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Mobile App for Epidemiological Surveillance in Football

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Master's in Informatics and Computing Engineering

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Abstract

Participation in sports is widely recognized as integral to individuals' well-being, offering physical and mental health benefits. However, the inherent risks associated with sports activities, particularly injuries, can hinder their positive impact. Football, the most popular and widely played sport globally, is no exception, with a notable prevalence of injuries among players. These injuries significantly contribute to professional athletes' loss of playing days and games, negatively impacting players' well-being and teams' performance and economy.

Epidemiological surveillance is crucial for injury prevention. Health professionals ensure players' well-being by defining recovery and injury prevention plans. Effective data collection methods are essential to tailor these plans, improve and assess their effectiveness, and ultimately reduce the incidence of injuries in football. Despite its importance, epidemiological surveillance in football still lacks consistent injury reporting and definition methods, hampering the development of preventive measures.

Currently, manual recording with pen and paper or club-specific spreadsheets are the most used tools, leading to incomplete and inconsistent data. Although there have been attempts to develop injury surveillance systems, none have effectively impacted epidemiological surveillance in football due to the lack of standardized reporting methods, context-specific definitions, and accessibility for football professionals.

This thesis presents the design and development of a mobile health application to enhance the collection, monitoring, and analysis of epidemiological data in football. The application aims to provide a quick, practical, and user-friendly solution that directly impacts the daily process of recording and monitoring injuries by clinicians. Following a user-centered design (UCD) methodology, the application was developed and evaluated through questionnaires and cognitive walkthroughs at three stages: after requirements gathering, user interface design, and development.

Evaluation results indicate that the mobile application offers a quick and efficient solution for recording player demographics, team exposures, and injury episodes. It features a clear, consistent, and user-friendly interface, interactive design, and an easy-to-learn system that centralizes clinical data and provides real-time feedback and statistical metrics, enabling the creation of an epidemiological overview of teams.

Furthermore, this work addresses current problems and lays the groundwork for developing predictive systems that can identify players at increased risk of injury and help assess the effectiveness of preventive measures in the future.

Resumo

A prática de desportos é reconhecida como essencial para o bem-estar dos indivíduos, oferecendo benefícios físicos e mentais. No entanto, os riscos inerentes às atividades desportivas, particularmente lesões, podem prejudicar e limitar o seu impacto positivo. O futebol, desporto mais popular e praticado a nível mundial, não é exceção, apresentando uma notável prevalência de lesões entre os jogadores. Estas lesões contribuem significativamente para a perda de dias de jogo dos atletas profissionais, influenciando negativamente o seu bem-estar, e o desempenho e economia das equipas.

A vigilância epidemiológica é crucial para a prevenção de lesões. Os profissionais de saúde asseguram o bem-estar dos jogadores ao definirem planos de recuperação e de prevenção de lesões. Métodos de recolha de dados são essenciais para adaptar esses planos, melhorar e avaliar a sua eficácia, e, consequentemente, reduzir a incidência de lesões no futebol. Apesar da sua importância, a vigilância epidemiológica ainda carece de métodos de definição e de registo de lesões consistentes no futebol, dificultando o desenvolvimento de medidas preventivas.

Atualmente, o registo manual usando caneta e papel ou folhas de cálculo específicas dos clubes são as ferramentas mais usadas, levando a dados incompletos e inconsistentes. Apesar de terem tentado desenvolver sistemas de vigilância de lesões, nenhum teve efetivamente um impacto na vigilância epidemiológica no futebol, devido à falta de métodos de registo estandardizados, de definições orientadas ao contexto, e à inacessibilidade desses sistemas para os profissionais de futebol.

Esta tese pretende desenhar e desenvolver uma aplicação móvel de saúde para melhorar a recolha, monitorização, e análise de dados epidemiológicos no futebol. A aplicação pretende oferecer uma solução rápida, prática, e com uma interface amigável que influência o processo de registo e monitorização no dia a dia dos clínicos. Seguindo uma metodologia de design centrado ao utilizador (UCD), a aplicação foi desenvolvida e avaliada utilizando questionários e fazendo "cognitive walkthroughs" em três etapas: após a recolha dos requisitos, do design da interface, e do desenvolvimento da aplicação.

Os resultados da avaliação indicam que a aplicação móvel oferece uma solução rápida e eficiente para registar dados demográficos dos jogadores, exposições da equipa e episódios de lesões. Apresenta uma interface clara, consistente e amigável, um design interativo e é um sistema fácil de aprender que centraliza dados clínicos e fornece feedback e métricas estatísticas em tempo real, permitindo a criação de um panorama epidemiológico das equipas.

Além disso, este trabalho aborda problemas atuais e estabelece as bases para o desenvolvimento de sistemas preditivos que podem identificar os jogadores com maior risco de lesão e ajuda a avaliar a eficácia das medidas de prevenção no futuro.

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Rui Alves

"Success is the sum of small efforts, repeated day in and day out."

Robert Collier

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Acronyms and Symbols

ACL	Anterior Cruciate Ligament
CEO	Chief Executive Officer
EPL	English Premier League
FIFA	Fédération Internationale de Football Association
FPF	Portuguese Federation of Football
HR	Hazard Ratio
IOC	International Olympic Committee
ISIS	Injury Surveillance Information System
JWT	JSON Web Tokens
LKIS	Liverpool Knee Injury Study
MDS	Minimum Data Set
OR	Odds Ratio
RR	Risk Ratio
SIRS	Sports Injury Recording System
SISS	Sports Injury Surveillance System
UCD	User-centered Design
UEFA	Union of European Football Associations
WHO	World Health Organization

Chapter 1

Introduction

1.1 Context

The most popular and extensively practiced sport in the world is football, and its participation has resisted the trend that suggests lifelong physical activity is most common in adulthood [42]. Football is a high-intensity sport where players run, jump, pass, shoot, perform abrupt speed changes by suddenly accelerating and decelerating, and even tackle the enemy in possibly aggressive duels. These activities are known for their fast-paced, intensive, and physically demanding technique from a professional standpoint [14, 78, 95].

Therefore, practicing football provides both benefits and injuries for players. On the one hand, previous studies have shown moderate to strong evidence that football activities lead to improvements in aerobic fitness, cardiovascular function, metabolic health, reduced adiposity, and mental well-being [76]. On the other hand, they may lead to higher injury risk and have a paradoxical negative effect on the health of those who practice football, as well as inconvenience for football teams, which may see their investment compromised [25].

Injuries and illnesses can significantly reduce player availability, which negatively impacts team performance and causes economic challenges for clubs, international football organizations, and governing bodies [25, 45]. Moreover, Sergei Palkin, the CEO of Shakhtar Donetsk, a Ukrainian football club, highlighted the financial burden in senior male football, stating that the average cost of a first-team player being injured for one month is approximately 500,000 Euros [25].

Epidemiological surveillance plays a vital role in proactively addressing the multifaceted challenge posed by injuries in football. By systematically collecting and analyzing health data related to football injuries [8], epidemiological surveillance provides a comprehensive understanding of injury patterns, prevalence, and contributing factors. This valuable insight serves as a guiding force for evidence-based decision-making and as the basis for developing and implementing preventive programs [43]. These programs, as highlighted by Bahr [4] and Rahnama [82], are not only crucial for averting injuries and safeguarding players' health but also play a vital role in minimizing costs and enhancing overall team performance. To perform such surveillance, clinicians

collect data mostly using pen-and-paper, leading to data and recording and monitoring methods inconsistencies. Furthermore, technical professionals of teams don't have a deeper understanding of the epidemiological situation of the players and the team overall, leading to an uninvolvement and interest by those professionals in such data due to a lack of visualization tools, where poor cooperation between coaching and medical teams may increase the risk of injury [39].

1.2 Motivation

Football presents one of the biggest sports markets. Despite that, injury rates are among the highest of all sports [7, 42, 48, 86], compromising the well-being of those who practice it and the performance and economic results of their teams [45, 67]. As a result, all the improvements that can be made to reduce injury prevalence may significantly impact football.

Epidemiological surveillance is crucial for football players' well-being as it helps to develop injury prevention methods. In order to help health professionals perform epidemiological surveillance, injury registering and monitoring systems are crucial [86]. Furthermore, the lack of tools to record and monitor injury incidence and prevalence is a reality in football, making football injury registry hard and inconsistent between teams [1]. Thus, the core motivation of this dissertation is the innovative advances in the field and the feasibility of integrating this solution into the daily habits of football health professionals, directly impacting how epidemiological surveillance is done in football.

Another force for this study is the need to collect large amounts of meaningful data on injury epidemiology, which is essential for the future aim of feeding predictive systems that inform about players at increased risk of injury. Additionally, it plays a pivotal role in evaluating the effectiveness of preventive measures, emphasizing the significance of robust data collection in advancing injury prevention strategies [43].

1.3 Objectives

Injury prevention is the final product of a set of steps defined as a "sequence of prevention" that starts with epidemiological knowledge, which is context-specific. Epidemiological studies in sports, and football specifically, face severe problems in terms of injury and methodological inconsistencies. Therefore, this dissertation aims to design, develop, and implement a quick, practical, and user-friendly injury registry software to record and monitor injury incidence and prevalence among football players, directly impacting how clinicians register injuries and perform epidemiological surveillance.

For that, this study aims to answer the following question: **What is the impact of using a mobile application in the injury recording and monitoring processes in football?** In order to answer this question, the following objectives were defined:

1. Analyze and describe the main problems in the injury recording and monitoring process

2. Study the impact of using a mobile app in the injury recording and monitoring process done by clinicians
3. Collect meaningful data on injury epidemiology for future feeding of predictive systems that inform about players at increased risk of injury
4. Collect meaningful data on injury epidemiology to help assess the effectiveness of preventive measures

1.4 Document Structure

The document is organized into seven chapters, each meticulously crafted to unfold distinct facets of the work developed, and the appendix:

Chapter 1 - Introduction: The first chapter initiates the exploration by providing a global perspective and context on football, examining its widespread popularity, and delineating its unique challenges. Motivations behind the study are then unpacked, navigating the dual nature of football activities—balancing benefits and inherent injury risks. Defined objectives guide the subsequent exploration. A concise overview of the document's structure is offered to orient the reader.

Chapter 2 - Epidemiological Surveillance in Football: This pivotal chapter establishes the foundational understanding of epidemiological surveillance concepts and their applications in football. The examination delves into injury epidemiology in sports, emphasizing risk measures, quantification challenges, and injury risk assessment. The sequential approach to sports injury prevention and insights into existing surveillance systems, specifically Injury Surveillance Information Systems (ISIS), are elucidated. The chapter concludes with a summary.

Chapter 3 - Methodology: This chapter presents the approach to reach the proposed solution solution to the problem. It explores each of the steps followed and explains the evaluation phases of the mobile application.

Chapter 4 - Requirements Gathering: This chapter delves into the requirements gathering step for the mobile application. Here, an explanation of the different users is presented, as well as the requirements for the mobile application and, more concretely, the data it will collect. Furthermore, it shows the constraints between the data and the validation of the idea of the mobile application, its content, and functionalities as a result of a questionnaire.

Chapter 5 - Mobile Application: In this chapter, the solution is presented. An overview of the architecture, the user interface for the mobile application pages, and its evaluation are shown. In the end, the architecture of the database is presented, followed by the summary of the chapter.

Chapter 6 - Mobile Application Evaluation and Results: This chapter further explains the cognitive walkthrough performed in the last evaluation of the mobile application, as well as its results and discussion.

Chapter 7: Conclusions - This final chapter summarizes the accomplishments of the research, discusses the limitations encountered and outlines potential directions for future work to improve the presented solution and epidemiological surveillance in football.

Appendix A: This appendix includes a set of figures and forms describing injury recording methods from UEFA forms and the architecture of some systems explored in the literature review.

Appendix B: This appendix presents the questionnaires provided in the three evaluation steps performed in the presented work.

Chapter 2

Epidemiological Surveillance in Football

This chapter explains some fundamental concepts of Epidemiological Surveillance applied to football as the result of a literature review on the field and the analysis of similar systems. The research performed was fundamental to deeply understanding the needs of the area and how the concepts are correlated, leading to a first definition of the system's requirement to develop.

2.1 What is Epidemiological Surveillance

Epidemiological surveillance is a fundamental component of public health initiatives, characterized by the systematic collection, analysis, and dissemination of health data. This process is crucial for the planning, implementation, and evaluation of public health programs, serving as a guiding force for evidence-based decision-making [8]. Recognizing the diverse nature of health events, including injuries, epidemiological surveillance emphasizes the need for context-specific studies. Reinforced by Van Mechelen *et al.* [69] and Hagglund *et al.* [43], context-specific insights collected from detailed analyses contribute to a deeper understanding of injury patterns and risk factors and, therefore, sports-specific measurements should be made to identify the aetiology or effectiveness of those strategies.

2.2 Injury Epidemiology in Sports

Injury epidemiology is a key factor in football to characterize injury occurrence and identify risk factors and their impact on injuries [62]. Consequently, the results from injury epidemiology are crucial to developing effective injury prevention strategies [24]. Injury epidemiology is not possible without prior injury surveillance, which consists of the continuous collection of data describing injury occurrences and the factors associated with it [28].

The high risk of injury presented in football led to an increased interest in understanding the circumstances and the activities performed at the time of injury and which potential mechanisms

teams and players can take to prevent it [1]. A trend of imprecise and perplexing terminology concerning injury and illness occurrence measures, coupled with communication about associated risks, has been observed [47], partially explained by the interchangeability of similar terms and ambiguous definitions, leading to confusion and debating within the field of epidemiology [9, 94].

In our daily vocabulary, the term "risk" often denotes the potential for harm or danger. Whether it's environmental factors or individual behaviors, identifying someone as "at risk" implies a causal link, suggesting an increased likelihood of harm, danger, or disease [9]. In epidemiology, risk usually refers to the probability of experiencing adverse outcomes, such as disease development or mortality, within a period of time [80]. The prime interest of epidemiology lies in understanding the association between these risks and various environmental, individual, and social characteristics known as risk factors. Several factors may affect injury rates, including the player's age, height, dominant kicking leg, playing position, and match-exposure playing time [92]. Additionally, exercise load (duration, intensity, and frequency of practice) strength, flexibility, injury recurrence, days of rehabilitation, and poor running performance have also been suggested as injury risk factors [92]. Those factors and any external condition must be collected and analyzed to assess the effectiveness of injury prevention measurement and find patterns in injury incidences [43]. The problem arises in the common risk factor definition. In epidemiology, in contrast to everyday language, the term risk factor does not necessarily imply that the characteristic has a causal effect, but an association [9], leading to imprecise interpretations in contemporary epidemiology, as the analysis of risk factors is the starting point of causal understanding in epidemiology but does not necessarily imply it. Therefore, risk factors are characteristics that are known to be associated with meaningful health-related conditions [80].

2.2.1 Risk measures and quantification issues

At the heart of quantitative epidemiology lies a simple fraction, where the upper part (numerator) and lower part (denominator) form the basic arithmetic. However, when we delve into epidemiological terminology, rooted in everyday language and mathematical concepts, nuances emerge that warrant careful consideration. A Dictionary of Epidemiology [80] defined *ratio* as "the value obtained by dividing one quantity by another", a generic definition that leaves room for interpretation. Moreover, it defined *rate* as "a measure of the frequency of occurrence of a phenomenon". In epidemiology, demography, and statistics, a rate is characterized as an expression of how frequently an event occurs in a defined population, typically within a given time frame, and is frequently used for ratios where the numerator and denominator have different properties, such as deaths/population[9]. The third definition for quantifying frequency is proportion, which, in epidemiology, is usually a ratio where the numerator is a part of the denominator, so both have the same qualities. Since the numerator and denominator have the same dimension, canceling out any dimensional content, resulting in a dimensionless quantity [9, 80]. Therefore, both rate and proportion are types of rations, which are used in different situations.

Epidemiologists often explore the occurrence of disease in a population, using both absolute and relative measures. When identifying the causes of disease, a comparative (relative) approach

is used. Meanwhile, assessing a population's health needs is most effectively done by examining the actual health pattern through an absolute approach [9]. Three ubiquitous statistical measures are further explained in order to deeply understand absolute and relative risk measures.

The risk ratio (RR) statistic, also known as relative risk, represents the ratio between two risks, indicating how many times the risk in one group is higher compared to another [38]. This brings limitations to this measure as, since the risk in a sample is an estimate of the risk in a population, then the sample must reasonably represent the population [38]. Also, since it is a relative measure between two ratios, further context of those ratios must be provided in order to deeply understand the result. As an example, the risk ratio for two groups that had a risk of 0.2% and 0.1%, and for two groups that had a risk of 90% and 45% is the same and equal to 2, but the conclusions from it may not be the same. Therefore, reporting only the RR can exaggerate the results in the first case while potentially minimizing it in other cases, the second one [38].

While risk reports "the number of events of interest in relation to the total number of trials", *Odds Ratio* (OR) reports "the number of events of interest in relation to the number of events not of interest" [38]. Therefore, as it determines the association between two variables and not their causality, OR does not suffer from the causal assumptions of RR and is more widely applicable [38].

As both RR and OR concern interventions and outcomes, they are reported across an entire study period. Therefore, *Hazard Ratios* (HRs) are a way to compare how quickly two groups experience a specific event over time, like developing a disease or passing away, comparing the slope of two survivorship curves [38]. Therefore, hazard ratios make the proportional rate assumption, as the hazard rates must be constant over time. The difficulty arises in determining whether the proportional hazard assumption applies and, therefore, hazard ratios can be used. Because of that, median times are often used to report HRs [38].

2.2.2 Injury risk

Although injury risk holds significance as a performance indicator across various industries, its theoretical foundations and practical application remain less understood within the realm of sports [35]. The concept of injury risk was initially introduced by Quarrie and Hopkins [81], who then proposed the term "injury burden" as a preferable alternative to mitigate potential confusion with other interpretations of the term "risk" in injury epidemiology, such as "the average probability of injury per athlete" [55]. Incidence has been defined as "the number of new health-related events in a defined population within a specified period of time" [80] and includes three key elements: new events (incidence number), a study population of people at risk (defined by characteristics, place, and time boundaries) [9], and a specific amount of time over which the study population is followed/observed [2]. Therefore, different study populations lead to different results, as incidence rate is "the number of new events among those at risk of developing the disease in the study population over a defined period of time" [31] and, therefore, different populations at risk produce different incidence rates. Moreover, incidence rate may be confused with prevalence proportion,

"the part (percentage or proportion) of a defined population affected by a particular medical disorder at a given point in time, or over a specified period of time" [94]. While incidence measures the rate of occurrence over a period in a longitudinal study, prevalence measures how frequently an event occurs at a particular moment, typically in a cross-sectional sample [94]. Researchers often misinterpret the specific definitions of terms due to their definition's specificity, particularly using "rate" interchangeably with "proportion" and sometimes with "ratio" [94]. As a consequence, comparing results between different studies is challenging and often impossible.

Injury incidence and burden rate are commonly employed metrics used to report injury statistics in sports [63]. Injury incidence is defined by Ekstrand *et al.* [24] as "the number of injuries per 1000 hours of exposure", encompassing training, match, or combined activities. Injury burden rate quantifies the "total number of days lost to injury per 1000h of exposure" in training, matches, or combined activities and has been suggested by Bahr *et al.*[6] to be used alongside injury incidence, emphasizing that incidence alone may be insufficient for defining injury risk comprehensively. Moreover, since injury burden is calculated as the product of injury incidence and severity, which is characterized by the mean days lost due to injury [70], it has been most recently suggested to represent burden as "a cross-product in a joined metric of severity, and incidence, using an injury burden matrix" by Bahr *et al.* [5].

2.3 Sports Injury Prevention

Injuries have severe consequences not only for the player, who sees his physical and psychological condition negatively affected, but also for the teams where they play [25, 45]. Recent studies have shown that team performance is affected by a decrease in players' availability and a negative correlation between a team's performance and the variables that characterize sports injuries [26, 67]. More specifically, in his study, Raya [84] concluded that the prevalence rate of professional players is 15%, meaning that in a 25-player team, approximately 4 players are not available to participate in every training session and/or official match, making sports injury the main factor that prevents football players from training and playing during the season [67]. Moreover, in his study in *English Premier League (EPL)*, Eliakim *et al.*[26] found a statistically significant relationship between the number of days out due to injuries suffered by team players during a season and a difference between the place they finished and the expected one in the EPL table. His results show that an EPL team loses an average of £45 million due to injury-related decrement in performance per season. Moreover, the study concluded that approximately 271 days out due to injury may cost a team one place in the EPL table and that approximately 136 days lost due to injury causes a team to lose one league point.

