals. Years of professional experience also vary, ranging from one to twenty years, providing a spectrum of perspectives regarding the application's usability and relevance to their field.

By considering a range of ages and experience levels, we were able to obtain diverse and comprehensive feedback on the application. This helped to ensure that the application's design and features would be accessible and useful to professionals at various stages in their careers.

Table 7.1: Usability Test Participants' Characteristics

Participant	Age (years)	Years of Experience	Profession
1	24	1	Physiotherapist
2	24	3	Physiotherapist
3	30	8	Nurse
4	42	20	Nurse
5	32	9	Nurse

7.2 Process of Task Evaluation

The evaluation process was initiated by allowing the participants to familiarise themselves with the mobile application and its features, for which each participant was given an iPhone 12. Each of the functionalities of the app were introduced and evaluated systematically, allowing participants to thoroughly explore and understand each feature.

The tasks encompassed the exploration of the following features:

1. Onboarding: Participants were asked to go through the onboarding process, which included an introduction to the purpose of the app.

2. Sign Up: Participants were asked to register for a new account by filling out the necessary forms.

3. Login: Participants were asked to log into the app using the account they created in the last step.

4. HomePage: Participants navigated through the app's homepage, familiarising themselves with its layout and features.

5. Leader Board: Participants were asked to check their standing and the scores of other users on the Leader Board, thereby understanding the gamified aspects of the app.

6. Profile: Participants were asked to access and edit their user profile.

7. Exercise Screen & Training Slides: Participants viewed various exercises and training slides for maintaining proper posture and musculoskeletal health.

8. Assessment Screen: Participants completed a self-assessment to evaluate their current risk factors related to their musculoskeletal health.

Following the completion of each task, participants were asked to rate the ease of task completion on a scale of 1 to 5, with 1 being very difficult and 5 being very easy. This served as a quick, immediate evaluation of each app feature, highlighting any aspects that may require further refinement.

This process was conducted in person at two different institutions, "WeCare Saúde" and "APELA - Associação Portuguesa de Esclerose Lateral Amiotrófica". This in-person approach allowed for the immediate capture of feedback and also the ability to observe any difficulties or errors made by the users during task completion, providing additional insights into the usability of the application.

It's important to mention that the process and the structure of the tasks were developed with the goal of covering all the main functionalities of the app, ensuring that the participants were able to explore and evaluate the app as thoroughly as possible. This structured approach also ensured that the feedback collected was comprehensive and could be utilized effectively to improve the application.

7.3 System Usability Scale

After completing the tasks mentioned earlier, the participants were asked to answer a set of questions. The system used was SUS (System Usability Scale). The statements were adapted to match with the newly adopted scale. represented here:

1. I think that I would like to use this system frequently.
2. I found the system unnecessarily complex.
3. I thought the system was easy to use.
4. I think that I would need the support of a technical person to be able to use this system.
5. I found the various functions in this system were well integrated.
6. I thought there was too much inconsistency in this system.
7. I would imagine that most people would learn to use this system very quickly.
8. I found the system very cumbersome to use.
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with this system.

Table 7.2: Participants' Answers on a scale from 1 (Strongly Disagree) to 5(Strongly Agree)

Participants	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**
Participant 1	5	2	5	1	4	1	4	1	5	1
Participant 2	5	2	5	1	5	1	4	2	5	1
Participant 3	3	1	5	2	5	1	4	2	5	1
Participant 4	4	2	4	2	5	1	4	1	4	2
Participant 5	5	1	5	1	4	1	4	1	5	1

System Usability Scale (SUS) Score Calculation

The System Usability Scale (SUS) is a widely utilized tool in the assessment of subjective usability. The SUS questionnaire comprises ten statements to which the participant expresses their level of agreement on a scale of 1 (strongly disagree) to 5 (strongly agree).

The calculation of the SUS score involves a specific sequence of operations. For each participant's responses:

1. Subtract 1 from the response to odd-numbered statements (1, 3, 5, 7, 9).
2. Subtract the response to even-numbered statements (2, 4, 6, 8, 10) from 5.
3. Sum the results of steps 1 and 2.
4. Multiply the sum by 2.5 to obtain the final SUS score.

The final SUS score ranges from 0 to 100.

To illustrate the application of these steps, consider the responses of five participants, denoted as Participant 1, Participant 2, Participant 3, Participant 4, and Participant 5.

$$\begin{aligned} S_{\text{P1}} =& 2.5 \times (5-1)+(5-2)+(5-1)+(5-1) \\ &+(4-1)+(5-1)+(4-1)+(5-1)+(5-1)+(5-1) = 92.5 \end{aligned} \tag{7.1}$$

$$\begin{aligned} S_{\text{P2}} =& 2.5 \times ((5-1)+(5-2)+(5-1)+(5-1) \\ &+(5-1)+(5-1)+(4-1)+(5-2)+(5-1)+(5-1)) = 92.5 \end{aligned} \tag{7.2}$$

$$\begin{aligned} S_{\text{P3}} =& 2.5 \times ((3-1)+(5-1)+(5-1)+(5-2) \\ &+(5-1)+(5-1)+(4-1)+(5-2)+(5-1)+(5-1)) = 87.5 \end{aligned} \tag{7.3}$$

$$\begin{aligned} S_{\text{P4}} =& 2.5 \times ((4-1)+(5-2)+(4-1)+(5-2) \\ &+(5-1)+(5-1)+(4-1)+(5-1)+(4-1)+(5-2)) = 82.5 \end{aligned} \tag{7.4}$$

$$\begin{aligned} S_{\text{P5}} =& 2.5 \times ((5-1)+(5-1)+(5-1)+(5-1) \\ &+(4-1)+(5-1)+(4-1)+(5-1)+(5-1)+(5-1)) = 95 \end{aligned} \tag{7.5}$$

As a result, the SUS score provides a quantitative measure of a system's perceived usability as reported by each participant.

A good System Usability Scale (SUS) score is typically higher than the average score of 68 [27]. Considering the specific SUS scores obtained earlier: 92.5, 92.5, 87.5, 82.5, 95, we can conclude that the average SUS score was 90. This indicates that participant 3 and 4 fall slightly below the average score. However,is still considered a good usability rating, but it does suggest potential areas for improvement in terms of usability.

7.4 Open Feedback

The study gathered qualitative comments via open-ended questions, in addition to the measurable evaluations from the System Usability Scale Adaptation. With the addition of rich, in-depth insights and individual viewpoints, this technique complements the numerical data to give a larger and more complex knowledge of the users' experiences. The open feedback questions were created to delve into particular user experiences, including their difficulties, navigational experiences, motivation levels due to gamification components, the usefulness of features, suggestions for enhancements, and the likelihood of recommending the application to their peers.

The following free-form inquiries were posed:

1. What difficulties did you face while using the app?
2. How easy was it for you to navigate through the app?
3. Did the gamification aspects of the app motivate you to use the app more often?
4. Which app feature(s) did you find most helpful?
5. Which feature(s) of the app would you change or improve? How?
6. Would you recommend this app to your colleagues? Why or why not?
7. Did you like and see the important role of the wearable implementation on your daily routine as a prevention method?

We'll go on to examine and summarize the responses after providing a thorough breakdown of the questions. These results will be given in accordance with every one of the open-ended questions, giving a thorough analysis of user experiences and ideas for enhancement. By doing this, it will be made sure that the subjective experiences are comprehended and contextualized correctly.

"1. What part of the app did you find most difficult to use?": In response to this question, there was general agreement among all participants that the sign-up page was the most challenging aspect of the application. The scroll feature made the account sign-up process more difficult because it focused only on the middle column of the page, where the sign-up fields were, rather than the entire page, so some users tried to scroll on static spaces of the screen. These findings point to the necessity for an interface upgrade to improve users' sign-up process.