Therefore, injury prevention constitutes one of the main topics in Sports Medicine and one of the main areas of interest for Sports Medicine practitioners [30]. Defined as a set of actions that aims to "eradicate, eliminate, or minimize the impact of disease and disability, or to retard its progress" [80], prevention has a vital role in reducing injury rates. As a result of this interest, several studies have been made, showing that injury prevention programs can significantly reduce

injury risks. One example is the "The11", developed with the support of the World Football Association FIFA, which reduced injury rates in Swiss junior soccer players by 21% [98].

2.3.1 The Sequence of Prevention

The impact of injury prevention strategies cannot be assessed without reviewing the "sequence of prevention" [70], which requires a picture of the broad epidemiological context [46]. This approach not only enables the assessment of the effectiveness of preventive measures but also facilitates the identification of aetiological [1] factors contributing to injuries [69]. This is the first step of injury prevention, and it is crucial for safeguarding athletes' well-being and optimizing time, logistics, and financial resources for efficient interventions [36]. Following the *sequence of prevention*, it is initially essential to ascertain and articulate the scope of the sports injury issue. Subsequently, it is vital to identify factors and mechanisms that contribute to sports injuries. The third step involves implementing measures to diminish the prospective risk and/or severity of sports injuries, grounded in the aetiological factors and mechanisms revealed in the second step [70].

As a result, collaboration between sports institutions and governmental bodies becomes imperative for elucidating the epidemiological data on sports injuries [29] and to adopt preventive measures or assess their effectiveness, as a recurrence of the initial step of the sequence of prevention and based on the epidemiological studies performed in the second step [43, 70]. Therefore, it is the responsibility of those entities to show an agenda of care for athletes' health in epidemiological research [28, 33].

2.3.2 Injury reporting and definition

Accurate and consistent recording and reporting of injury mechanisms are pivotal, allowing for the combination, comparison, and generalization of findings across studies [43]. However, the domain of sports injury definitions confronts a notable challenge marked by a lack of consistency and uniformity across existing literature [34]. Therefore, significant limitations in the reliability of broad surveillance definitions stem from the data collector's level, where issues arise due to inconsistent data collection methods and varying injury definitions. These discrepancies result in inconsistent data gathered from different systems [17].

Injury is defined by the International Olympic Committee (IOC) [5] as "tissue damage or other derangement of normal physical function due to participation in sports, resulting from rapid or repetitive transfer of kinetic energy". Moreover, an injury can be classified as a "medical attention injury" when it results in a player receiving medical attention, or a "time-loss injury" when an injury results in a player being unable to take a full part in future football training or match play [34]. These different injury definitions and reporting methods lead to inconsistencies and make it difficult to make direct comparisons between studies [43]. Additionally, some practitioners may have an alternative modus operandi [32]. This leads to heterogeneity in clinical reporting

[1] the cause, set of causes, or manner of causation of a disease or condition.

and, therefore, the impossibility of treating the data and performing any epidemiological study [19]. The problems in data gathering are likely to be even worse in lower-level leagues, as clinicians have even fewer resources (both technological, time and/or knowledge or the possibility of discussion) [85].

In the pursuit of methodological rigor and coherence in sports injury research, the establishment of standardized definitions and uniform data collection procedures is of paramount importance. Acknowledging this imperative, several attempts have been made to reach a consensus both in definition and reporting [34, 43], but since no definition is likely to suit all needs [17] and different contexts of surveillance lead to different choices of definition (one size does not fit all) [69], none of those were completely adopted. This resulted in a fragmented landscape that complicates the understanding and reporting of sports-related injuries, emphasizing the need for further developments in sport-specific guidelines to capture inciting circumstances effectively [1, 34].

Despite being regarded as important, there is no definitive methodology to gather clinical epidemiological data. Several studies have been conducted in many countries, with different methodological approaches: studies conducted in Spain [88], Norway [11], Qatar [22], England [51] or Netherlands [97] have used clinical records specifically required for the clinicians to fill-out during the study. Others, such as Italy [27] or Germany [54] have used data from databases containing clinical information gathered for the general public or for public interest, such as internet databases in Italy or data from insurance companies in Germany.

These epidemiological descriptions fall short since their follow-up is often short in time, not allowing for recording trends in injuries and, therefore, making it difficult to infer the preventive effectiveness of intervention measures and extrapolate from previous to the current epidemiological landscape. Also, these studies often only account for some sports populations, mainly adult men's football, showing a lack of generalization [23]. When considering data from hospitals and/or insurance companies, injuries that do not require medical care in hospital facilities or do not go through the insurance process are lost. The only published attempt in which governing bodies have promoted a concerted epidemiological record is from England [95], in which more than 50 clubs have reported clinical injuries in both adult men's and women's football and youth teams. This initiative began in 2012 with the Injury and Illness Surveillance Study prompted by the Football Association, the English football governing body.

2.4 Surveillance Systems

The traditional pen-and-paper method has long been a staple in recording injury data within the realm of football [52]. Coaches, medical staff, and sports professionals document injuries, their contexts, and subsequent treatments in physical forms. These forms are used to record player's baseline information, exposure data, and injuries. As stated before, several attempts have been made in order to standardize this information, and for information recording, UEFA provided template forms to report player's baseline information, exposure data, and injuries (*see Figure A.1, Figure A.2, and Figure A.3*) that currently are used by several European Teams [34].

This approach, along with injury definition problems stated previously, creates substantial difficulties for professionals in gathering data and performing epidemiological studies [12]. First, they have to enter data twice, once for their own records and again for surveillance purposes. Second, they have to mail or fax injury and exposure data. This practice introduced multiple opportunities for data-entry errors, further emphasizing the drawbacks of this methodology in terms of efficiency and accuracy [52]. Moreover, the subjectivity in injury reporting, coupled with the potential for data loss or incomplete records, underscores the need for a more sophisticated and technologically advanced approach [17].

2.4.1 Injury Surveillance Information Systems (ISIS)

While injury definitions may be challenging to adopt and universally accepted, as they depend on sports-specific context [43, 34], the issues with pen-and-paper registry could be solved using web-based systems. The aim of those systems is to ensure a more comprehensive collection of data, thereby providing more accurate estimates of injury incidence in sports-related settings [52], following Van Mechelen *et al.* [70] statement that "injury prevention benefits from ongoing monitoring of injury incidence", and updated descriptive epidemiology is needed. Furthermore, the implementation of injury surveillance information systems (ISIS) allows the management of vast amounts of injury data required for epidemiological studies, real-time data access, enhances the quality of care, reduces medical and medication errors, decreases documentation time, and provides rich data for research [71]. Moreover, these systems allow continuous data collection and analysis, one of the major problems with previous pen-and-paper registries, and allow systematic reviews of injury surveillance, improving injury prevention measures and reducing injury incidence [99].

Accurately calculated and reported injury indices can inform policy-making, reduce the burden of injuries, and optimize service provisions [71]. For instance, the World Health Organization (WHO) defined injury surveillance guidelines and suggested a Minimum Data Set (MDS) of information to be collected from an ISIS [41]. As noted in the WHO guidelines, the priorities of an ISIS and respective available resources influence the amount and type of data collected. Therefore, extra information can and should be added apart from the MDS to gather insightful information from a specific context [71].

A review done by Mirani *et al.* [71] shows that the data collected from ISIS depends on the purpose of the system. In some studies, the data elements of the Injury Surveillance Information System (ISIS) are categorized into core and supplementary data. Each category includes mandatory and optional MDS to facilitate quick data introduction. Additionally, the inclusion of extra information is highly context-dependent and should be reported as supplementary data.

2.4.1.1 ISIS Advantages

The extensive range of data collected by Injury Surveillance Information Systems (ISIS) is notable. Despite the challenges posed by data divergences, these variations offer valuable opportu-

nities for conducting targeted epidemiological studies in specific contexts. This diversity in data elements contributes to a more comprehensive understanding of the injury landscape, facilitating effective injury monitoring and surveillance. Furthermore, the data richness supports various levels of injury prevention, encompassing primary prevention (preventing injury events), secondary prevention (mitigating the nature and severity of injury), and tertiary prevention (providing timely and appropriate medical care and rehabilitation) [71].

Therefore, using injury surveillance information systems to register and monitor data is inevitable. Sklaver *et al.* [91] emphasized the importance of the Injury Surveillance Information System (ISIS) for outcome evaluation and proposed an electronic framework capable of collecting, tracking, and sharing injury data, while also generating reports tailored to various levels of the healthcare system. Mitchell *et al.* [72] considers data linkage as one of the most important functions of an ISIS and that using a web-based data warehouse can improve its effectiveness. To ensure high data quality, injury data must be continuously monitored, which can be accomplished by having a well-designed database in the specific context [71, 73, 57]. Martinez *et al.* [66] highlighted the importance of visual forms in order to understand patterns and trends and to transform data into understanding. They presented two real-case studies underscoring the crucial role of data visualization platforms within Injury Surveillance Information Systems (ISIS). The use of such visual tools enhances the likelihood of data utilization by policy-makers and injury surveillance managers, fostering knowledge creation in the process [71].

Another advantage of using ISIS is the possibility of distributing injury data. By initially filtering and summarizing data according to confidentiality policies and users' requirements, an ISIS allows the dissemination of data while ensuring data privacy with a reduced cost and time [66, 71].

2.4.1.2 ISIS Disadvantages

Despite all the advantages of injury surveillance systems, difficulties emerged from their usage. First, the developed systems are context-targeted, with different specifications and definitions. Most of these systems aim to reduce mortality by reporting the proportion and characteristics of injuries in the at-risk population, having different data registries and definitions, leading to data losses [71] and difficulties in merging their data to perform epidemiological studies, as there are inconsistencies in data. Second, the management of injury data remains a complex and challenging process, as current injury surveillance systems are not sufficiently developed to accurately quantify the burden of injuries on individuals, health services, and society [87].

Furthermore, and characterized by their specificity, the existence of diverse ISISs also constitutes a problem in terms of data linkage, where different definitions may lead to different results [17, 69]. With this, difficulties in the development of the system also come across, which may require extended efforts to reach stakeholders and full-time professionals for its development and for monitoring injuries [71]. Moreover, it is noteworthy that despite technological developments, developing and using ISISs is slow, especially in developing and under-developed countries where access to technology is reduced [71].

2.4.1.3 Mobile Health Applications

One emerging domain in the development of injury surveillance information systems is mobile health (mHealth) applications. Involving mobile computing for the development of mobile applications, mHealth has been recognized as a transformative area in sports medicine [100] as it helps monitor parameters of performance and injury of athletes' health while ensuring data consistency and easy data registry. Healthcare professionals have widely adopted specific mobile applications in clinical practice, leveraging these tools to enhance clinical decision-making outcomes and monitoring capabilities [3, 74].

In sports, mobile applications have also been a trend with several attempts for prospective injury and exposure monitoring. Robinson *et al.* [90] developed a mobile application for monitoring anterior cruciate ligament (ACL) injuries during dynamic sporting activities in a two-year prospective cohort study. The developed application for the referred study, Liverpool Knee Injury Study (LKIS), weekly collected data concerning sports exposure and dynamic-loading-related injuries, as well as the time of exposure. Focusing on simplicity, the application provided simple yes/no questions to the participants, as described in the flow-chart of Figure A.4. The system comprised a mobile application designed for data collection, with data stored on a dedicated web server and checked weekly by the researcher (Figure A.5). The welcome page, menu page and log activity/injury page of LKIS application can be seen in Figure 2.1. Despite efforts, the study did not observe any ACL injuries, and, therefore, no conclusions were taken. Robinson *et al.* [90] suggested that the timing of participant recruitment and assignment to the LKIS mobile app, along with the limited participant numbers, could have influenced the observed outcomes. Despite these challenges, Robinson *et al.* [90] expressed confidence in the suitability of the LKIS mobile monitoring app for its intended purpose and proposed that other factors, such as the method of self-reporting, likely played a more significant role in the success of monitoring and presented hiring research assistants or establishing a larger interdisciplinary team, to ensure more rigorous enforcement of injury reporting as possible solutions.

Soomro *et al.* [93] developed a mobile application, TeamDoc, to monitor injuries and workloads in junior cricket. Throughout its development, the authors emphasized critical considerations for mHealth applications. Therefore, the system should be designed to ensure confidentiality, where the player is the one who provides data. On a second priority, the app should be user-friendly and allow an easy data registry process that does not last more than 2 minutes. As the last, the application should be usable and adaptable to several operating systems, leading to more data registries, where injury and workload data should be easy to read and interpret. To ensure all of these, another consideration was the need for a back-end server to store the data securely for further analysis. Similarly, in its study to compare two sports injury surveillance systems, Ebrahimi *et al.* [99] reinforced the importance of easy access and user-friendly tools for injury recording.

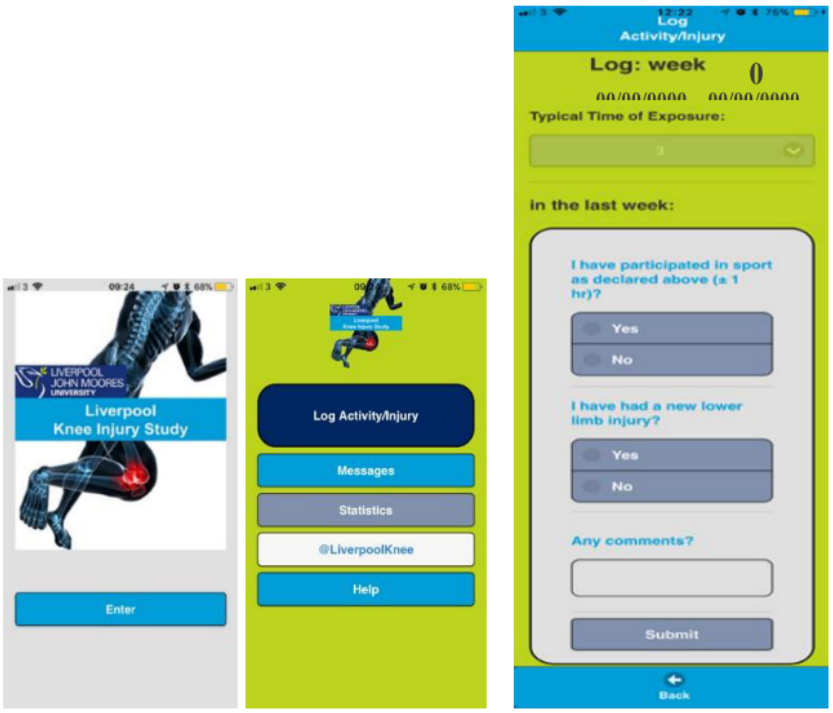


Figure 2.1: (Left to right) LKIS mobile application welcome page, menu page, and log activity/injury page.

2.4.1.4 TeamDoc

To safeguard player privacy, Soomro *et al.* [93] developed TeamDoc, a mHealth application consisting of three components: a player interface, a coach interface, and a back-end system for data storage. The software was structured around a client-server architecture where the player and coach interfaces function as clients, making resource and service requests, while the back-end system serves as the server. For that, two different applications were developed for the players and coaches.

The player application was designed with a write-only function to allow data entry exclusively, preventing access to individual output data to maintain data privacy. Similarly, the coach application features a read-only function that restricts data access, ensuring that coaching staff cannot modify data once entered by players, thereby maintaining data security and authenticity, which is crucial in environments where multiple coaches may be involved. Additionally, a server-side operations website was developed to monitor data, enabling both players and coaches (or medical staff) to log in, register, and, if necessary, reset their passwords.

TeamDoc had considerable positive results in terms of data validation. In its study, despite only 3 out of 8 cricket club teams agreeing to participate, Soomro *et al.* [93] validated the data collected by the app against the data stored on the server, showing a 100% accuracy rate in their findings. Furthermore, using "branching" logic in data insertion allowed a dynamic feature introduction, reducing data inconsistencies and errors. The major user perception of the application was the

lack of the user interface, requiring more interactive options, feedback, and data visualization tools, with, for example, graphical representations of injury reports. This absence of interactive features also led to a negative user perception, as they felt that they were investing too much time in filling out information compared to the benefits derived from it.

For future developments, Soomro *et al.* [93] highlighted the need for improved user interface (UI) and interactivity to attract and retain users, which, along with time-consuming and forgetfulness, was one of the reasons for not using the app. Some examples of the user interface of the TeamDoc application can be seen in Figure 2.2 and Figure 2.3.

2.4.1.5 Sports Injury Surveillance System (SISS)

Varkiani *et al.* [99] identified several shortcomings in the sports injury recording system (SIRS). They noted that the system lacks essential indices such as injury type, severity, timing, re-injury occurrences, and other pertinent information crucial for the subsequent steps in injury prevention, which could negatively affect the prevention of injuries. Moreover, it highlighted the system fails to accurately report injury incidence rates and lacks standardized classification of injury reports. The authors highlighted a specific implementation flaw where athletes' paper-based injury reports submitted to the provincial board of the Sports Medicine Federation contributed to inefficiencies, and that the absence of a clear injury definition within the SIRS resulted in incomplete data, underscoring a significant weakness in the system.

In order to overcome those deficiencies, Varkiani *et al.*[99] developed a sports injury surveillance system (SISS) and compared the results with the sports injury recording system (SIRS) used in Iran for sports injury data collection. In the developed SISS, Varkiani *et al.*[99] included numerous essential epidemiological indexes to improve data completeness and further epidemiological studies and compared the results with the previous SIRS system. In their findings, Varkiani *et al.* [99] observed a notable disparity in injury incidence between the two systems under investigation. Over a span of 6 months, the mobile Sports Injury Surveillance System (SISS) recorded 81 sports injuries across five selected sports disciplines in Alborz Province. In contrast, the traditional Sports Injury Recording System (SIRS) reported only 19 sports injuries during the same period.

Varkiani *et al.* [99] emphasized that the structure of the Sports Injury Surveillance System (SISS) addresses several deficiencies of the traditional Sports Injury Recording System (SIRS), including issues such as athletes failing to report to the board, underreporting of low-intensity sports injuries, athletes' reluctance to report injuries, and inadequate documentation of athletes requiring medical treatment services. Furthermore, Varkiani *et al.*[99] also reinforced the importance of employing practical, easy-access, and user-friendly tools for the reporting of injuries, as it allows a fast and easy injury reports registry anywhere, even near the court, reducing injury loss. Some pages of the mobile application developed can be seen in Figure 2.4.

2.5 Summary

Briefly, this chapter discusses the importance of epidemiological surveillance in reducing injury risk and incidence in football. With the sequence of prevention in mind, epidemiological studies are the foundation for creating and assessing injury prevention measures, which can only be done with previous data collection. The conventional pen-and-paper method for recording injury data in football has long been the standard practice, but its inefficiencies and drawbacks have prompted the exploration of more advanced alternatives. The introduction of Injury Surveillance Information Systems (ISIS) marks a significant shift, aiming to streamline data collection, enhance accuracy, and facilitate epidemiological studies in sports-related settings. The ISIS approach not only addresses the challenges of data entry errors and subjective injury reporting but also allows for continuous data collection and real-time analysis, thus improving the overall quality of care and supporting research initiatives.

The advantages of ISIS are evident in its diverse data collection capabilities, providing valuable insights for different levels of injury prevention—ranging from primary prevention to the timely and appropriate provision of medical care and rehabilitation. Organizational guidelines and minimum data set recommendations like the ones provided by the World Health Organization contribute to the collection of more precise injury indices, enabling informed policy-making and alleviating the burden of injuries. Despite these merits, ISIS faces challenges, including system context specificity, diverse specifications, and slow adoption in certain regions. The complexity of managing injury data and the lack of universal standards contribute to data linkage and overall system development difficulties. Additionally, the emergence of mobile health applications, exemplified by TeamDoc, the Sports Injury Surveillance System (SISS), and the Liverpool Knee Injury Study (LKIS), represents a promising frontier in injury monitoring. These applications leverage mobile computing to ensure data consistency, easy registry, and user-friendly interfaces, addressing the limitations of traditional methods.

In conclusion, the evolution from pen-and-paper methods to technologically advanced systems, such as ISIS and mobile health applications, signifies a crucial advancement in injury surveillance in sports. While challenges persist, the potential for enhanced data accuracy, accessibility, and prevention measures positions these systems as valuable assets in sports medicine.