"2. How did you find navigating through the app?": All survey participants said they had no trouble navigating the system, which they attributed to the home screen's simplicity and the large, prominent buttons. The repeated access to the workouts and posture control regions, displayed on the main screen and in the navigation bar at the bottom, was a point of confusion mentioned by two participants. This shows that app functionalities need to be more efficiently organized to avoid duplication and ensure simple navigation.

"3. Did the gamification aspects of the app motivate you to use the app more often?": All responders rated the leaderboard element of the app's gamification features high marks, demonstrating its ability to promote competition and teamwork within a hospital unit. A participant made an interesting suggestion to consider senior healthcare personnel, who could be less acclimated to such gamified elements.

"4. Which feature(s) of the app did you find most helpful?": Regarding the most useful aspects, the feedback was varied. The targeted exercises were deemed to be the most helpful by three of the five participants, while the remaining two regarded the game to be a valuable resource for brushing up on ergonomics and postural best practices. All participants unanimously agreed that the wearable posture control feature would be most helpful for actively promoting healthy posture once fully functional.

"5. Which feature(s) of the app would you change or improve? How?" : The participants offered a variety of suggestions for increasing the functionalities of the app. Exercise difficulty levels, more thorough sections on the profile page, and an automatic display of the Body Mass Index (BMI) were a few of the suggested enhancements. Participants also recommended improving the scroll function on the sign-up page, making the options in the drop-down menus clearer, adding edit buttons to the profile page to make it clear that personal data may be altered, and using icons more frequently for easier navigation. These suggestions highlight particular areas that might be improved and reflect the participants' desire for a better user experience, assuring clarity and usability throughout the app.

"6. Would you recommend this app to your colleagues? Why or why not?": All participants responded positively to this question, highlighting the significance of musculoskeletal injury prevention. Given its user-friendliness and subject urgency, they shared the opinion that the app would be a helpful resource for colleagues, particularly those with a history of musculoskeletal injuries.

"7. Did you like and see the important role of the wearable implementation on your daily routine as a prevention method?": In response to the follow-up question, all participants expressed their happiness with the creation of the wearable implementation and acknowledged its significance in their daily lives as a preventive measure. They claimed the wearable was simple to use and thought they would be very helpful in preventing musculoskeletal injuries. Participants gave the present implementation very positive comments despite still being a proof of concept. They understood the wearable device's potential to monitor and encourage good posture in the present actively. The participants expressed appreciation for the idea and layout of the elements that had been put in place.

heir enthusiastic response reveals that they strongly accept and believe in the wearable device's potential advantages. It will be vital to fix any technical issues as the development progresses and ensure that the final implementation meets the participants' expectations.

In addition to the foregoing, all participants complimented the application's layout and colour scheme, showing a favourable opinion of its aesthetic appeal.

In conclusion, this feedback offers vital insights into the advantages and room for development of the application. These suggestions can be taken into consideration as the app is further developed to improve usability and efficiency for healthcare practitioners and hence promote musculoskeletal health in this high-risk group.

7.5 Implemented Changes After Participants Feedback

In response to the valuable feedback provided by the participants, some changes have been implemented to address their suggestions and enhance the usability of the mobile application. These changes were aimed at improving the sign-up process, navigation, and overall user experience. The following screenshots demonstrate the updated features:

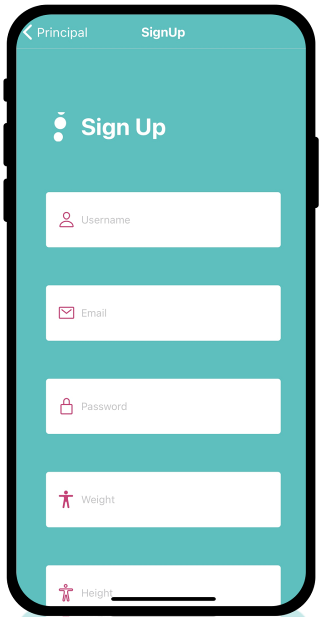

Figure 7.1: Application's profile screen.

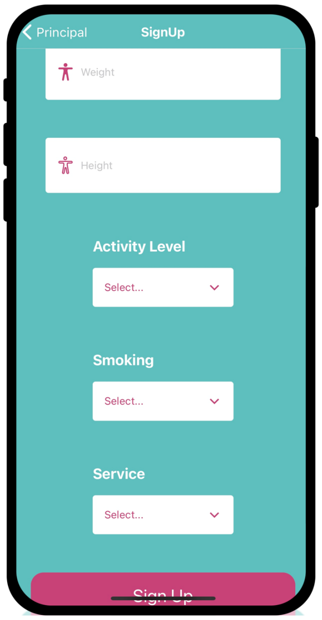

Figure 7.2: Application's game screen.

Figure 7.1 and 7.1 showcases the redesigned sign-up page, which now features an improved scrolling functionality. The entire page is scrollable, allowing users to access all necessary fields without any confusion or difficulties. This change ensures a smoother and more intuitive sign.up process.

Regarding the participants' feedback on the profile page, an "Edit" button has been added to each field, as shown in Figure 7.3. This enhancement clearly indicates that all fields on the profile page can be edited. Additionally, the dropdown menu boxes now include an arrow icon, indicating that they can be expanded and edited. It was also added a BMI (body mass index) field to the page, since it was an important feedback from some participants.

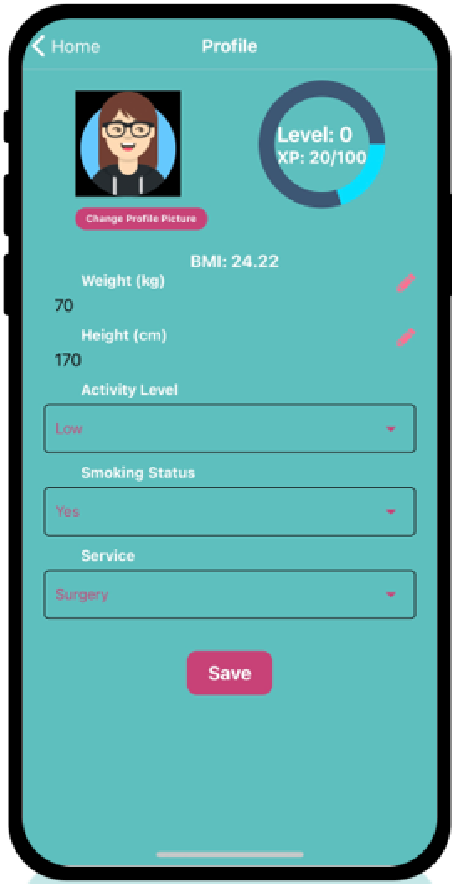

Figure 7.3: Enhanced profile screen with "Edit" button and BMI field.

These implemented changes address the participants' feedback and aim to improve the overall user experience of the mobile application. By making the sign-up process more seamless and clarifying the editability of fields on the profile page, we aim to enhance usability and ensure that users can easily interact with and customize their profiles.

By addressing the specific areas of improvement highlighted by the participants, we aim to provide a seamless and user-friendly experience that meets the needs of healthcare professionals in promoting musculoskeletal health.

It is important to note that the screenshots presented here are a representation of the implemented changes and may not reflect the entirety of the application's features. The ongoing development and refinement of the application will continue to incorporate user feedback to further optimize its functionality and user experience.

Overall, these improvements based on participant feedback demonstrate the continuous enhancement and the responsiveness to the needs and preferences of the users.

7.6 Discussion

The usability evaluation results provide valuable insights into the mobile application's performance and user experience. By examining the participant feedback and quantitative measurements, we can assess the application's strengths and areas for improvement.