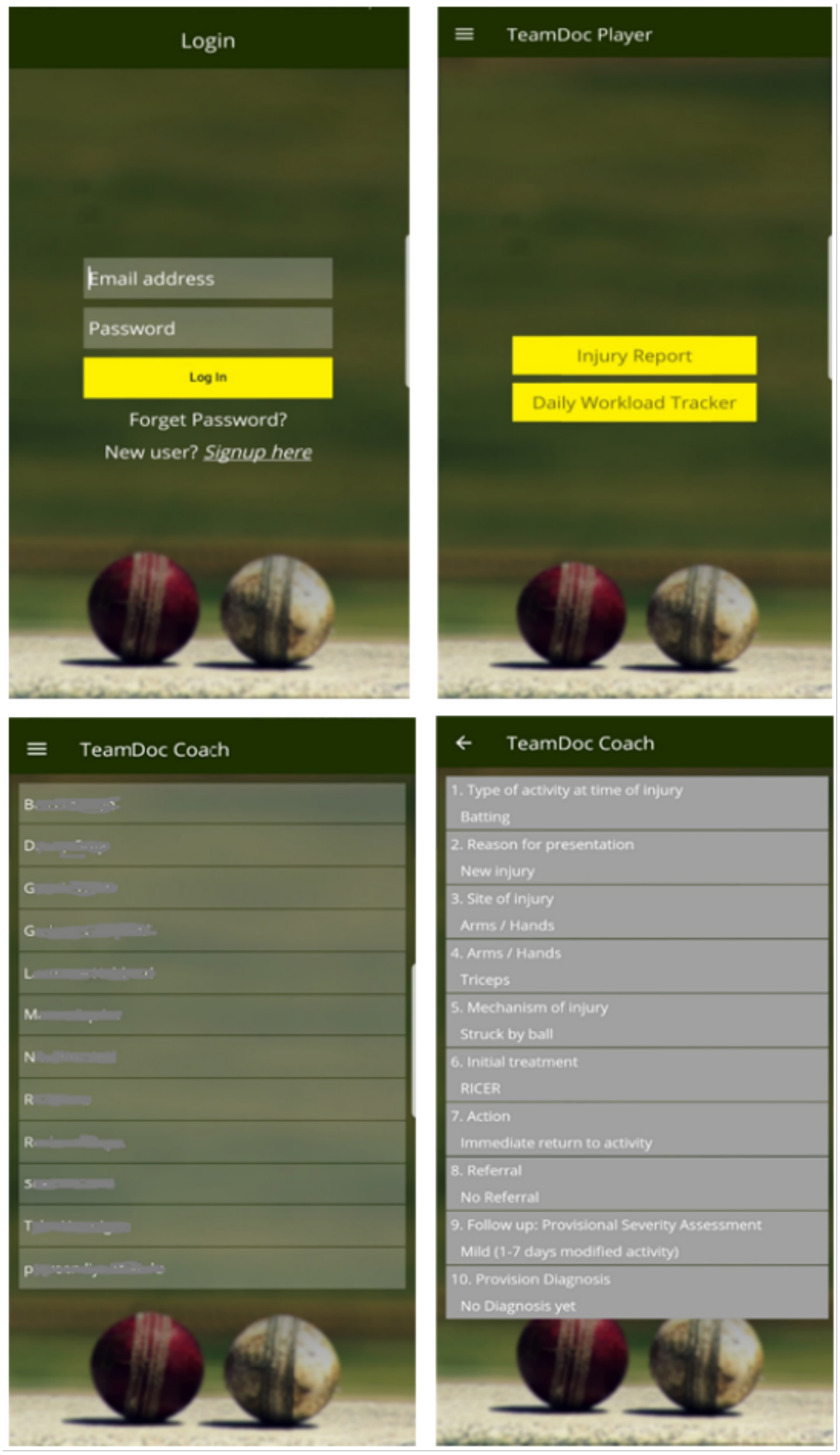


Figure 2.2: User interface of the TeamDoc app. Top left: log-in view; top right: main tab of the player app; bottom left: main tab of the coach app; bottom right: injury report tab in the coach app.

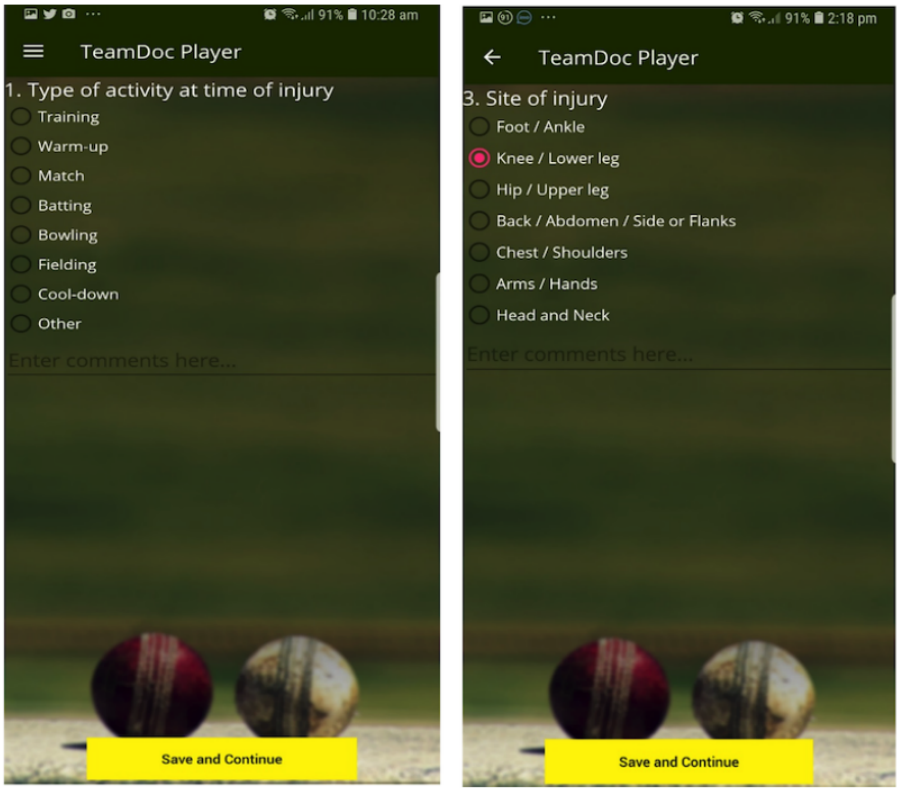


Figure 2.3: User interfaces for the injury reporting tab in the TeamDoc player app.

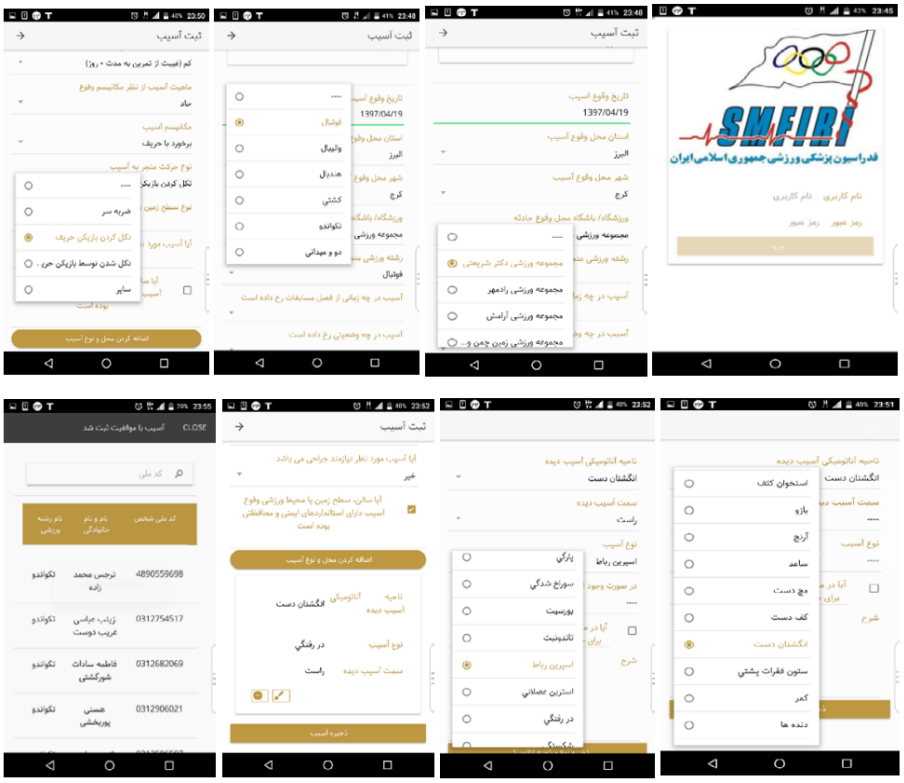


Figure 2.4: Some pages of sports injury record application via mobile SISS

Chapter 3

Methodology

This chapter identifies the problem this dissertation attempts to solve and details the approach taken to reach the proposed solution and to evaluate it. Initially, the problem this study aims to address, and the respective goals are identified, along with the proposed solution for that. Subsequently, how the *Requirements Gathering* (subsection 3.1.2) phase was conducted is detailed, followed by a description of the *Design Phase* (subsection 3.1.3), focused on the design and evaluation processes. Finally, the *Development Phase* (subsection 3.1.4) and subsequent *Application Evaluation* (subsection 3.1.5) processes are explained.

3.1 Methodology

User-centered design (UCD) is a multidisciplinary design approach that focuses on users' needs, goals, and satisfaction by iteratively involving users throughout the design process [65, 50]. This methodology is considered the most proper one to provide a valuable and usable product, overcoming the limitations of traditional system-centered design [65]. User-centered design can be broken down into four primary steps: understand the context in which the product will be used, identify user needs and requirements, craft solutions to meet those needs, and assess those solutions against the established requirements, as illustrated in Figure 3.1.

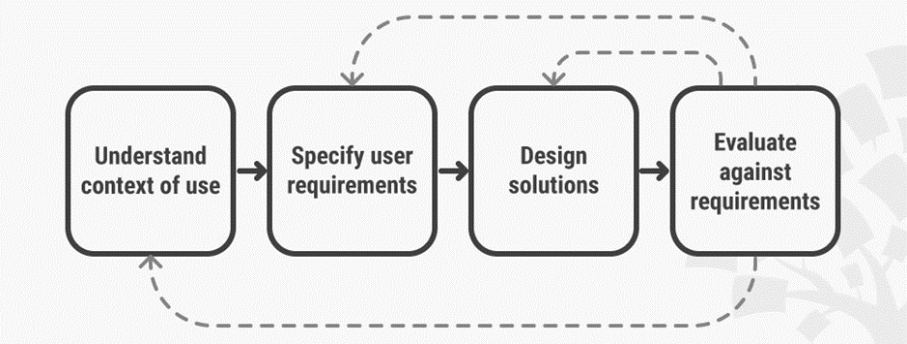


Figure 3.1: UCD Diagram [50]

Therefore, this iterative design approach was adopted to address this problem and achieve the proposed solution. Figure 3.2 illustrates the stages of the adopted methodology, structured as an iterative process to continuously refine and improve the application based on user feedback.

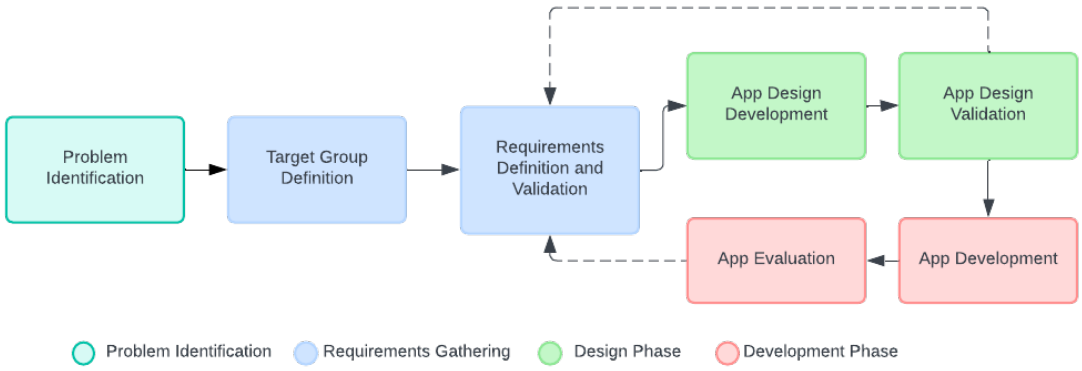


Figure 3.2: Methodology Diagram

3.1.1 Problem Identification and Goals

An overview of epidemiological surveillance in sports, specifically focusing on football, was provided in chapter 2. As concluded, despite the recognized importance of injury surveillance, football still encounters several significant challenges in this domain, as outlined below:

- **Lack of user-centered injury surveillance systems:** Current injury recording methods predominantly rely on pen and paper, a practice highly susceptible to human error [52]. Manual records can result in inaccurate and incomplete data, posing a significant challenge for tracking and managing injuries effectively. Additionally, manual documentation is cumbersome to update, share, and analyze comprehensively, thus limiting its utility in broader epidemiological studies essential for developing effective injury management and prevention strategies [71].

- **Inconsistencies in injury reporting and definition methods:** The lack of standardized definitions and reporting methods for injuries leads to significant discrepancies in the data collected. This inconsistency complicates the comparison of metrics across different teams and studies, hampers the identification of trends, and undermines efforts to implement effective, evidence-based prevention strategies [17, 69].

Several systems have been developed to address the issues faced in epidemiological surveillance in sports. However, these systems were not able to solve the issues faced in football and meet the requirements of this context, mostly due to the following points:

- **Lack of interactivity and user interface elements:** Many existing systems offer a poor and time-consuming user experience due to low interactivity and user interface design. The

absence of intuitive design elements often leads to decreased user engagement and interest, reducing the effectiveness of injury reporting and surveillance [93, 66].

- **Different context-targeted specifications and definitions:** Existing injury surveillance systems are often designed for a broad range of sports or specific contexts that do not align with the unique requirements of football teams (see subsubsection 2.4.1.2). As noted by Van Mechelen [69] and Clarsen [17], this misalignment results in systems that are not fully effective in capturing and analyzing the specific types of injuries and relevant data in football, as effective injury surveillance in football requires a tailored approach that addresses the sport's unique injury patterns and data needs.

- **Lack of accessible systems:** Some existing solutions focus on desktop or web applications (see subsection 2.4.1). In a football context, where professionals mostly work in the field, there is no access to such devices, leading to forgiveness or incomplete data registry in later moments.

In light of these challenges, the presented work aims to develop a comprehensive and user-centered solution that centralizes clinical data and provides real-time feedback while allowing the building of an epidemiological overview of the team by collecting meaningful data on injury epidemiology. The solution proposed must offer a simple and easy-to-use implementation for injury registry and monitoring.

3.1.1.1 Proposed solution

To address previously defined issues, this study aims to provide a solution by developing a mobile health (mHealth) application following the UEFA guidelines on injury definitions and reporting methods, defined in the International Olympic Committee (IOC) consensus statement and its subsequent revisions and extensions [43, 34, 5, 101]. With this, the primary goal of the mobile application is to centralize epidemiological data while ensuring the consistency and correctness of the data collected.

A mobile application is chosen for its accessibility and ease of use, allowing data to be collected in real-time from anywhere, which is particularly beneficial in dynamic environments like football training and matches. Mobile applications provide a user-friendly interface that can be easily navigated by users with varying levels of technical expertise, ensuring that coaches, medical staff, and players can efficiently input and access data as needed. The portability of mobile devices means that data entry can occur immediately after an injury or exposure event, reducing the likelihood of forgotten or inaccurately recalled information. Furthermore, the proposed solution is designed to be a multi-platform application, capable of running on both *Android* and *iOS* devices. This ensures broad accessibility, allowing users to utilize the application regardless of their preferred operating system. However, due to current constraints related to iOS development and associated costs, the initial development will focus on an Android solution. This strategic decision

allows for the efficient use of resources while still addressing a significant portion of the target user base.

The mobile application should be user-friendly and straightforward yet capable of collecting detailed and meaningful information about epidemiological data and injuries in football. A key aspect for maintaining user engagement and interest in the application is the incorporation of visual feedback mechanisms. These mechanisms not only enhance the user experience but also ensure that the data collection process is intuitive and engaging by using interactive graphical data, error notifications, and visual cues for data entry, like using different colors to describe the state of the elements and guide the user.

The solution focuses on a simple but consistent design across different pages to achieve this. The application should enable fast injury data registration, taking no more than two minutes, and offer meaningful data, visual feedback on user interaction, and an epidemiological overview of teams.

3.1.2 Requirements Gathering

The second stage of the methodology focuses on identifying the target groups and defining and validating the application requirements. This stage is critical to ensure that the developed application meets the needs and expectations of its users and aligns with the goals of injury surveillance in football, addressing its current challenges. This stage was divided into *target group identification* and *requirements definition and validation*, as explained below.

3.1.2.1 Target group definition

Initially, it was essential to identify the different target groups that would interact with the application and benefit from its use. Following the *problem identification* step (subsection 3.1.1), the following target groups were defined:

- **Medical Staff:** This group comprises the primary users of the application, including professionals with medical expertise and experience in football, such as nurses, physiotherapists, doctors, and other medical team elements. Their primary role involves injury recording, treatment, and monitoring.
- **Technical Staff:** This group includes football professionals who are part of the team's technical staff, such as coaches, assistant coaches, data analysts, and other technical team elements. They use the application to monitor players' health, integrating this data into training and game strategies along with the medical staff.
- **Regulation Organization:** This group comprises experts that integrate organizations regulating football teams, such as the *FPF (Portuguese Federation of Football)* and similar organizations. They may use aggregated data from the application for policy-making and to enhance injury prevention programs.

- **Other Football-related entities:** This group includes a diverse set of stakeholders such as football players, team directors, and other entities that directly or indirectly impact football.

These groups were defined to tailor specific requirements, enhancing the application's impact on daily football activities and providing valuable insights and feedback about the mobile application and its requirements. Furthermore, all members of these groups were required to have any experience in football.

3.1.2.2 Requirements definition and validation

In this second step of the *requirements gathering* stage, the focus is the definition of the application requirements and their subsequent validation by expert users. Initially, requirements were defined along with three experts and based on the literature review process. Those requirements were then validated by participants encompassing the target groups previously defined through a questionnaire.

The questionnaire was done using *Google Forms* and shared with football professionals to reach the target groups defined previously, and structured into 4 sections (*see Table B.1*). The first consisted of an informational section explaining the context and intention of the study. The following two sections were, respectively, related to the socio-demographical data of the participants to validate their professional experience in football and to collect feedback about the impact of the application in the defined context and main requirements. The last section was related to getting participants' compliance to participate in further questionnaires, semi-structured interviews, and cognitive walkthroughs for further evaluation phases.

This step was essential for defining most of the application's requirements, features, and different user permissions in the solution.

3.1.3 Design Phase

The design phase consisted of the third stage of the methodology. In this stage, the main goal was to define and validate the application's design. As shown in Figure 3.2, this stage, along with *requirements definition and validation* step (subsubsection 3.1.2.2), was an iterative and repetitive, with revisions and validations provided by the experts, to accomplish the final design of the mobile application.

To reach a final design of the system and user interface of the application, this phase was divided into two steps: *Application design* and *Application user interface evaluation*

3.1.3.1 Application design

Figma, an online collaborative tool for designing and creating prototypes, was used for designing the application user interfaces. Initially, the color palette, typography, and layout constraints were defined following *Material Design*[1] guidelines.

[1] open-source design language developed by *Google*

Focusing on the visual design of the application and information flow, a non-functional prototype was developed. This prototype served as a basis for the later development of the application. To reach the final user interface design solution, two designs were developed to compare different approaches to the problem:

- **Injury Episode Focus:** In this design, an injury episode consisted of the higher entity defining a lesion, integrating all the information about it
- **Events Focus:** In this design, an event consisting of more than one injury episode was defined, where injuries had a relation between them

The subsequent step (subsubsection 3.1.3.2) was crucial for the final decision on the design to be used for the mobile application. Furthermore, this phase also entailed designing the system architecture and respective interactions, as further explained in section 5.1.

3.1.3.2 Application user interface evaluation

The application user interface evaluation comprised the last step of the *Design Phase (subsection 3.1.3)*. For this, a cognitive walkthrough followed by a questionnaire was conducted. Nine experts from the *Medical Staff, Technical Staff, and Regulation Organizations* target groups participated in the interviews. All the elements presented in the validation steps had experience in football, following previously defined target groups (see subsubsection 3.1.2.1). Otherwise, they would been excluded.

A cognitive walkthrough is a structured approach to assess how well a new user will understand and use the interface, testing the usability of a product [61, 79]. It begins by defining tasks that the users are expected to perform, and the steps to achieve the expected results [49]. In order to assess the easiness of each task, the tester should ask four questions regarding the user actions, as suggested by Polson et al. [13]:

- **Q1**: Was the correct action evident?
- **Q2**: Did the user recognize the correct action?
- **Q3**: Did the user interpret the result correctly?
- **Q4**: Was the user able to progress towards the goal?

As a result of the previous questions, the tester is able to identify usability issues of the product. Cognitive walkthroughs can be used in all phases of the design and development process [13], and have been used not only for web applications [13] but also in mobile applications [68, 10]. Furthermore, Khajouei et al. [53] showed that cognitive walkthroughs work significantly better for identifying usability problems that affect the learnability of a system, suggesting the usage of cognitive walkthroughs to evaluate systems design for novice users. compared with heuristic evaluations.

Therefore, a pre-defined set of actions was defined, consisting on:

- **User Authentication:** The actions regarding user authentication consisted of the creation of an account and login into an account.
- **User account:** The actions regarding the user account consisted of the processes of visualizing and editing the information of the user.
- **Team players:** The actions regarding the team players consisted of the processes of creating, editing, or visualizing the information of a player of the team, including search actions.
- **Team exposures:** The actions regarding the team exposures consisted of the processes of creating, editing, or visualizing the information of an exposure, including search actions.
- **Team injuries:** The actions regarding the team injuries consisted of the processes of creating, editing, or visualizing the information of an injury, including search actions. As further explained in subsection 4.3.3, due to its particularity, the action of closing an injury (releasing a player) was also evaluated.
- **Statistics:** The action regarding the visualizing of the information of a specific statistic.

As suggested by Polson et al. [13], all the actions should be defined using "contextually rich descriptions of user goals (100-200 words long) incorporating more information about users' understanding of their tasks and underlying motivation".

The cognitive walkthrough process followed a script and was divided into four steps. Initially, the moderator presented an overall introduction about the interview goals and the study in case, as well as a personal presentation. Secondly, a brief explanation about the non-functional prototype and *Figma* was given, along with an explanation of how the interview would be conducted using that tool. The third step involved the participant executing the pre-defined set of actions and providing feedback about these actions, as well as the tester's evaluation of the user behavior to achieve the result. All the actions were done using the non-functional prototype and were performed using both *Injury Episodes Focus and Event Focus* designs defined previously (see subsubsection 3.1.3.1) for comparison. In the end, a questionnaire (see Table B.2) was administered to collect further details and opinions about both designs, the application's impact and importance in the defined context, and the correctness of the information collected in the application, evaluating not only its usability but also its contextualization.

3.1.4 Development Phase

A relaxed version of the Scrum Agile methodology was followed for the application development to reach a robust and complete solution. Weekly sprints were conducted, starting with an initial meeting with four experts to define the functionalities to be implemented during the week according to established priorities. At the end of each week, another meeting was held to review and validate the functionalities implemented during the week, and the user interface was compared against the previously defined non-functional prototype. This iterative process ensured consistent development and organization of the project, leading to the completion of the product.

3.1.5 Application evaluation

After the development phase, the final validation of the developed solution was vital. This validation was done in two steps: a cognitive walkthrough and a final questionnaire.

Both evaluation elements involved participants from the *Medical and Technical Staff* (see subsubsection 3.1.2.1). Those participants were selected from the first cognitive walkthrough conducted in the *App design evaluation phase* (subsubsection 3.1.3.2), where all the participants of the current evaluation phase also participated in the previous one.

The cognitive walkthrough was done synchronously and remotely with the participants and consisted of three main steps. Initially, since the participants were already familiar with the application contexts, the application was provided so they could install it on their mobile phones. Secondly, a predefined set of actions was provided, which the participants performed while the moderator/expert evaluated their actions, as previously done in subsubsection 3.1.3.2. The set of actions was extended to include the usage of filter elements (for searching and exporting specific data) and error simulation actions, which was not possible using the non-functional prototype, to analyze the application error prevention and the ability of the user to identify the steps to fix introduced errors. Lastly, a final questionnaire was provided to the participants, as explained below.

3.1.5.1 App evaluation questionnaire

To lastly evaluate the mobile application, a questionnaire was done based on heuristic evaluation and a mobile application rating scale to evaluate mobile applications according to engagement, functionality, aesthetics, and information.

To evaluate the usability of an interactive design, Nielsen *et al.* [75] suggested ten heuristics:

1. Visibility of system status
2. Match between system & the real world
3. User control & freedom
4. Consistency and standards
5. Error prevention
6. Recognition rather than recall
7. Flexibility and efficiency of use
8. Aesthetic and minimalist design
9. Help users recognize, diagnose & recover f/ errors
10. Help and documentation

On the other hand, a mobile application rating scale focused on the user was suggested by Stoyanov *et al.* [96]. Characterized by questions on engagement (A), functionality (B), aesthetics (C), and information (D), this rating scale provides a final score for the mobile application based on the sum of A, B, C and D divided by four.

The questionnaire resulted in the combination of the previous heuristics stated by Nielsen *et al.* [75] and the user version mobile application rating scale suggested by Stoyanov *et al.* [96], encompassing the new heuristics *"Navigation"* and *"User Engagement"* recognized by Galavi *et al.* [37].

The questions of the questionnaire can be seen in Table B.3.

Chapter 4

Requirements Gathering

This chapter focuses on explaining and defining the requirements of the application. It initially provides an overview of the requirements of the application gathered through the literature review process (see chapter 2), followed by the target group definition and more specific user requirements and user permissions (section 4.2). Subsequently, it provides an explanation of the data collected and respective constraints (section 4.3). Lastly, it discusses the results of the initial questionnaire provided and concludes the requirements definition according to it (section 4.4).

4.1 Introduction

The literature review (chapter 2) provided an overview of the most difficulties across epidemiological surveillance, mostly due to the lack of injury surveillance systems and consensual injury definition and reporting methods. As a result, developing an injury surveillance system to record and monitor injury incidence and prevalence among football players, as well as providing meaningful data on injury epidemiology, is crucial in the football context and is the primary goal of this study.

The initial requirements for the application were defined based on the previous literature review, where the application should allow the registry and monitoring of athlete's demographic data, team exposure, and team injuries.

4.2 Requirements

The application's specific requirements were defined from the users' perspective, detailing the functionalities and features the application must have to meet their needs. The requirements were gathered through the literature review, expert consultations, and a questionnaire targeting potential users of the application. The requirements are supported by a use case diagram to visually represent user and system interactions (see Figure 4.1).

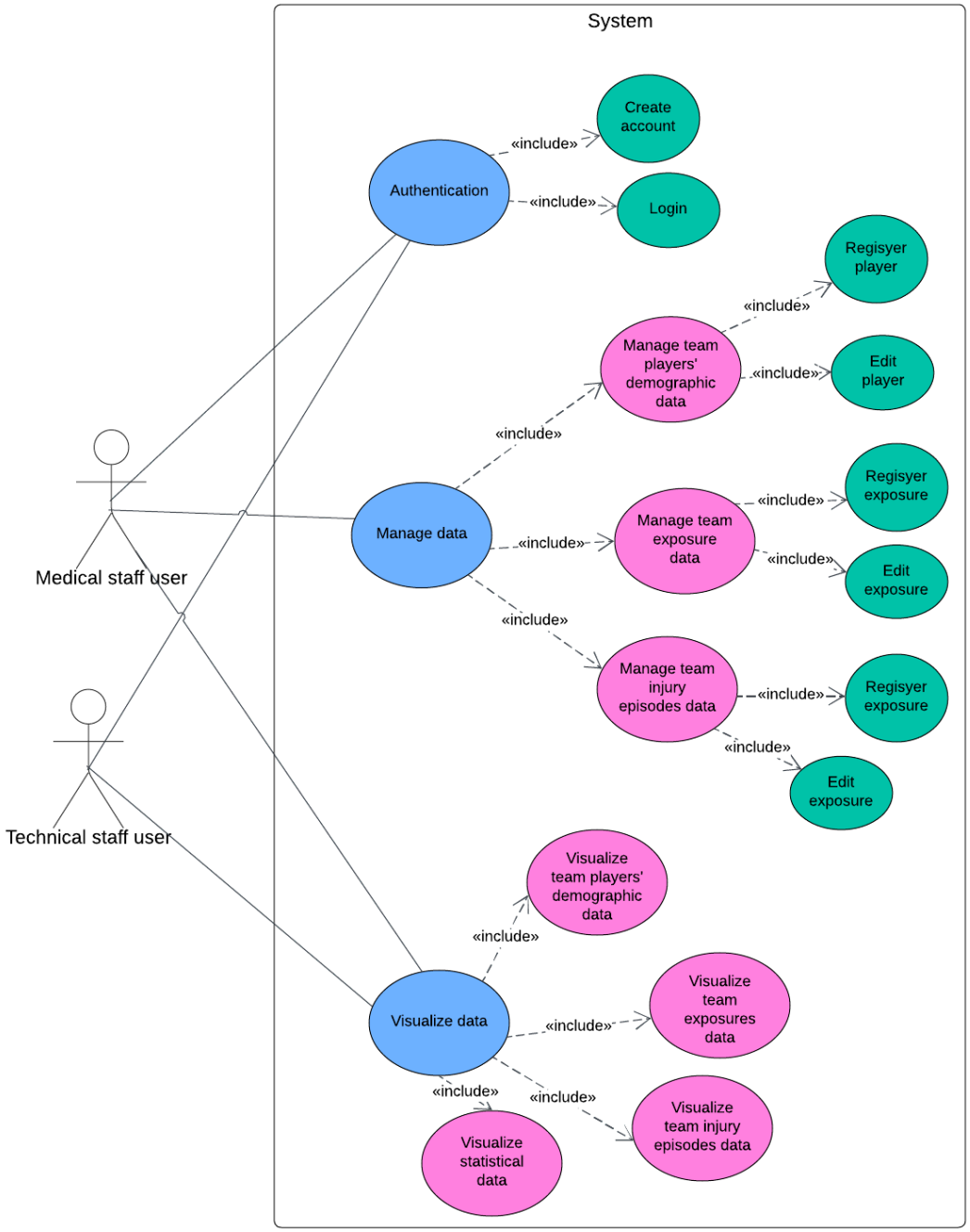


Figure 4.1: Use case diagram of the mobile application

To ensure the application meets the needs of all stakeholders, user requirements were systematically gathered and categorized. The primary goal is to provide an efficient and user-friendly way of recording and monitoring various data points related to football injuries. The initial requirements focusing on the overall application are described below:

- **Quick and practical:** The application should enable quick and easy data entry to ensure that users can register data with minimal time and effort
- **User-friendly interface:** The application should offer a user-friendly interface. At the same time, the application should provide feedback on the user's actions, prompting errors in the data introduced, guiding the user to correct them and perform the desired task, and maintaining consistency across different pages and the data.
- **Real-time data:** The application should provide real-time data registered for a particular team, continuously update, and real-time statistics on the data collected.
- **Persistent and secure data:** The application should ensure that all data is persistently and securely stored and accessed only by authorized users.

4.2.1 User Types and Permissions

Despite the possibility of using the data collected by the application for further epidemiological studies by researchers or by organizational entities for policy-making, the users that interact with the application and that register and monitor data were defined as follows:

- **Medical staff user:** This type of user includes healthcare professionals with experience in football and connected to professional football teams, as stated in the Target group definition subsubsection 3.1.2.1
- **Technical staff user:** This type of user represents any element of the technical team of a football team, such as coaches, assistant coaches, and other technical team elements, as stated in the Target group definition subsubsection 3.1.2.1

These different types of users were defined to ensure more complete and accurate registries of athletes' demographic data, team exposures, and injuries, given the distinct educational backgrounds and responsibilities of each user group within the professional team.

4.2.2 User Requirements

As a result of the literature review process and the questionnaire provided, the specific requirements of the applications were defined from a user perspective and validated by experts to fulfill the application's generic requirements.

Privacy concerns must be considered since the data collected is regarding football players of specific teams. Therefore, users must have a validation process in the registration phase, where the type of user and the team the user is registered in must be validated by upper entities. In the presented study and educational context, this process was held by the application developer, who should always ensure that the user registered in one team is a member of the team and the defined user type.

As a result, the following requirements were defined concerning users' accounts:

- **Account:** The application should permit the creation of an account by a user. That account must specifically identify the type of user (*medical or technical staff user*) and the team the user is registered in, along with further details defining the professional owning the account, such as name, gender, and date of birth.
- **User account validation:** The application should ensure that the accounts created undergo a validation process, ensuring the privacy of each team's data. As a result, the account should initially be deactivated and, in case a validation process verifies the data of the account's legitimacy, be activated.

4.2.2.1 Players' demographic data

To accomplish the application's goals, the registration of the players of a specific team is mandatory. Subsequently, the following requirements of the mobile application were defined regarding players' demographic data:

- **Player demographic data management:** The application should allow the registration and edition of a player's demographic data of the team the user is registered in. This functionality should be available exclusively for *Medical staff* users.
- **Team players' demographic data visualization:** The application should allow the visualization of the demographic data of all the team players the user is registered in. This functionality should be available for both *Medical and Technical staff users*.

4.2.2.2 Team's exposure

A team's exposure is related to the type of activity a team is exposed to, such as training or matches. Recording exposure is vital for training management and preparation, being used by both technical and medical staff professionals. Therefore, the application should allow the registering and monitoring of exposures of the team:

- **Team's exposure management:** The application should allow the creation and edition of a team's exposure. Despite not having specific health data, only *Medical Staff users* should be allowed to record exposures due to their relation with the players, further explained in subsection 4.3.4.
- **Team's exposure visualization:** In order to manage the team's exposure, define training plans, and manage players' exposition to certain conditions, the visualization of the team's exposure during the season is crucial. Therefore, the application should allow the visualization of previously registered exposures of the team for both *Medical and Technical staff users*.

4.2.2.3 Injury episodes

The end goal of the application is to implement a system that leads to decreasing injury incidence in football, providing meaningful data on injury epidemiology. Therefore, the registry of injury episodes constitutes the main feature of the mobile application, resulting in the following requirements:

- **Injury Episodes data management:** The application should allow the registry and edition of an injury episode. Due to its detailed health characteristics (see subsection 4.3.3), only *Medical staff users* should be allowed to perform such actions.
- **Team's injury episodes visualization:** Keep track of injuries player's injuries is essential for both *Medical and Technical staff*, for training and playing session planning. Therefore, the application should allow the visualization of previously registered injury episodes by both *Medical and Technical staff users*.

4.2.2.4 Statistics

Providing an epidemiological overview of teams and Portuguese football is one of the main goals of the application. To accomplish that, providing meaningful insights and facilitating analysis of injury patterns through graphical statistical data is one of the application's requirements, where it should dynamically generate graphs that display the distribution of injuries by various categories over time.

The application should allow user interactivity with the graphs, exposing more detailed information regarding the data point selected, filtering the graphical statistic data generated according to the data fields for players' demographic data (subsection 4.3.1), teams' exposures (subsection 4.3.2), and injury episodes (subsection 4.3.3). These filters are used to get more detailed graphical data regarding specific metrics (e.g., player position), giving a broader understanding of teams' epidemiological situation.

The statistical data should be presented in two different ways:

- **Total distribution of injuries:** In this representation, graphics should provide a visual representation of the distribution of the injuries of a team per each of the injuries data fields collected in the application, using pie charts.
- **Distribution of injuries per month:** In this representation, graphics should provide a visual representation of the distribution of the injuries of a team per each of the injuries data fields collected in the application and per month, giving a broader understanding on the evolution of the epidemiological situation of a team towards the season, using bar charts to represent each of the percentage of injuries on each month.

Exceptionally, injury incidence should be represented by a line graph, as it is typically defined as the number of injuries per 1000 hours of exposure. For this calculation, the total player exposition time should be considered, and not only the duration of the exposure itself. The mathematical

calculation of the injury incidence is further represented, where n represents the number of exposures, e_i the exposure i, m the number of players that participated in exposure e_i, p_j the player j, and $e_i(p_j)$ the participation time of the player j in the exposure i:

$$\sum_{i=1}^{n}\sum_{j=1}^{m} e_i(p_j) \tag{4.1}$$

Therefore, injury incidence will be represented as the number of injuries per 1000 hours of exposure per month.

4.2.2.5 Application Interactivity and Data Management Requirements

To retain user attention and engagement with the application, several features apart from the functional ones stated previously are necessary. These features enhance the overall user experience by providing feedback on user actions, preventing errors, and ensuring a quick and easy data registry. Subsequently, the following requirements were defined in order to provide the user a better experience:

- **Error Prevention:** The application should implement mechanisms to prevent common user errors. This includes validation checks for all input fields to ensure that the data entered is correct and within acceptable parameters before submission, as well as having predefined options of input fields, in the form of dropdowns.
- **Informational Elements:** In case of user errors, critical data, or just to provide more information regarding some aspect of the application, informative popups or snack bars indicating the nature of the error and guiding the user on the task to complete should be used.
- **Fast Forms Completion:** The application should be designed to allow rapid completion of forms. This includes using auto-complete features, dropdown lists, and other user-friendly input methods to minimize the time required for data entry.
- **Filters:** The application should have tools to help the user find data (players, exposures, or injury episodes), such as filters, providing a better experience and reducing time to perform the desired action.

4.3 Data collected and constraints

The precise and systematic collection of data is essential for understanding and mitigating injury risks. The data gathered through the mobile application serves multiple critical purposes, including tracking player health, analyzing injury trends, and evaluating team exposures and injuries to various activities. By collecting detailed and accurate data, the application can provide an overview of the epidemiological profile of teams that aids in the prevention and management of injuries, supports research initiatives, and informs policy decisions.

The data collection process focuses on three main categories: Player Demographic Data, Team Exposure Data, and Injury Episode Data. Each category is vital for different aspects of injury analysis and prevention, where collecting each of these data types comprehensively and accurately allows for a nuanced understanding of injury dynamics in football.

In the context of the application, injuries were defined as injuries that result in "a player being unable to complete the current or future training session or competition" [5], following the *Time-Loss* definition of an injury.

All the data collected is aligned with the FIFA injuries, exposure, and player registry forms and with the IOC consensus statement [34] and its subsequent revisions and extensions [5, 101] and the UEFA model [43].

4.3.1 Player Demographic Data

Player demographic data encompasses a range of personal and physical attributes critical for individual risk assessment and injury trend analysis. This includes:

- **Name:** The identification of a player is crucial to accurately track and manage players' records.
- **Gender:** Research consistently shows that male football players have a higher overall injury incidence compared to their female counterparts [58, 40, 95, 86]. Therefore, recording the gender of athletes proves to be crucial for identifying injury patterns and for implementing different targeted injury-risk mitigation strategies.
- **Date of Birth:** As identified by André Luis [62], researchers have been conflicting about considering players' age as a risk factor. Despite some studies finding some correlation between age and injuries, others did not. Consequently, collecting the age is essential for further injury analysis and epidemiological studies to identify it as a risk factor.
- **Dominant Foot:** A recent systematic review and meta-analysis study [20] has shown that football players have a 1.6 times greater risk of injury to the dominant limb. Therefore, collecting this data is vital for further epidemiological studies, as the dominant foot has a direct relation with the risk of injury.
- **Playing Positions:** Several studies have found differences in the risk of injury. Mallo et al. [64] have concluded that forwards and central defenders are more prone to injury, particularly ligament sprains and muscle strains. Similarly, Leventer et al. [60] concluded that wing midfielders and central defenders have higher injury rates and burden, while wing defenders have lower rates of groin injuries.
- **Previous Injuries:** Previous injuries have been consistently identified as a significant risk factor for future injuries in football [44, 16, 56]. Therefore, collecting this factor is vital for future epidemiological studies and for efficient epidemiological surveillance.

- **Familiar History:** Genetic factors have been suggested as intrinsic risk factors for several injuries [18, 89]. Therefore, collecting the familiar history of injuries of a player may provide insightful information and be used for future epidemiological studies regarding risk factors and injury patterns.
- **Relevant Pathologies:** Providing more relevant data regarding a player's health may be helpful in studying injury patterns and managing playing and training conditions.

4.3.2 Team Exposure Data

Team exposure data is crucial in understanding the relationship between training and match activities and the incidence of injuries among football players. Recording and analyzing this data allows for assessing workload, identifying periods of increased risk, and developing strategies to balance training intensity with recovery across the season. By systematically collecting team exposure data, we can gain valuable insights into how different types of exposures impact injury rates and overall player health, aiding in creating optimized training schedules and injury prevention programs.