The participants, consisting of physiotherapists and nurses with expertise in musculoskeletal health, were selected specifically to evaluate the usability and relevance of the application in a healthcare setting. Their diverse backgrounds and experience levels ensured a comprehensive evaluation of the application's features and design.

Overall, the participants found the application user-friendly and easy to navigate. The simplicity of the home screen and the prominent buttons were particularly praised for their intuitive design. However, some difficulties were reported during the sign-up process, specifically regarding scrolling functionality. This highlights the need for interface upgrades to improve the sign-up experience and ensure seamless account creation.

The gamification aspects of the application, especially the leaderboard feature, received positive feedback from all participants. It was noted that the leaderboard element motivated users by promoting competition and teamwork within their healthcare units. One participant suggested considering the preferences and familiarity of senior healthcare personnel, who may have different levels of comfort with gamified elements.

The targeted exercises and posture control features were identified as the most helpful aspects of the application. Participants recognized the value of these features for promoting musculoskeletal health and maintaining proper posture. The potential of the wearable posture control feature was highly regarded, although it was acknowledged that it was not fully functional in the current prototype. This highlights the need for further development and integration of the wearable device for real-time posture monitoring.

Participants provided several recommendations for improving the application. These included adding exercise difficulty levels, enhancing the profile page with more detailed sections and automatic BMI display, clarifying drop-down options, and using icons for improved navigation. These suggestions align to enhance user experience and address specific user needs.

All participants expressed their willingness to recommend the application to their colleagues, emphasizing the significance of musculoskeletal injury prevention in their field. The user-friendly interface and the app's relevance to healthcare professionals with a history of musculoskeletal injuries were cited as key factors in their positive recommendation.

The open feedback from participants complemented the quantitative measurements obtained through the System Usability Scale (SUS) questionnaire. The qualitative insights provided a deeper understanding of user experiences, difficulties faced, and suggestions for enhancement.

This comprehensive feedback will be valuable in guiding future iterations of the application to improve usability and cater to the specific needs of healthcare professionals.

In conclusion, the usability evaluation results indicate that the mobile application holds promise as a valuable tool for promoting musculoskeletal health in healthcare settings. The positive feedback from participants and their recommendations for improvement will inform the ongoing development and refinement of the application. By addressing the identified areas for enhancement, the application can further enhance its usability, user satisfaction, and effectiveness in supporting musculoskeletal health among healthcare professionals.

Chapter 8

Conclusion

In this concluding chapter, it is provided a concise overview of the main findings and contributions of this Master's thesis. We will summarize the key achievements and contributions on the 8.1 section, acknowledge the study's limitations on the 8.2 section, and outline potential avenues for future research and development on the 8.3 section.

8.1 Contributions

This Master's thesis has made significant contributions to the field of musculoskeletal disorder (MSD) prevention among healthcare professionals through the development of a user-centric mobile application and the exploration of wearable technology. The research results and accomplishments demonstrate the potential of digital health solutions and their function in increasing musculoskeletal health, improving the well-being of healthcare personnel, and establishing a secure and healthy working environment.

Through a systematic review of the literature, important gaps and challenges in MSDs prevention were identified. The review emphasized the need for multidisciplinary approaches and highlighted the promise of digital health solutions in addressing these challenges. The comprehensive analysis of existing solutions provided a strong foundation for the subsequent research and development phases.

The methodology employed in this thesis, including literature review, requirements elicitation, development, and usability testing, facilitated the creation of a mobile application that effectively promotes musculoskeletal health. The application's user-friendly interface, intuitive design, and gamification elements received positive feedback from participants, demonstrating its potential to engage and motivate healthcare professionals in adopting healthy habits and preventing MSDs.

Additionally, real-time posture tracking's potential for reducing musculoskeletal injuries was demonstrated by creating a wearable, as proof of concept. The prototype had its limits but was a concrete illustration of the research's technical proficiency and originality. Integrating the wearable device with the mobile application highlighted the synergistic effects of combining different digital health solutions for a comprehensive approach to MSDs prevention.

The achievements of this thesis extend beyond the technical aspects. By involving healthcare professionals in the research process, their needs, experiences, and feedback were incorporated, ensuring the relevance and applicability of the developed solutions. The willingness of participants to recommend the application to their colleagues further validates its potential impact on healthcare professionals' well-being.

This dissertation has resulted in several contributions. Firstly, a poster entitled "Applying Gamification to Prevent Work-related Musculoskeletal Injuries in Health Institutions" was presented at the symposium named *II Simpósio Internacional de Inovação, Tecnológica e Jogos em Saúde* organized by the association "ADITGameS" on May 31st, 2023. Additionally, an article with the same title, "Applying Gamification to Prevent Work-related Musculoskeletal Injuries in Health Institutions," was published in the proceedings book of the *II Simpósio Internacional de Inovação, Tecnológica e Jogos em Saúde*. Furthermore, an article titled "Usage of Technology and Gamification Elements to Help Prevent Work-related Musculoskeletal Injuries: A Systematic Review" was submitted to the journal *Nurse Educator*.

In conclusion, this dissertation has effectively shown how digital health solutions may be used to prevent and manage MSDs in medical professionals. This research has paved the way for future developments in musculoskeletal health and has the potential to have a significant impact on the well-being of healthcare professionals and the sustainability of healthcare systems by prioritising user needs, engaging in iterative development, and embracing innovation.

8.2 Limitations

While this master's thesis has made significant progress in addressing musculoskeletal disorder (MSDs) prevention among healthcare professionals, it is important to acknowledge the limitations of the study. These limitations include:

1. **Sample Size**: The participant pool for the usability testing phase was relatively small and may not fully represent the diverse range of healthcare professionals. A larger and more diverse sample size would provide a more comprehensive understanding of the application's usability and effectiveness.

2. **Generalizability**: The findings and recommendations of this study may be context-specific and may not apply universally to all healthcare settings. Factors such as workplace environments, organizational cultures, and individual differences among healthcare professionals may influence the application's effectiveness and adoption.

3. **Technical Constraints**: The proof of concept for the wearable device had certain technical constraints, such as limited functionality and prototype limitations. Further research and development are needed to overcome these constraints and refine the wearable device for real-time posture tracking.

4. **Long-Term Evaluation**: While the usability testing provided valuable insights, a long-term evaluation of the mobile application's impact on preventing MSDs is necessary. Conducting longitudinal studies to assess the application's effectiveness over an extended period would provide more robust evidence of its long-term benefits.

5. **Cost and Implementation**: The cost implications and feasibility of implementing the mobile application and wearable device in healthcare settings were not extensively explored in this study. Further investigation is required to evaluate the financial implications, compatibility with existing systems, and potential barriers to implementation.

Despite these limitations, the findings and achievements of this master's thesis lay a solid foundation for future research and development efforts in the field of MSDs prevention. Addressing these limitations through further studies and improvements will contribute to the advancement of digital health solutions and their effective implementation in healthcare settings.

8.3 Future Work

This master's thesis has made significant contributions to the field of musculoskeletal disorder (MSD) prevention among healthcare professionals. Building on the findings and achievements of this research, several areas of future work can be explored:

1. **Refinement of the Mobile Application**: Further refinement of the mobile application based on user feedback and usability testing results. This includes more rounds of user testing and incorporating additional features.

2. **Integration with Existing Healthcare Systems**: Exploring possibilities for seamless integration of the mobile application with existing electronic health record systems and healthcare workflows.

3. **Expansion of the Wearable Device**: Expanding the capabilities of the wearable device prototype developed in this study. This includes incorporating additional sensors for monitoring other aspects of musculoskeletal health and refining the real-time posture monitoring feature for more accurate and immediate feedback, using, for example, machine learning techniques

4. **Long-Term Evaluation**: Conducting long-term evaluations to assess the sustained impact of the interventions on preventing MSDs and improving the overall well-being of healthcare professionals. This would involve tracking participants' progress over an extended period, collecting data on long-term adherence, and analyzing the effectiveness of the interventions in real-world settings.