Regarding this subject, the following data is collected:

- **Type of exposure:** Several studies have shown that injury incidence and severity differed in training, matches, and the type of match [62, 95, 86]. Therefore, collecting information regarding the type of exposure is vital for further epidemiological studies
- **Date of exposure:** To manage exposure and monitor training and matching sessions, collecting exposure data is crucial.
- **Duration:** The duration of the exposure is essential for accurately tracking player activity and assessing overall team exposure. This information is crucial for understanding the extent of participation and the potential impact on player health and performance.
- **Meteorology:** Several studies have shown weather conditions' impact on sports injuries [83, 77, 59]. Therefore, collecting this data field is crucial for future epidemiological studies and keeping track of playing conditions.
- **Type of field:** Several studies have been conducted to study the impact of the type field on soccer injuries. Dragoo et al. [21] found a higher overall injury rate on first- and second-generation artificial turf surfaces compared to natural grass, but no significant difference between third-generation turf and natural grass. On the other hand, Carling et al. [15] found no variation in injury rates between seasons or match formats but differences in injury types and positional roles. Therefore, collecting the type of field in each team exposure is vital for further epidemiological studies and in finding injury patterns.
- **Players exposure:** This field provides information regarding each player's participation in the associated exposure. This information comprises the player and the participation time of the player in the exposure.

4.3.3 Injury Episode Data

Injury episodes are the focus point of the injury registry system, providing critical insights into the nature, frequency, and circumstances of injuries sustained by football players. Detailed and accurate data on injury episodes is essential for identifying patterns, understanding causative factors, and developing effective prevention and management strategies.

Collecting detailed injury episode data enables granular analysis of injuries, facilitating the identification of high-risk periods, activities, and player characteristics. This information is vital for tailoring training programs, improving player safety, and enhancing overall team performance. The following data points are collected for each injury episode:

- **Exposure:** This data is regarding the exposure where the injury episode occurred. Further details of the information of the exposure can be seen in subsection 4.3.2.
- **Player:** This data is regarding the player who got injured. Further details on the information of the player can be seen in subsection 4.3.1.
- **Injured body part:** The injury body part consists of the part of the body of the player that got injured. This information is vital to build an epidemiological overview of injuries and to find injury patterns in lesions.
- **Injury side:** The injury side consists of the side where the injury occurred. This information is vital to identify the location of injury along with the injured body part data field.
- **Type of injury:** This data field consists of the diagnostic of the injury of the player.
- **Etiology:** Following the UEFA Report form Figure A.2 developed in the FIFA consensus statement [34], one vital characteristic to deeply understand injury patterns is the etiology of the injury. This data field is characterized by the type of contact that leads to the injury or the lack of it.
- **Injury mechanism:** The football-specific extension of the IOC consensus [101] statement has recommended using the definition of the mechanism of injury from the IOC consensus statement [34] defining the injury mechanism of an injury as non-contact, indirect contact and direct contact. Collecting this data field provides insightful context regarding the injury.
- **Stopped activity:** This data field is related to the activity of the player at the moment the injury occurred by identifying if the player stopped the activity (training or match, represented by the *type of exposure* field of the *Exposure*). This information improves the details regarding the injury and its context, being a vital data field for future epidemiological studies regarding injury patterns.
- **Minute of injury:** This data field identifies the moment when the injury occurred, describing the minute it happened within the *Exposure*. This may provide insightful information regarding the injury risk and patterns during the exposure.

- **Recidive lesion:** The football-specific extension of the IOC consensus [101] statement agreed to recommend using the categories from the IOC consensus statement [34], identifying a recidive injury as a subsequent injury to the same location (*Injured body part*) and side of a previous one, after a player's return to full participation from the index injury. This field provides insightful information regarding re-injuries and recovery issues, where further epidemiological studies may study the impact of several pieces of information related to this field along with re-injuries. This data field must not include injuries that affect the same site but other tissues.

- **Release decision and time to release:** Following the time-loss injury definition provided previously and used in the application, the injury is said to be cured once the player can play again. Therefore, the injury is declared solved when the player is declared able to play by the *medical staff* or *technical staff*. Recording the decision is important to understand further injury patterns and recurrent lesions, where *technical staff* may use a player who has not fully recovered from injury or even just made a wrong decision. Along with this, the time to release should also be provided, giving numerical data regarding the time the player took from the day he got injured until the day it was recovered.

- **Other relevant information:** This data field should be an open field where the user provides specific details regarding the injury. This may be used to provide further concrete injury diagnosis or any informational data regarding the context of the injury.

4.3.4 Data Constraints

Different categories of data were defined, which had intrinsic relationships between them (e.g., an exposure has a player's participation time; an injury episode has the player that got injured and the exposure in which it occurred). Therefore, specific constraints arise to ensure data integrity, consistency, completeness, and reliability of the data collected. These constraints are essential for accurate tracking and analysis of player health, exposure, and injury episodes.

Regarding the *team exposure data*, conflicts may arise when considering the *duration* of the exposure and the player participation in the exposure (see *players exposure* field from subsection 4.3.2), as the player participation cannot be higher than the duration of the exposure. On the other hand, injured players cannot participate in new exposures, according to the time-loss injury definition, and should be automatically assigned 0 minutes of participation time. A participation of 0 minutes from a player in the exposure should mean that the player did not participate in the exposure.

As stated in subsection 4.3.3, an injury episode has an intrinsic relation with an exposure and a player. On the other hand, the exposure has the participation time of the player in the defined exposure, where the player may also have not participated in the exposure. Therefore, the relationships between injuries, exposures, and players should follow some constraints.

Firstly, a player who did not participate in an exposure cannot be associated with an injury that occurred in that exposure. Subsequently, the *minute of injury* (see subsection 4.3.3) of an injury

cannot be higher than the total duration of the participation of the player within the exposure (e.g. a player cannot have an injury at minute 85 if he only played until minute 80). Lastly concerning players and exposures, the minute of injury of a player who *stopped activity* in the moment of injury should be automatically assigned to the minutes the player participated in the exposure, following its definition.

Concerning *recidive lesions*, and following its definition (see subsection 4.3.3), the mobile application must only allow the definition of recidive lesion that has the same *player*, *injured body part*, *injury side* and *type of injury*.

4.4 Questionnaire

As stated in subsubsection 3.1.2.2, a questionnaire was provided in the *Requirements Gathering* phase. The main goal of this questionnaire was to understand the impact of the mobile application and identify its primary requirements. The questionnaire can be seen in Table B.1.

The questionnaire reached a total of 138 people. Out of these, 110 consisted of people from *Medical staff*, 11 of people from *Technical staff*, nine football players, one ex-football player, one element from a regulation organization, and one element from other football-related entities (investigator). The remaining five answers were discarded since they did not follow the requirements of the target groups defined (see subsubsection 3.1.2.1). Out of the 133 results, one element from the *medical staff* did not have experience in football, and, therefore, its answer was discarded, 16.5% (22) had less than one year of experience, 48.1% (64) had between 1 and 5 years of experience, 11.3% (15) had between 6 and 10 years of experience, and 23.3% (31) had more than 10 years of experience. In the end, 132 answers were analyzed.

From the filtered results, 41.3% had experience in amateur football, 30.2% in semi-professional football, and 28.6% in professional football. Out of those, 81,8% answered that they never had contact with a system for monitoring epidemiological data. From the remaining 18.2% (24 answers), 43.5% (10) have used Excel for injury registry and monitoring, 17.4% (4) have used Kitman Labs software, and 13% (3) have used Emjogo software. These results show the previously stated problem of inconsistencies in injury reporting and definition methods as most professionals do not have a registry and monitoring tool for epidemiological surveillance, and the ones who use Excel use Excel files specifically created by each team, leading to inconsistencies in the data collected.

4.4.1 Results

Three questions were posed regarding the impact of the mobile application. The first one was *"On a scale from 1 to 4, where 1 is 'no impact' and 4 is 'a lot impact', what are your expectations of the impact of the mobile application in recording and managing epidemiological data in football?"*. The mean of the expectation of the impact of the application in recording and managing epidemiological data in football was 3.45 (sd = 0.66 and 95% CI 3.34-3.57), showing that the application may have a high impact in the record and management of epidemiological data in football (see

Figure 4.2 and Figure 4.3). The second one was *"On a scale from 1 to 4, where 1 is 'no impact' and 4 is 'a lot of impact', what are your expectations of the impact of the mobile application in epidemiological surveillance and injury prevention in football?"*. The mean of this expectation was 3.52 (sd = 0.59 and 95% CI 3.41 - 3.62), showing that the system may have a lot of impact on epidemiological surveillance and injury prevention in football (see Figure 4.4 and Figure 4.5). The last question was *From 1 to 4, where 1 is "Not probable," and 4 is "Much probable," what is the probability of using the mobile application for recording and visualization of epidemiological data?"*. The mean of the results was 3.48 (sd = 0.71 and 95% CI 3.36 - 3.60), showing a high interest in using this application in this context (see Figure 4.6 and Figure 4.7).

Figure 4.8 shows the results regarding the question *Which are the 3 main factors that would make you use the mobile application?*. The features that the participants consider that would influence their decision to use the mobile application are: "Statistical information regarding injuries and athletes," "Easy data introduction," "Real-time data access," "Clinical data centralization," and "Graphical visualization of data." This goes according to the initial requirements defined and with problems with previously studied solutions that the current solution is trying to solve. Regarding the main functionalities, Figure 4.9 shows that a quick and practical data introduction and automatic data synchronization are the most important features, but the offline mode of the mobile application and import/export of data is also highly requested. 92.4% of participants considered that the automatic data synchronization with teams and players' data from existing databases or systems is an important feature.

Considering the data to be collected with the mobile application, Figure 4.10 shows that the type of injury, specific player details, the severity of the injury (described by the days until full recovery), and location of the injury are the most important data to be collected. The burden of an injury was also a relevant data type.

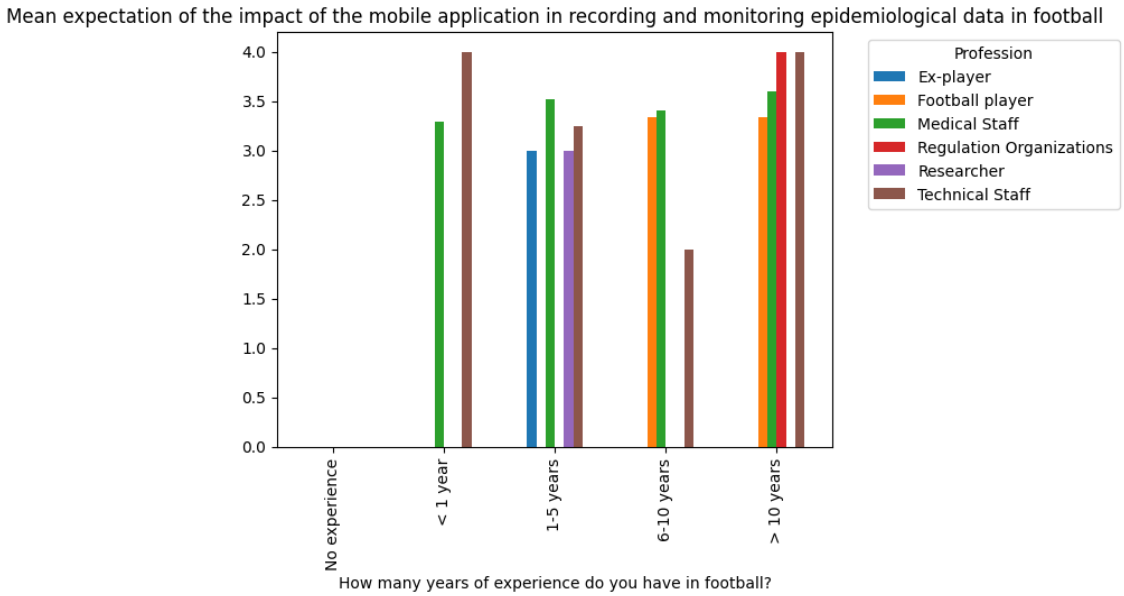


Figure 4.2: Mean of the expectation of the impact of the mobile application for recording and monitoring epidemiological data per year of experience and profession

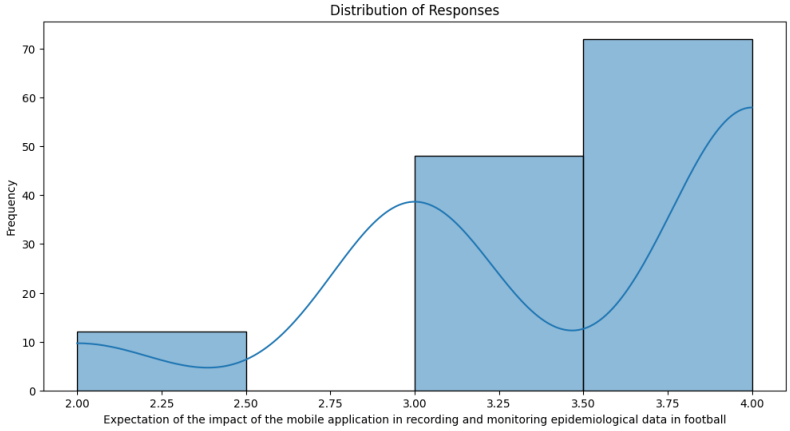


Figure 4.3: Histogram of the expectation of the impact of the mobile application for recording and monitoring epidemiological data

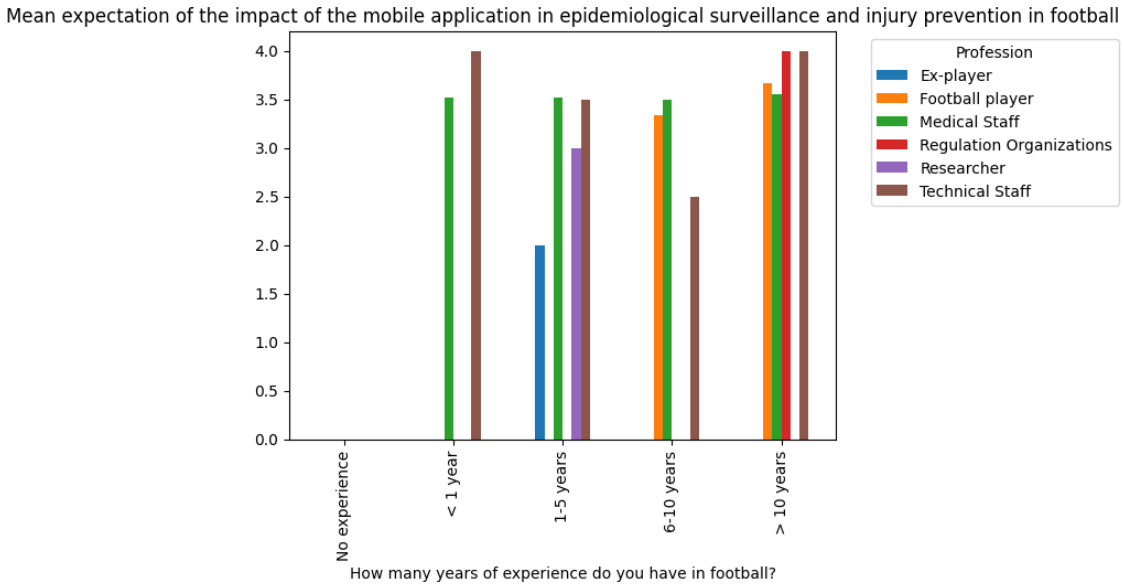


Figure 4.4: Mean of the expectation of the impact of the mobile application on epidemiological surveillance in football per year of experience and profession

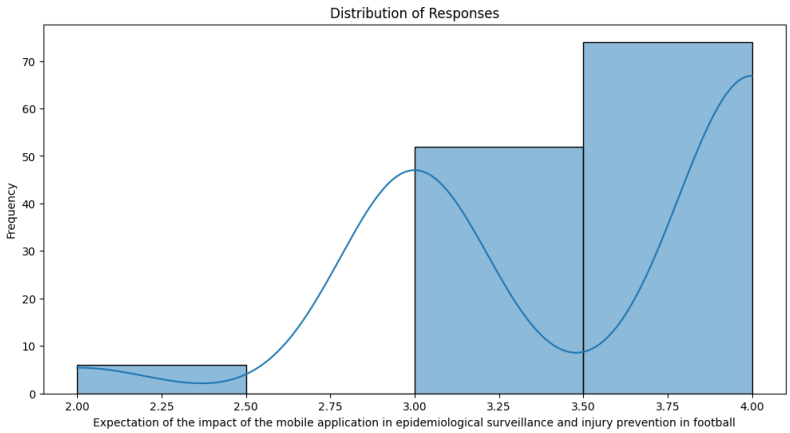


Figure 4.5: Histogram of the expectation of the impact of the mobile application in epidemiological surveillance and injury prevention in football

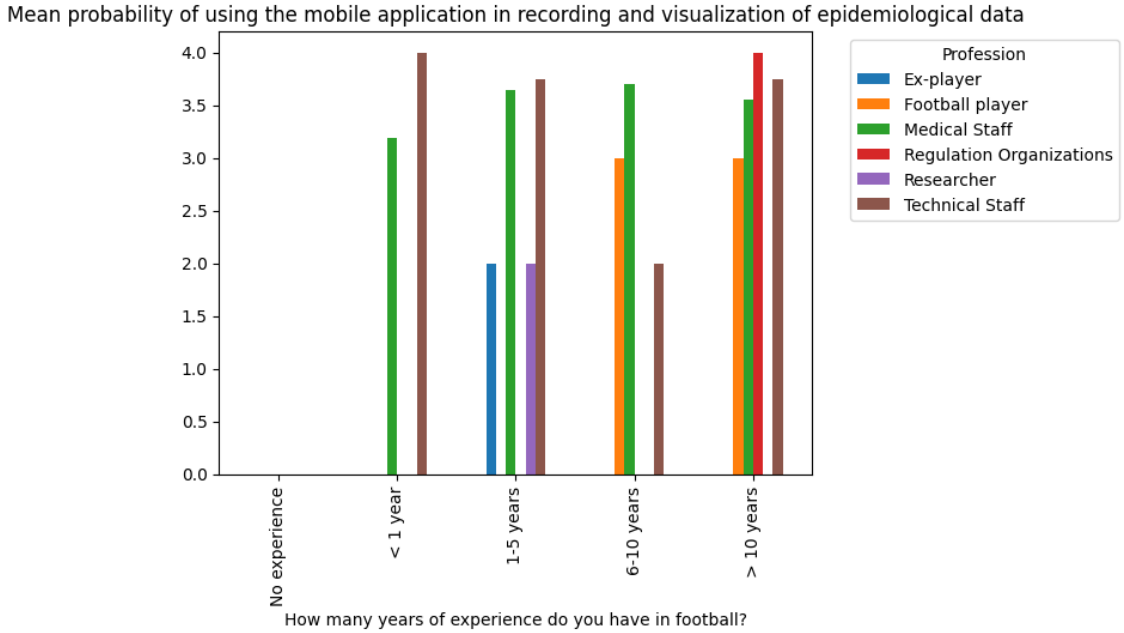


Figure 4.6: Mean of the probability of using a mobile application for recording and monitoring epidemiological data

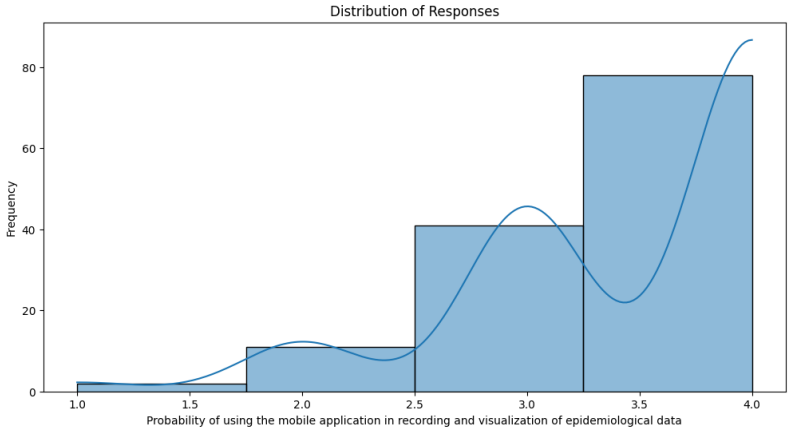


Figure 4.7: Histogram of the probability of using a mobile application for recording and monitoring epidemiological data

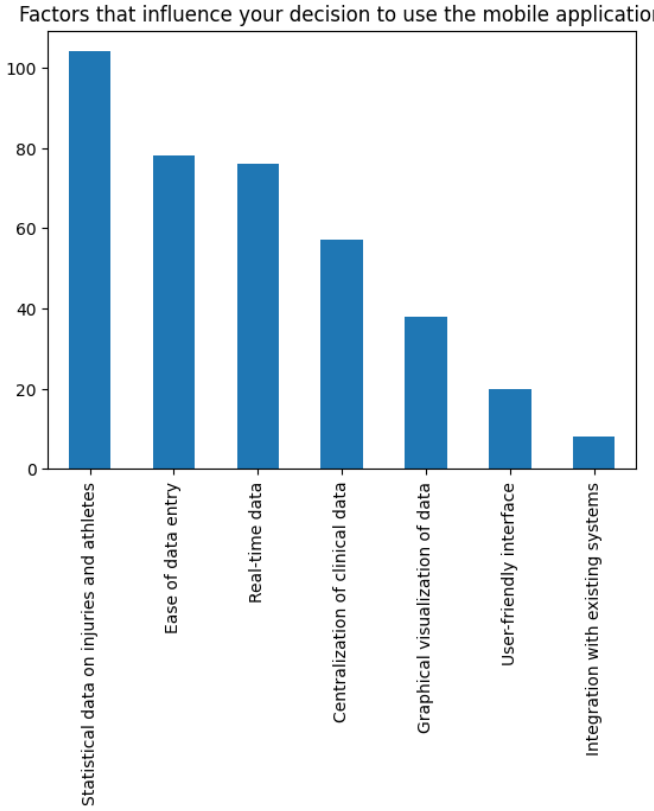


Figure 4.8: Main factors that would make a person use the mobile application

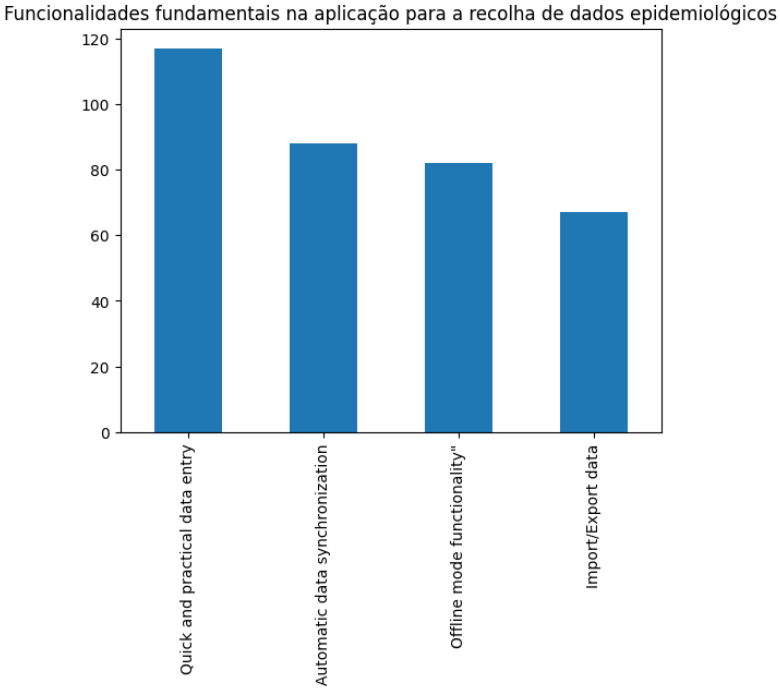


Figure 4.9: Main functionalities for the mobile application for epidemiological surveillance in football

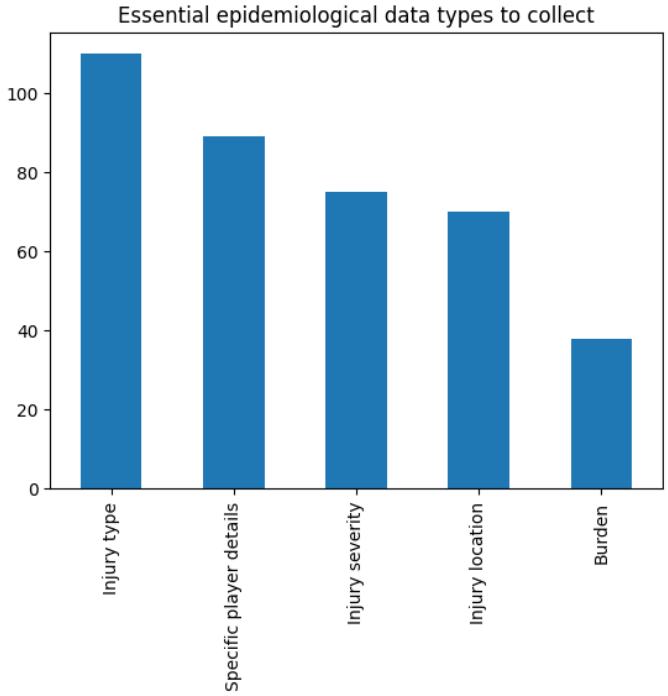


Figure 4.10: Essential type of epidemiological data for an efficient monitoring of injuries

4.5 Summary

After the *chapter 2*, the definition of the requirements and subsequent validation by the stakeholders of the mobile application is vital for the development of a valuable system. The initial requirements were defined, where the mobile application should provide a quick and practical way for epidemiological data registry and monitoring (such as players' demographic, teams' exposure, and injury episodes data), have a user-friendly interface, and provide real-time data and persistent and secure data.

Since football professionals have different backgrounds, different user permissions were defined, dividing the users of the application into *Medical staff user* and *Technical staff user*, where the *Medical user* has permissions to create, edit, and visualize all the data collected within the application, and the *Technical staff user* only has permissions to visualize data.

From the questionnaire provided, 133 results were analyzed, in which 81.8% of participants never had any contact with a tool for injury registry and monitoring, showing the lack of solutions within epidemiological surveillance in the football context. Participants also declared a high interest in the mobile application to be developed, where the expectation of the impact of the mobile application on recording and managing epidemiological data, and performing epidemiological surveillance and injury prevention in football was considered to be high, with, respectively, a mean of 3.45 (sd = 0.66 and 95% CI 3.34 - 3.57) and 3.52 (sd = 0.71 and 95% CI 3.36 - 3,60) out of 4 (where 1 represents "no impact" and 4 represents "high impact"). The participants also showed high interest in using the mobile application for the defined purposes, with a probability of using

it with a mean of 3.48 (sd = 0.71 and 95% CI 3.36 - 3.60), where 1 means no probability, and 4 means a lot of probability.

Chapter 5

Mobile application

In the previous chapter 4, the requirements of the mobile application, user types, permissions, and the main data to be collected were defined. Essentially, the mobile application should provide a quick and practical way to record and monitor data regarding team players' demographics, exposures, and injuries. The aim is to streamline the process of epidemiological surveillance in football, making it more efficient and accessible for clinicians and football professionals.

In this chapter, it is presented a comprehensive solution designed to address the current challenges in epidemiological surveillance within football identified in subsection 3.1.1. The proposed solution is a mobile application developed to facilitate the recording, monitoring, and analysis of epidemiological data. This chapter delves into the system design and the tools and technologies used (section 5.1), the mobile application user interface design (section 5.2), the intermediate evaluation of the mobile application design (section 5.3), and the database architecture (section 5.4).

5.1 System Architecture

In order to provide a solution that persistently stores epidemiological data, a client-server architecture was followed comprising two main components: a server, which persistently stores the information and retrieves it to the mobile application, and a mobile application, where the user registers the data and the previous stored one is displayed. The system was designed to ensure seamless integration between the mobile application and the server, where the mobile application acts as a client and communicates with the server to create, update, or retrieve the data through stateless communication, ensuring that the system can handle multiple users, scale efficiently and maintaining high levels of performance and security. The system architecture is illustrated in Figure 5.1.

Having a centralized server ensures that all data is consistent across the system. When multiple users use the mobile application to collect data, the server aggregates this data, ensuring that all users have access to the most up-to-date and accurate information. This centralization prevents data fragmentation and inconsistencies that could arise from having data stored only on individual devices. Along with this, the server provides a persistent storage solution that guarantees data is

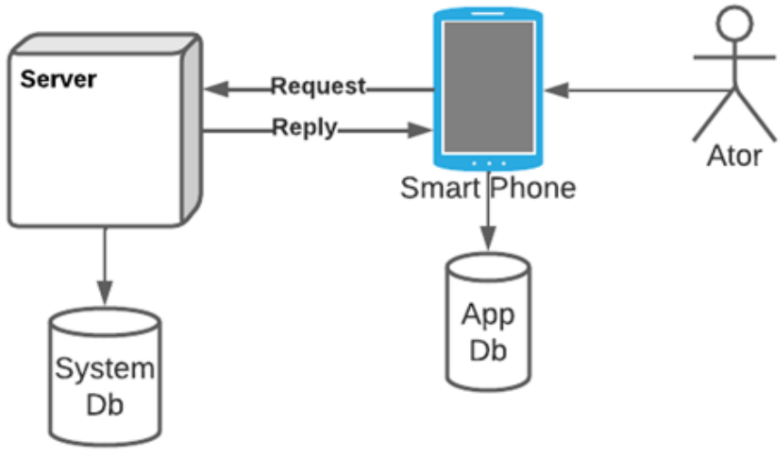


Figure 5.1: System Architecture with 2 main components: a server and respective database; the mobile application and respective database

not lost, even if individual devices are lost, damaged, or replaced. By storing data in a centralized database, the system ensures long-term data retention and reliability, which is extremely important for epidemiological surveillance where historical data is crucial for identifying trends and patterns.

The mobile application serves as the interface between the data and the user. Using their mobile device, users can record and monitor all relevant data, which is sent to/retrieved from the server. The mobile application is also connected with local storage capabilities to ensure that data can still be accessed even when there is no internet connection.

5.1.1 Tools and technologies

The development and deployment of both the server and the mobile application use a variety of sophisticated tools and technologies. One of the goals of the system is to provide an accessible solution and, therefore, a cross-platform solution. As such, the following tools and technologies were used to develop the mobile application:

- **Flutter:** Flutter is an open-source framework created by Google for building natively compiled applications for multi-platforms from a single codebase. Flutter's ability to compile native ARM code for both Android and iOS ensures that the application performs smoothly on both platforms, offering a solution for both Android and iOS devices. Flutter comes with a rich set of customizable widgets that adhere to both Material Design (for Android) and Cupertino (for iOS) standards, ensuring that the app looks and feels native on both platforms, providing a consistent user experience across different devices. It uses the Dart programming language and provides a rich set of pre-built widgets that allow fast development of custom and expressive user interfaces.

- **SQLite:** SQLite is used for local data storage on the mobile application. It is a lightweight, embedded database that provides a reliable way to store and manage data on the client side.

The use of SQLite ensures that the application can function offline and synchronize data with the server when a connection is available.

Regarding the development and deployment of the server and its database, the following tools were used:

- **Java and Spring Boot:** Java is a versatile, object-oriented programming language widely used in enterprise-level applications due to its robustness, security features, and platform independence. Its rich ecosystem and mature libraries make it a reliable choice for server-side development.

  Spring Boot complements Java by simplifying application development with pre-configured templates and reducing boilerplate code. This framework streamlines the setup of new applications by providing default configurations for various components and leverages dependency injection to manage application components, promoting loose coupling and easier testing. The framework also includes embedded servers like Tomcat and Jetty, simplifying the deployment process.

- **Spring Security and JSON Web Tokens (JWT):** Spring Security is a powerful and customizable authentication and access-control framework for Java applications. It supports various authentication mechanisms, like basic authentication, form-based login, OAuth2 integration, and authorization management for user roles and permissions, ensuring users have appropriate access to resources based on their roles. Along with this, JWT is used for stateless authentication. JWT tokens include user information and expiry details, ensuring secure and time-limited access without the need to maintain a session state on the server. This approach enhances security and scalability by reducing server-side session management overhead.

- **PostgreSQL:** PostgreSQL is a powerful, open-source relational database management system known for its robustness, scalability, and support for advanced data types and indexing techniques. PostgreSQL ensures compliance with ACID (Atomicity, Consistency, Isolation, Durability), which is crucial for maintaining the integrity of epidemiological data. It offers various performance optimizations like indexing, full-text search, or JSON support, enhancing the efficiency of data retrieval and manipulation. It also supports large-scale deployments with horizontal and vertical scaling capabilities, making it suitable for handling extensive epidemiological datasets. Therefore, this was the database language chosen for developing the **server database**.

- **Docker:** Docker is a platform for developing, shipping, and running applications using containers. Containers bundle the application and its dependencies, ensuring consistency across different environments, which is vital for the deployment of the server. Containers can run on any system that supports Docker, providing flexibility and consistency in deployment without depending on the operating system. Each container operates in an isolated environment, improving security and preventing conflicts between applications.

- **AWS EC2, RDS and Virtual Private Groups (VPC):** Amazon Elastic Compute Cloud (EC2) is a part of Amazon.com's cloud-computing platform, Amazon Web Services (AWS), that allows users to rent virtual computers on which to run their computer applications. By using Virtual Private Clouds (VPCs), security groups, and key pairs, AWS EC2 ensures secure access and communication between the mobile application and the server, offering a public IP address to the second one. Along with this, Amazon Relational Database Service (RDS) is used to manage the PostgreSQL database, providing automated backups, software patching, and seamless scaling.

5.2 Mobile application design

The mobile application is the communication element between the user and the server. The primary objective is to create an intuitive and efficient tool that football professionals can use to swiftly input, access, and analyze epidemiological information. As a result of the requirements defined in subsection 4.2.2, the application was divided into six main pages: the authentication page, the user's account page, the players' demographic page, the exposures page, the injuries page, and the statistics page.

Each of these pages plays a critical role in the app's overall functionalities, contributing to a comprehensive and integrated system for injury surveillance. The design focused on simplicity and speed, allowing professionals to perform their tasks with minimal effort and maximum accuracy. By organizing the app into these main sections, the system ensures that data is both easy to manage and highly accessible, aiding in the prevention and management of injuries through real-time data collection and analysis.

A video presenting some of the aspects and pages of the mobile application can be seen in *https://drive.google.com/file/d/1YaXaxDqzKfRvbf5ewgtgJQLIjVpJQkwa/view?usp=sharing*.

5.2.1 Custom components

As the mobile application is focused on a specific target group, its design should also be done specifically for that target group. Therefore, several custom components were designed and developed to offer a customized application tailored for quick and practical epidemiological data registry and monitoring.

5.2.1.1 Text Input Component

The customized text input component was designed to allow text data insertion and visualization. Tailored to be used in different parts of the application, this component offers several features, like error visualization, disable option, and validation within forms sections. To provide more information regarding the field and its objective and meaning, this component was designed to have a label displaying an icon and a text describing it.

The flexibility of usage for this component is vital to ensure consistency across different pages. As a result, the *text input component* allows 3 different states: enabled, allowing the user to write its content; disabled, where the user cannot change its content; and error, or required. The component and its different states can be seen in Figure 5.2.

(a) (b) (c) (d)

Figure 5.2: Text input component in its different states: (a) Enabled and empty text input; (b) Enabled and filled text input; (c) Disabled and filled text input; (d) Required or with errors text input

5.2.1.2 Button Component

Buttons are often used so the user can do some sort of action, like complete the creation of a player, cancel its edition, or just confirm some action. Therefore, these button styles must be consistent on all the pages of the application, ensuring an easy-to-learn interface. For that, *the button component* was designed as follows: the button should allow the usage of icons and provide visual information regarding the actions to do. Therefore, the color of the button should be descriptive of its action: cancel an action, create data, action with no side effects when clicked (normal button), and a button with side effects outside the application (e.g., export data to mobile phone). The four types of buttons can be seen in Figure 5.3.

(a) (b) (c) (d)

Figure 5.3: Button component in its different states: (a) Normal button; (b) Create button; (c) Cancel button; (d) External action button

5.2.1.3 Dropdown Component

Providing pre-defined options for data input is vital for a fast and simple way of registering epidemiological data. Therefore, a *dropdown component* was designed, providing a simple way of introducing data and maintaining data consistency in their definitions (see subsection 2.3.2), one of the identified problems in epidemiological data of football. To be reusable across the application, this component was designed in a similar way to the *text input component*, being an extension of it. Consequently, the dropdown component offers three stages: enabled, disabled, and required or with errors. Along with those states, the dropdown supports two other possibilities: being a single or multi-select dropdown, which allows, respectively, the selection of one or multiple options. All the states regarding the dropdown can be seen in Figure 5.4.

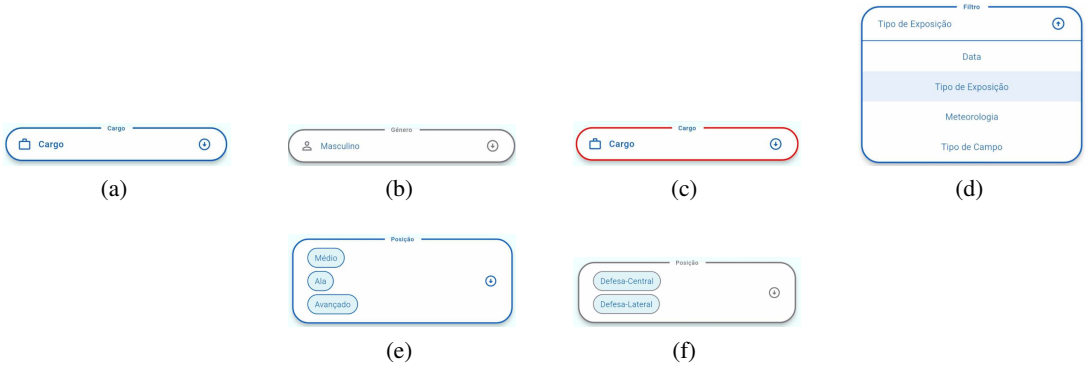


Figure 5.4: Dropdown component in its different states: (a) Enabled single selection dropdown; (b) Disabled single selection dropdown; (c) Required or with errors single selection dropdown; (d) Enabled and open single selection dropdown; (e) Enabled multi-selection dropdown; (f) Disabled multi-selection dropdown

5.2.1.4 Content card

This component was used to show relevant information to the user. Mainly, its goal is to provide an overview of the data with lots of descriptive fields, like players, exposures, and injuries, offering a simple and faster way for the user to visualize, filter, and select the data. This component was designed to display different colors and content, providing a simple way of displaying data from various entities by only developing the widget displaying the data and not the card itself, as seen in Figure 5.5. Furthermore, this component allows a clickable action, being used for navigation across the pages to visualize players', exposures', and injuries' details.

Figure 5.5: Content card component for different data: (a) Content card displaying player data; (b) Content card displaying exposure data; (c) Content card displaying injury data; (d) Content card to select player;

5.2.1.5 Charts

One of the most important features of the mobile application is the visualization of statistical data of team injuries. Therefore, the development of customized charts is vital for the appropriate display of statistical information regarding injuries and respective distributions. As such, three charts were designed and developed: a line graph, a pie chart, and a bar chart. The line graph was used to provide information regarding the injury incidence across the year, showing its result

per month. Similarly, the bar chart was used to show the frequency of lesions per month per characteristic. The pie chart was used to show the distribution of lesions in the year, showing the percentage per characteristic.

All the developed charts respond to user interaction, displaying specific information regarding the selected element: the line graph shows the specific value of the month selected, and the pie and bar charts show the frequency of the selected element. Figure 5.6 show each of the graphs and respective interactions.