5. **Collaboration with Healthcare Organizations**: Collaborating with healthcare organizations to implement the interventions on a larger scale and evaluate their effectiveness in

diverse healthcare settings. This would involve working closely with healthcare professionals, administrators, and policymakers to address any implementation challenges and optimize the interventions' impact.

By pursuing these areas of future work, researchers and practitioners can further enhance the effectiveness and practicality of interventions for MSD prevention among healthcare professionals. These efforts will contribute to creating healthier work environments and improving the overall quality of care provided by healthcare professionals.

Appendix A

A. User Interview Script

Introduction 2min
- Moderator introduction - Thank for participation - Present the goal of the study - Describe the outline of the session - Confirm permission to record the audio of the session
Questions 25min
1. What are the most common musculoskeletal injuries that you or your colleagues suffer at your work?
2. How often do you see yourself or a colleague with these types of injuries? (1-10)
3. What do you think is the main reason why these injuries occur so often? Lack of warning or other factors?
4. What strategies do you currently use to prevent musculoskeletal injuries?
5. What challenges do you face in preventing these injuries?
6. What type of information or guidance would be useful in preventing musculoskeletal disorders?
7. Have you ever used any application or mobile tool that has been helpful in the prevention of musculoskeletal disorders or in improving your posture and movements?
8. What features would you like to see in a mobile application that would help prevent musculoskeletal injuries?
9. What would motivate you to use a mobile app for this purpose every day?
10. How much time per shift would you be willing to spend using a mobile application to prevent musculoskeletal injuries?
11. How important is it to you that a mobile application is easy to use and navigate? (1-10)
12. Are there any other factors or considerations that are important to implement in this mobile application to prevent musculoskeletal disorders in healthcare professionals?
13. What could be some of the impediments to using a mobile application in the context of your work environment?
14. What could the app have to help combat these impediments?
Conclusion 2min
Thank participants for their participation.

Table A.1: Interview Script

Appendix B

B. Code Snippet

```
const TrainingSlides = ({ exercises, onClose }) => {
 // ... Code for component functionality ...

 return (
   <View style={styles.container}>
     <Swiper
       ref={swiperRef}
       loop={false}
       showsPagination
       activeDotColor="#1e90ff"
       onIndexChanged={() => setKey((prevKey) => prevKey + 1)}
     >
       {exercises.flatMap((exercise, index) => {
         const exerciseSlide = (
           <View style={styles.slide} key={exercise.id}>
             <Text style={styles.exerciseTitle}>{exercise.name}</Text>
             <Image source={exercise.image} style={styles.
                 exerciseImage} />
             <CountdownCircleTimer
               key={key}
               isPlaying={!paused}
               duration={30}
               onComplete={() => handleNextExercise()}
               colors="#1e90ff"
               size={120}
             >
               {({ remainingTime }) => (
                 <Text style={styles.timerText}>{remainingTime}</Text>
```

```
          )}
        </CountdownCircleTimer>
        <View style={styles.instructionsContainer}>
          {exercise.instructions.map((instruction, index) => (
            <Text key={index} style={styles.instructions}> {
                instruction}</Text>
          ))}
        </View>
      </View>
    );

    // ... Rest of the code ...

    return exerciseSlide;
  })}
 </Swiper>
 {/* ... */}
</View>
);
}

const styles = StyleSheet.create({
 container: {
  flex: 1,
  backgroundColor: '#5EBFBF',
 },
 instructionsContainer: {
  marginTop: 10,
  alignItems: 'left',
  flexWrap: 'wrap',
 },
 exerciseTitle: {
  fontSize: 20,
  fontWeight: 'bold',
  textAlign: 'center',
  marginBottom: 10,
 },
 // ... Styles for UI components ...
});
```

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