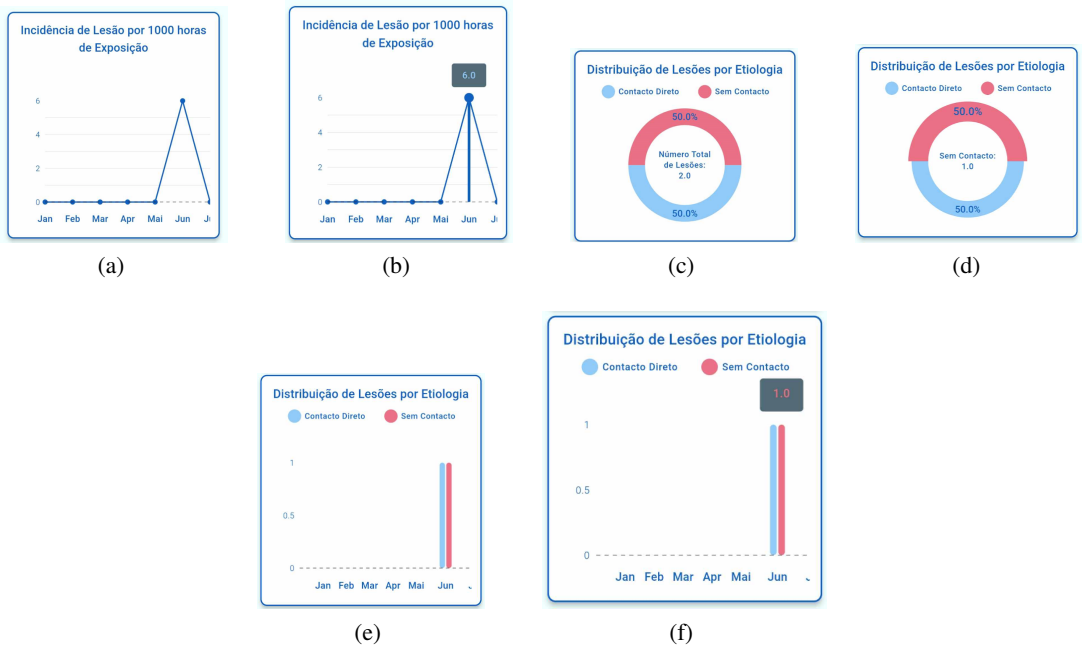


Figure 5.6: Different chart components used in the mobile application: (a) Line chart; (b) Line chart with interaction; (c) Pie chart; (d) Pie chart with interaction; (e) Bar chart; (f) Bar chart with interaction

5.2.1.6 Popups and Snackbars

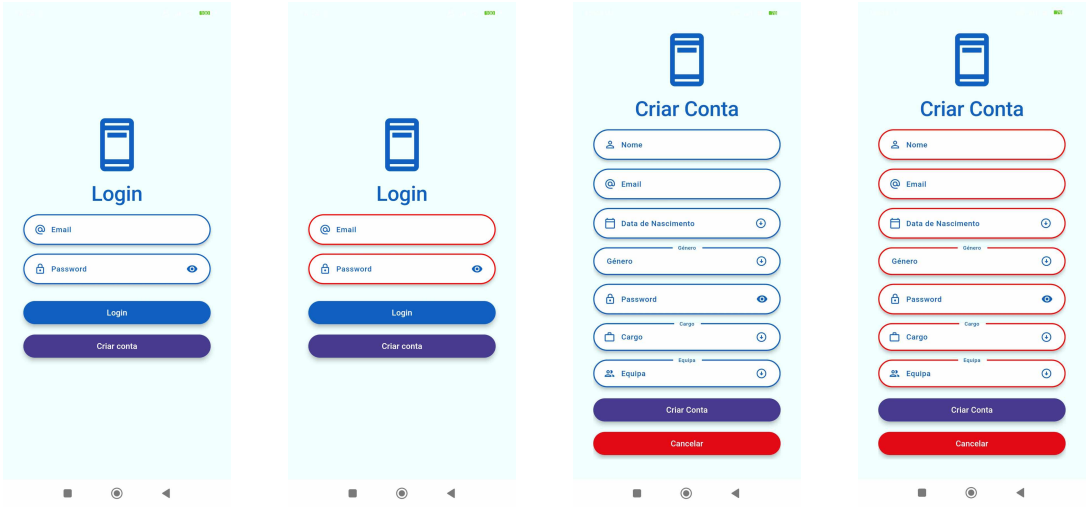
Several actions induce errors in the registry process due to the constraints in the data. One way of guiding the user to correctly fill the forms is by using *Popups* and *Snackbars*. Popups are containers displayed above the remaining content of the page, they were used to confirm user actions (*Confirmation Popup*), select data, such as exposures and recidive injuries (*Selection Popup*), and display information regarding specific fields (*Informational Popup*), like the *stopped activity* field of injuries. The *Snackbars* are used mostly as guidance to the user, displaying errors that may have occurred when performing an action or simply connection issues with the server. These components can be seen in Figure 5.7.

(a) (b) (c) (d)

Figure 5.7: Snackbar and Popups used in the mobile application: (a) Snackbar; (b) Informational Popup; (c) Confirmation Popup; (d) Selection data Popup

5.2.2 Authentication pages

As stated in subsection 4.2.2, one important issue regarding the context of the application is the privacy and authenticity of the data collected. As such, the application must provide an authentication method for users to create and log in to their accounts, as shown in Figure 5.8. The elements presented on both pages are required, and, therefore, the text input with the error was used to show the user the missing elements. The same happens on the login page.



(a) (b) (c) (d)

Figure 5.8: Authentication Pages: (a) Login page; (b) Login page with missing values; (c) Create account page; (d) Create account page with missing values

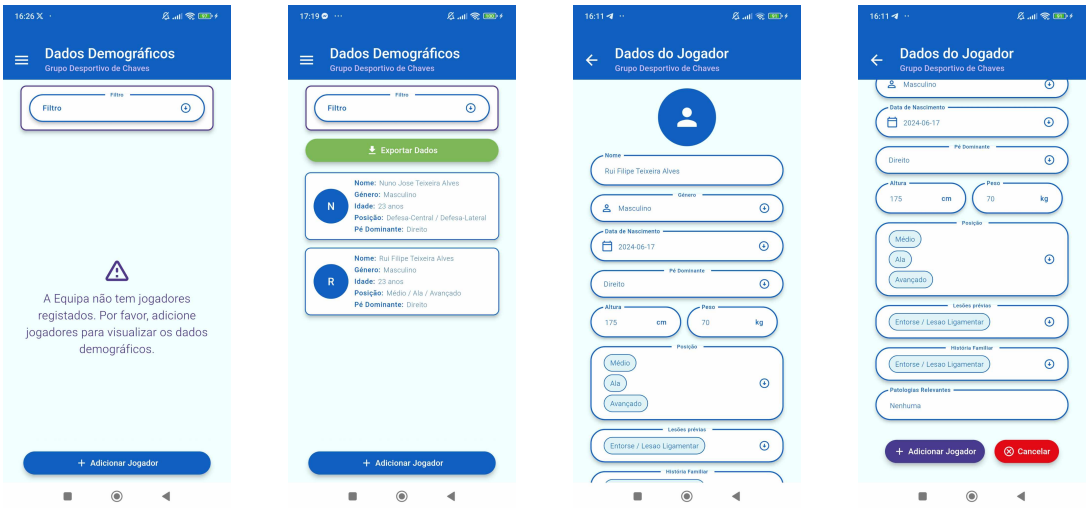
5.2.3 Players pages

Players' demographic data is a crucial element for epidemiological surveillance in football. Therefore, the players' page serves as the primary interface for clinicians to register and see detailed demographic information about the football players they monitor.

The process of registering and monitoring players' demographic data is divided into two pages. The first one is the team players' page, where an overview of all the team players' information is displayed. The user can see the most important information regarding the players registered within the team. Using the filter at the top of the page, the user can filter the players and find the ones he wants according to the players' characteristics: name, gender, position, and dominant foot. The export data button below the filter allows the user to export the filtered players into a *CSV* file downloaded to the user's mobile phone.

The second page is the player page, where the user can manage a player's demographic data. This page is reused for both editing and registering a player's demographic data, accessible through the button in the team players' page or clicking in the *card components* of the players. On this page, the user is presented with *text input components* displaying or requiring a player's data, according to being the creation or edit/visualization of the player, respectively. All the pages can be seen in Figure 5.9.

As previously stated in subsection 4.2.1, two types of users interact with the mobile application: the *medical staff* user and the *technical staff* user. Due to the specificity of the data collected and their technical knowledge, only the *medical staff* users can create and edit information about the players. To prevent that, the mobile application does not display the buttons for the creation and edition page in case the authenticated user is a *technical staff* user.



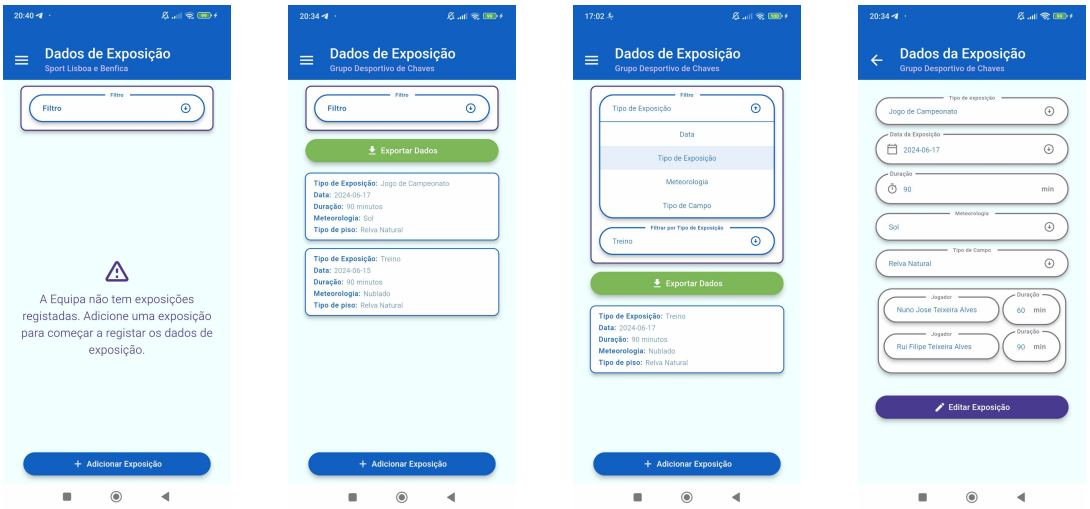
(a) (b) (c) (d)

Figure 5.9: Players' demographic data: (a) Team players page without players; (b) Team players page; (c) Specific player page - part 1; (d) Specific player page - part 2

5.2.4 Team exposures

The exposure of a team is a vital element in understanding the environment and context in which the injuries occur. Therefore, recording and monitoring the exposures of a team is a requirement that the mobile application must meet. For that, a similar approach to the players' page design (see

subsection 5.2.3) was done, having one main page where all the exposures of a team are displayed using *card components* for a broader overview, with a filter in the top along with the export data button below. On this page, the filter has options regarding the characteristics of the exposure (see subsection 4.3.2). The page showing more details of an exposure can be accessed by clicking on the *content cards* of the exposures, and it was done to also allow the creation and edition of an exposure, ensuring the consistency on the pages and the simplicity of the application. All the pages can be seen in Figure 5.10



(a) (b) (c) (d)

Figure 5.10: Teams' exposures: (a) Team exposures page without exposures; (b) Team exposures page; (c) Team exposures page with open filter; (d) Exposure details

Similarly to what happens on the players' page (see Figure 5.9), in case the authenticated user is a *technical staff user*, the buttons for the creation and edition of a player are not displayed, preventing the user from accessing the respective pages and managing data regarding the teams' exposures. In the registry or edition process of exposure, all the fields are also required, and in case they are not filled, they are displayed in red, and a snack bar showing the error is used.

Since the majority of the players normally participate in the exposures (games and training), when the duration of the exposure is introduced, the application automatically assigns that duration to the participation time of all the players who are not injured. The injured players' participation time is blocked and is equal to 0, as they are not able to participate in the exposure, following the *time-loss* injury definition.

5.2.5 Injury episodes

Injuries are the final data required for the epidemiological surveillance process. As defined in subsection 4.3.3, injuries incorporate all the information regarding the lesion and the conditions where it occurred and to whom. Subsequently, this presents the vital entity for performing epidemiological surveillance, finding injury patterns, and developing injury prevention methods. For

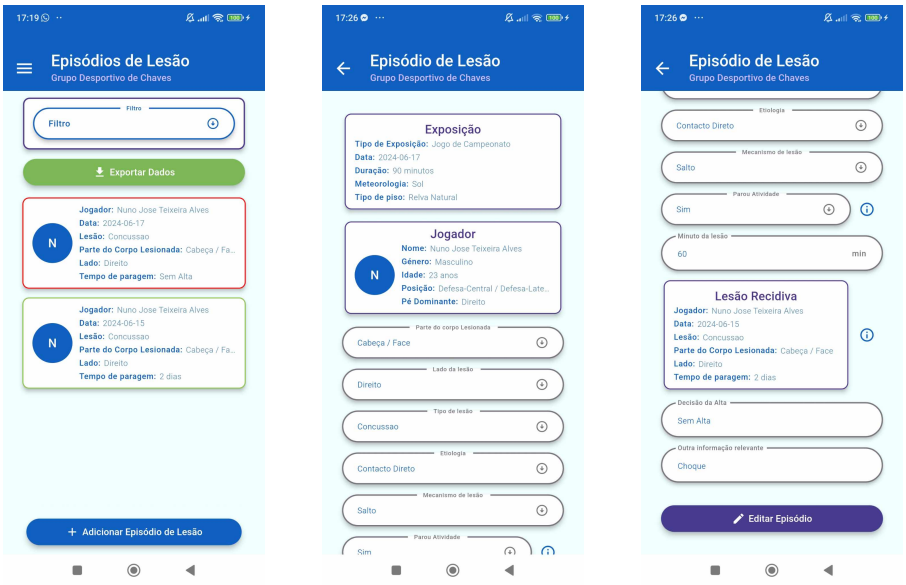
that, injuries can have two different states: open and closed. An injury is said to be open if the player who got injured is still not ready to play and, therefore, injured. On the other hand, an injury is said to be closed if the player who got injured has already recovered from the injury and is ready to play. The clinician must specify the release decision to define an injury as closed. Subsequently, the mobile application automatically calculates the time the player got injured and the time to return to play. Once the injury is defined as closed, it becomes blocked not only for the *technical staff* user but also for *medical staff*, being unable to edit it.

Due to its peculiarities and to get the most possible value on the information collected, two designs were done regarding the injuries pages: the first focused on injuries, and the other focused on injury events. Injury events are events that happened in an exposure and that resulted in one or more injuries (for example, two players colliding with each other and both getting injured). The design focused on injuries provides a more straightforward and quicker way of recording and monitoring data on injuries, where the search process for a specific injury is easier, as well as the process of closing an injury. On the other hand, the design concerning the events focus provides more information regarding injuries and their relation, making it possible to aggregate different data and better understand how the injuries occurred.

5.2.5.1 Injury Focus

In this design, the main goal is to provide a simple way of recording and monitoring injuries. Therefore, the design of the pages regarding injuries took a similar approach to the previous pages. To search for a specific injury, the user accesses the injuries page, where an overview of some details regarding each injury of the team is displayed. For that, the user can use the filter to search for some defined parameters and export the data using the button at the top of the page. Contrarily to the other filters which were specific to the page they were inserted in (e.g., the search filter on the players' page only has players' characteristics to filter by), the filter used in the injuries page allowed filtering for injuries using characteristics of the other entities (players, exposures, and injuries), providing complete flexibility for the user to find injuries regarding some parameters. As an example, with this filter, the users are able to search for injuries that occurred to players who play as midfielders, or that occurred in natural grass fields.

As shown in Figure 5.11 (a), two injuries were registered in the team. The red and green colors describe, respectively, injuries as open and closed, where the red means that the player is unable to play because it is still injured, and the green that the player is already able to play. In Figure 5.11 (b) and Figure 5.11 (c), we can see the information regarding the injury. As described, injuries contain references to the exposure where/when it occurred, the player that got injured, and the recidive injury of the current injury (in case the injury is recidive). Since these elements contain further details, the *card component* was used to provide an overview and provide a fast way of checking the most important data of those elements. By clicking on each of the cards, the user is redirected to the respective page (e.g., clicking on the exposition card, the player is redirected to the page showing the details of the exposure, defined in subsection 5.2.4). All those pages that the user can access using the cards are only for visualization, not allowing its edition, having the same



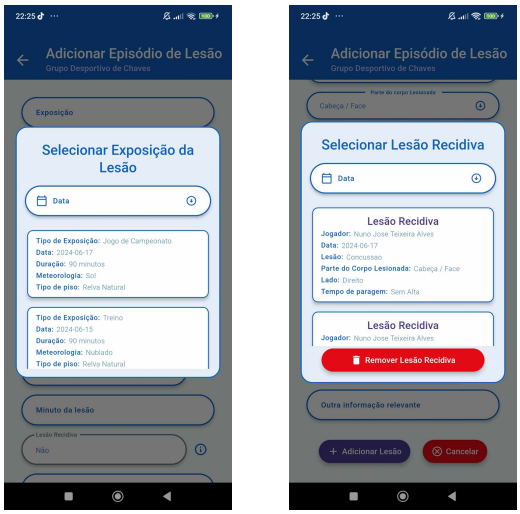
(a) (b) (c)

Figure 5.11: Injuries pages: (a) Team injuries page; (b) Specific injury page - part 1; (c) Specific injury page - part 2

behavior for both *medical staff* and *technical staff* users. This was done in order to ensure the consistency and constraints between the different data elements (players, exposures, and injuries).

When creating injuries, the user is required to select an exposure and a player. As previously defined, players can participate in exposures, having a participation time within the exposure. When that participation time is equal to 0 minutes, it means that the player did not participate in the exposure. As such, when the user selects an exposure, it is not allowed to introduce a player that did not participate in the exposure. For that, the application automatically updates the *dropdown component* that shows the players that are able to be selected as injured. Similarly, when the user first selects the player that got injured and then wants to select the exposure, only exposures where the player participated are shown. In case the player stopped the activity when the injury occurred, the application automatically defines the minute of the injury as the minute of participation of the player in exposure, blocking the user from editing it.

Since the exposures and recidive lesions have no identifier and, therefore, the user cannot differentiate them using only one element, their selection cannot be made using the *dropdown component*. Instead, a *popup* containing *card contents* with all the exposures and recidive lesions is used, as shown in Figure 5.12. To easily find the exposure and recidive injury to select, a filter of the date when they occurred can be used. As stated in subsection 4.3.3, a recidive lesion is a subsequent injury to the same location and side as a previous one. Therefore, the user is unable to select a recidive injury in case it does not introduce the data regarding the body part, the side, and the injury. After selecting that data, only injuries that occurred previously of the new one and that have those elements (same body part, side an injury) are displayed.



(a) (b)

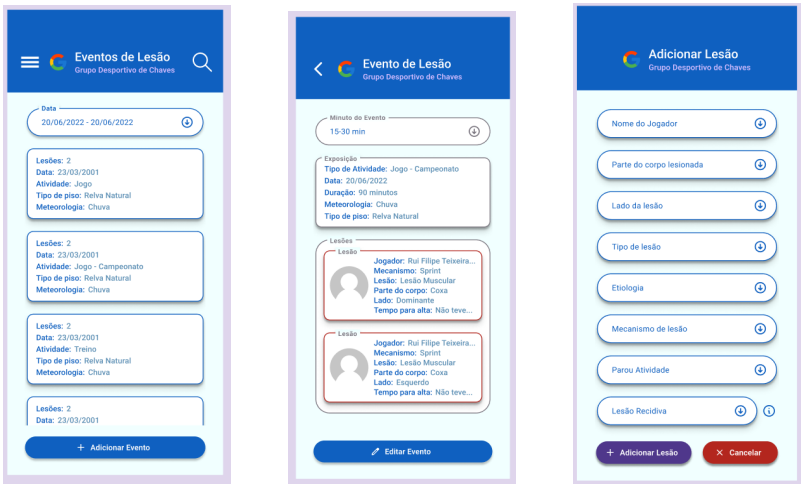
Figure 5.12: Injury data selection: (a) Popup to select injury exposure; (b) Popup to select injury recidive lesion

5.2.5.2 Events Focus

In the event-focus design, the main goal is to collect more information regarding injuries and their context. Therefore, to register a new injury, the user has to go by two steps: register a new event, and then register a new injury within that event. This process blocks one of the main goals of the mobile application, being the simple and quick recording and monitoring of epidemiological data. Furthermore, this design makes the edition of a specific injury harder, where the user has to primarily search for the event, and then for the injury inside the event. Despite that, the design was done in order to compare both solutions and to understand the trade-off of having more information with harder recording and monitoring processes. The design of such a solution can be seen in Figure 5.13, where (a) shows the events of injury, (b) the details of an event, and (c) the details of an injury of an event.

5.2.6 Statistics

Statistical data visualization is crucial for a further understanding and analysis of injury patterns and the situation of injuries in a team. Therefore, the statistical page provides a simple but complete way of describing a team's injuries. Using line, pie, and bar charts regarding a team's injuries, the mobile application offers an extensive description of the injuries. The line chart provides data regarding the incidence of injury on a team. Calculated following the subsubsection 4.2.2.4 definition, the mobile application calculates the incidence per 1000 hours of exposure per month, giving an overview of the changes in the injury incidence through the season. The pie charts provide a frequency distribution of the injuries per characteristic (see subsection 4.3.2) in percentage. The bar charts show the frequency of the injuries per characteristic per month, describing the injury patterns through the season.



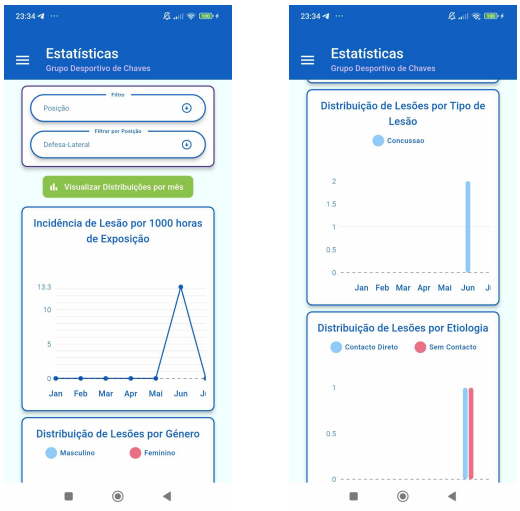
(a) (b) (c)

Figure 5.13: Events data: (a) Page of all events of injury of a team; (b) Page of the details of an event; (c) Page of the details of an injury of an event

Using the filter at the top of the page, users can get statistical data regarding only injuries that follow the selected filter. For example, the user can choose only a specific position of the players to get more concrete statistics. To calculate the injury incidence, the application automatically parses the injuries and calculates their value only using the total exposure time of the players whose injuries follow the filter. The graphs displaying statistical data can be seen in Figure 5.14 and Figure 5.15.

(a) (b) (c) (d)

Figure 5.14: Statistical data per season: (a): Statistical page - part 1; (b): Statistical page - part 2; (c): Statistical page - part 3; (d): Statistical page - part 4



(a) (b)

Figure 5.15: Statistical data per month: (a): Statistical page with filter; (b): Statistical page - bar chart example;

5.3 Mobile application intermediate evaluation

As explained in subsubsection 3.1.3.2, the first evaluation of the mobile application user interface was done in two phases: a cognitive walkthrough conducted with the participants and a questionnaire. In the cognitive walkthrough, an overall explanation about *Figma* and the design was done. Then, several actions were performed by the users and evaluated: the process of creating and login into their account; the process of visualizing and changing their account data; the process of recording (creation, edition) and monitoring (visualization) players, exposures, and injuries data, with and without using the filters; and the process of visualizing a specific statistic using the filters.

Nine people participated in this evaluation step. Out of those, there was one *technical staff user* that had more than ten years in semi-professional football, four *medical staff users* with more than ten years of experience in football (two in professional and two in semi-professional football), two *medical staff users* with six to ten years of experience in amateur football, one with one to five years of experience in professional football, and one with less than one years of experience in amateur football. None of the elements had any difficulty identifying the required steps to perform the actions stated above, as shown by their answers to the questionnaire.

The questionnaire, which can be seen in Table B.2, was divided into five sections, each one for each main functionality of the mobile application (authentication, players' demographic data registry and monitoring, team exposures registry and monitoring, injuries recording and monitoring, and statistical data visualization) and one for final considerations regarding the application. The injuries recording and monitoring was divided into three sub-sections: one to evaluate the design focused on injuries (see subsubsection 5.2.5.1), another to assess the design focused on events (see subsubsection 5.2.5.2), and a final one comparing both of them.

All the participants considered the authentication process (account creation and login) easy,

and the data used was adequate, with a mean of 4 out of 4 in the questions regarding this section, with 1 meaning "very hard" and 4 "very easy". As an open feedback, one user suggested fingerprint authentication as an improvement to the mobile application, offering a more secure authentication process.

The answers were also consensual regarding the players' demographic data recording and monitoring. All participants described it as an easy process, and the data was adequate to the context and clear, having a mean of 4 out of 4 in the questions regarding this section, with 1 meaning "very hard process" or "very unclear information displaying", and 4 "very easy process" or "very clear information displaying". Nevertheless, one user suggested having a body chart to improve understanding of the athlete's conditions.

The users identified the exposure information was clear, with a mean of 3.77 out of 4, with 1 meaning "very unclear" and 4 "very clear".

As previously stated, the questionnaire had 3 three sections regarding injury recording and monitoring within the application. In the *injury focused design* section, the participants described this design as having adequate fields to describe an injury, with a mean of 3.88 out of 4 on a scale from 1 to 4, with 4 meaning "very adequate," and 1 "very inappropriate". Regarding the clarity of the display of the information, the participants considered it very clear, with a mean of 4 out of 4 on a scale from 1 to 4, with 4 meaning "very clear" and 1 "very unclear". The participants considered that finding a specific injury was very easy, with a mean of 3.88 out of 4 on a scale of 1 to 4, with 1 meaning "very hard" and 4 "very easy". Nevertheless, the easiness of the process of closing an injury and releasing a player had a score of 3.77 out of 4, with 4 meaning "very easy" and 1 "very hard". One participant suggested, as an improvement, having intermediate states of release of the player, where the player could be identified as not 100% ready to play, but able to return to training. This suggestion was considered and discarded due to the definition of injury used, in order to maintain the consistency with the recording methods and injury definitions. In the *event focus design* section, the users described it as easy to use and the information adequate, with a mean of 3.77 out of 4 for both questions. Its information clarity and easiness to search had a mean of 3.66 out of 4. One question was posed for the users to identify the meaning of the green and red colors of the *card component* for injuries, where all the users correctly identified the green color as describing the injury as closed and the player as ready to play, and the red as the injury open and the player not ready to play, showing that it was easy to identify which injury is closed or open.

Regarding the decision of the design to develop, 6 participants identified the design focused on injuries as easier to navigate and monitor injuries, while 1 participant identified B. The remaining did not have a preference. In terms of clarity of the design, 7 participants chose the design focused on injuries as more clear, while 2 participants did not have a preference. Regarding the information collected, 7 participants chose the design focused on injuries as the most efficient one to record injury data, while 2 participants chose the design focused on events. The last question of the injuries section was for the user to select which design they would choose, with 8 participants choosing the design focused on injuries and 1 participant choosing the design focused on the

events. As such, and since the other questions also had more positive answers for this design, the design focused on injuries was the design chosen and developed for the solution.

The last section was regarding the overall mobile application evaluation. The participants considered the application as engaging, with a mean of 3.66 out of 4, with 1 meaning "not engaging" and 4 as "very engaging". All the participants considered the navigation between the pages as "very intuitive", with a mean of 4 out of 4, where 1 means "not intuitive" and 4 "very intuitive". The participants considered the mobile application visually attractive and the colors and layout pleasant, with a mean of 3.55 out of 4 for both questions, with 1 meaning, respectively, "very unattractive" and "very unpleasant", and 4 meaning, respectively, "very attractive" and "very pleasant". The participants also considered the mobile application elements (buttons, icons, menus, and content), visual content, and design as appropriate, with, respectively, a mean of 3.44 and 3.66 out of 4, with 1 being "very inappropriate" and 4 "very appropriate".

All the participants stated that they would recommend this application to someone in this context.

5.4 Database architecture

As concluded in section 5.3, the most chosen design within the mobile application evaluation process was the design focusing on injuries, with the injury as a reference element and not the event. Therefore, in order to persistently store the data, the design of the database is presented as follows in Figure 5.16:

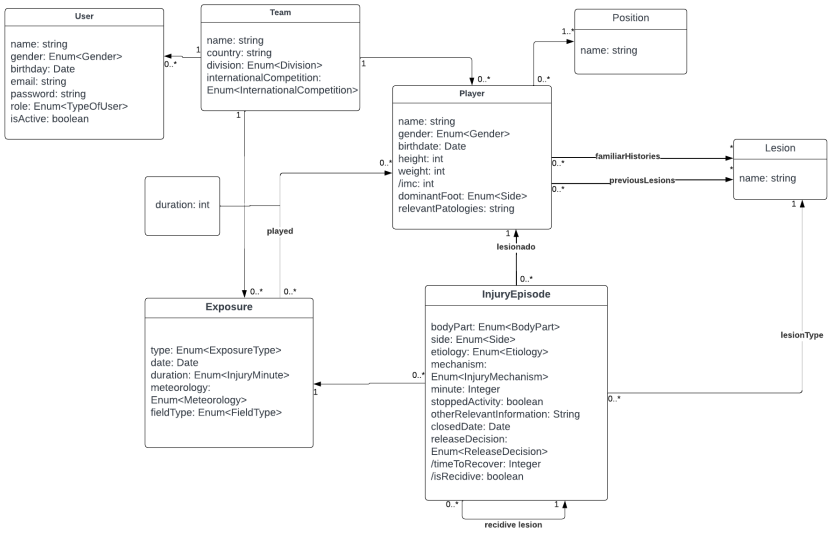


Figure 5.16: Database design for both the server and the mobile application.

The database consists of 5 main entities: the team, the user, the players, the exposures, and the injury episodes. The team represents the central entity, from which most of the relationships arise. As explained in section 4.3, users are registered in a specific team, and players also belong

to a team. On the other hand, teams have exposures where the players participate. Injury episodes happen in a specific exposure, affect a specific player, and may be recidive from other injuries.

5.5 Summary

In this chapter, the system's architecture and the mobile application's design were presented. Constituted by one server and the mobile application that communicates between them, this architecture ensures the development of the proposed solution for the current problems with pen-and-paper injury recording and monitoring and injury recording and definition methods, with a solution that follows the definition of IOC consensus statement [34], its subsequent revisions and extensions [5, 101] and UEFA model [43].

To reach the solution, an initial mobile application design was done. Its interface is organized into six main pages: the authentication page, the user's account page, the players' demographic data, the teams' exposures page, the team's injuries page, and the statistics page. The interface design followed a simple but coherent design on all the application's pages, allowing for a quick and practical way of recording and monitoring epidemiological data.

The intermediate evaluation of the mobile application interface's design was conducted to assess its usability, and two, evaluate two designs regarding injuries perspective. Generally, the participants considered the application very easy to use and the content of each page clear and appropriate, with only one suggestion for data improvement. The design focused on injuries was the one used for developing of the injuries pages, providing an easier and faster way of recording and monitoring injuries compared with the design focused on events, as expressed by 8 out of 9 participants in the questionnaire.

Chapter 6

Mobile Application Evaluation and Results

This chapter presents the evaluation steps that followed the application development and the discussion of its results. It initially explains the evaluation process in section 6.1, describing the cognitive walkthrough and the questionnaire, and then presents a discussion of the results section 6.2. Lastly, it provides a summary of it section 6.3.

6.1 Evaluation

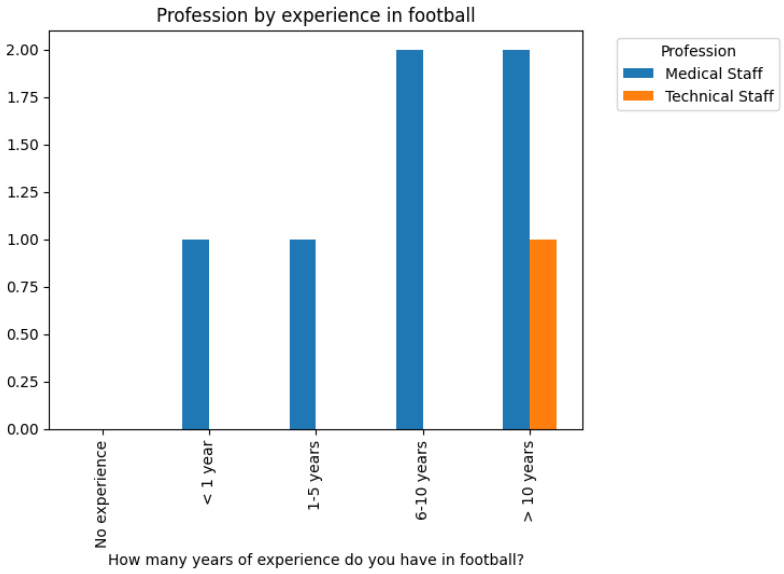
After the application's development, a user evaluation was performed. Seven participants, of which one *technical staff user* and six *medical staff users*, participated in this phase. All participants had previously engaged in the earlier user interface evaluation phase (see section 5.3). Further details on the participants can be seen in Figure 6.1.

The main goal of this evaluation was to test the usability of the application and its correctness. For that, a cognitive walkthrough was performed with the participants, followed by a questionnaire.

6.1.1 Cognitive Walkthrough

The cognitive walkthrough followed a similar approach as the one performed previously (see section 5.3), and it was performed remotely via *Google Meets*. Initially, an overview of the mobile application was explained, and the *apk* was given to the participants so they could install the application on their own smartphones. Subsequently, the participants shared their smartphone screens to allow real-time observation and assessment. After this, the participants were requested to perform the following tasks:

1. **Account Creation:** The participants should create an account. For that, they should enter the app, click on the create account button to redirect them to the creation account page, fill in all the required fields, and then click on the submit button.



(a)

Figure 6.1: Demographic data of the participants of final user evaluation questionnaire

2. **Login:** After creating an account, the participants were requested to authenticate in their registered account. For that, they should correctly introduce their credentials on the login page.

3. **See and edit their account information:** The participants were requested to see and subsequently edit their account information. For that, they should click on the top left icon on the main page to open the navigation drawer, click on their account icon or name, click on the edit button, change one of the fields of their account, and submit the forms. After that, they should confirm the edition by clicking on the yes button of the *confirmation popup* that appears.

4. **Create player information:** The participants were requested to create a player's information. For that, they must go to the team players' page, click the add player button at the bottom of the page, fill in all the required fields, and submit it. After that, the participant must confirm the change on the *confirmation popup*.

5. **Edit player information:** The participants were requested to edit a player's information. For that, they must go to the team players' page, search for the player, click in their *content card*, click the edit button on the player's page, edit one field regarding the player's information, and submit it. After that, the participant must confirm the change on the *confirmation popup*.

6. **Create exposure:** Similarly to the creation of a player, the participants were requested to create an exposure. For that, they must go to the exposures page, click on the add exposure button, fill in all the required fields, click the submit button, and then confirm the creation

of the exposure. In case the participation incorrectly introduces the duration of the players in the exposure, they must correct it after trying to submit the information the first time and then try to submit it again.

7. **Edit exposure information:** Similarly to editing a player, the participants were requested to edit an exposure information. For that, they must go to the exposures page, select the *content card* of an exposure, click the edit button, edit one field, submit the new information, and confirm.

8. **Create an injury:** The participants were requested to create an injury. For that, they must go to the injuries page, click the add injury button, select the exposure where it occurred using the *selection data popup*, fill in the remaining fields, and confirm the creation on the *confirmation popup*.

9. **Close an injury:** The participants were requested to edit an injury information and close it. For that, they should select the *card content* of an open injury, fill the *release decision* field, and confirm the data.

10. **See statistical data:** The participants were requested to analyze the statistical data displayed in the app. For that, they must go to the statistics page and analyze the charts displayed. This action was extended so the users also filter the statistical data, showing, for example, only the statistics for a particular player or playing position.

11. **Use filters:** The participants were requested to search for particular players, exposures, and injuries, using the filters. For that, they must go to one of the players, exposures, or injuries pages, select the filter they want to use, and select the value they want to search for. This was requested on all those pages, so the user could use different parameters to filter for.

12. **Export data:** The participants were requested to export data regarding the team's players, exposures, and injuries. For that, they must go to one of the players, exposures, or injuries pages, click the export data button, accept the permissions in case they did not already, and then open the created *csv* file. This action was extended so the users use the filter along with this functionality, downloading only filtered players, exposures, or injuries.

All the participants showed no difficulties in performing the majority of the actions, except for two participants who could not export the data due to their old Android version on their smartphones and, consequently, issues in the permissions to download the *csv* files. Tasks number 6 and 8 were requested to be done more than once, having exposures of different dates. This happened so the users could create a recidive injury, where they had to select the injury the new one is recidive of, similarly to selecting an exposure.

6.1.2 Questionnaire

After the cognitive walkthrough, a questionnaire was given to the participants. The main goal of this questionnaire was to collect their feedback regarding the application's usability, engagement,

functionalities, aesthetics appropriateness, and information relevance. As previously stated in subsubsection 3.1.5.1, the questionnaire was done based on the heuristics suggested by Nielsen et al. [75], and the user version of the mobile application rating scale [96]. The questionnaire can be seen in Table B.3.

Regarding the authentication process, the participants considered it very easy for both the creation of an account and login in the created account, with a mean of 4 for the creation, and 3.86 for the login, on a scale from 1 to 4, where 1 means "very hard" and 4 "very easy."

In terms of players' information recording and monitoring, the participants considered the information collected very appropriate, where all the participants answered 4 on a scale from 1 to 4, with 1 meaning "very inappropriate" and 4 "very appropriate". Regarding the easiness of recording new players, the participants considered it "very easy", where every participant answered with a 4 on a scale from 1 to 4, with 1 meaning "very hard" and 4 "very easy". Regarding the clarity of the information displayed, the participants considered it very clear, with only one participant answering 3 and the remaining ones 4, with 1 meaning "very unclear" and 4 "very clear".

Regarding exposure data, the participants considered the data to collect about exposures very appropriate, where only 1 participant answered with 3 and the remaining ones 4, on a scale from 1 to 4, with 1 meaning "very inappropriate" and 4 "very appropriate". The process of recording a new exposure was shown to be very easy, with all the participants answering 4 on a scale from 1 to 4, with 1 meaning "very hard" and 4 "very easy". In terms of the visual display of exposures, the participants considered the information displayed very clear and appropriate to the context, where only 1 participant answered 3 and the remaining ones 4, in terms of clarity, on a scale from 1 to 4, where 1 means "Not clear" and 4 "Very clear", and, in terms of appropriateness, 2 participants answered 3 and the remaining ones 4, on a scale from 1 to 4 where 1 means "very inappropriate" and 4 "very appropriate".

All the participants considered the injury data very appropriate, very easy to search and register, and the process of closing an injury very easy to do, with the answers to those questions being all 4 on a scale from 1 to 4, where, respectively, 1 means "very inappropriate" and "very hard", and 4 means "very appropriate" and "very easy", showing the focus on a clear design that allows easy and fast recording and monitoring of injuries.

The statistical page of the application shows a statistical overview of the epidemiological data registered within a team. The participants considered that the graphs displaying the data were very relevant, with only 2 participants answering 3, and the remaining answering 4, on a scale from 1 to 4, with 1 meaning "Not relevant" and 4 "Very relevant". Regarding its clarity, only one participant answered 3 and the remaining ones 4, on a scale from 1 to 4, with 1 meaning "very unclear" and 4 "very clear". Lastly, all the participants considered vital to show the distribution of injuries per month.

The last section encompasses final considerations about the mobile application, with its generic evaluation. The participants considered the user interface and its content very appropriate within the context, with only two participants answering 3 and the remaining ones 4 on a scale from 1 to 4, where 1 means "very inappropriate" and 4 "very appropriate". In terms of the user interface

components and its displaying, the participants considered it very adjusted, with a clear, organized, and professional design, with only one participant answering 3, and the remaining ones 4 on a scale from 1 to 4, where 1 means "very misadjusted, unclear, and not professional", and 4 "very adjusted, clear, and professional". In terms of visual appearance, the participants found the user interface appealing, where three of the participants answered 3 and the remaining ones 4, with a mean of 3.58 on a scale from 1 to 4, with 1 meaning "not appealing" and 4 "very appealing". In terms of interactivity, the participants found the application very interactive, with only one participant answering 3 and the remaining ones 4 on a scale from 1 to 4, with 1 meaning "Not interactive and no user input feedback" and 4 meaning "high level of interactivity with interactive features and feedback to user input". Regarding the functionalities and the components used for them (for example, visualization of players' data or statistical results by using charts), almost all the participants found it very appropriate, with only one participant answering 3 and the remaining ones 4 on a scale from 1 to 4, with 1 meaning "very inappropriate" and 4 "very appropriate". All the participants found the mobile application very easy to learn, with everyone answering 4 on a scale from 1 to 4, with 1 meaning "very hard" and 4 "very easy". Four participants considered the navigation between pages easy to understand, while three considered it logical, easy, clear, and intuitive.

Regarding the content of the application, all the participants considered it correct and relevant, with 1 participant answering 3 and the remaining ones 4 on a scale from 1 to 4, with 1 meaning "Not correct/relevant" and 4 "Very correct/relevant", and its displaying very concise and clear, with all participants answering 4 on a scale from 1 to 4, with 1 meaning "Incomprehensible, insufficient or excessive" and 4 "comprehensive and concise". Along with it, the visual display of its information its clear, with three participants answering 3 and four answering 4 on a scale from 1 to 4, with 1 meaning "very unclear" and 4 "very clear".

All the participants answered that they would recommend this application to record and monitor injury incidence and prevalence among football players, performing epidemiological surveillance in football.

6.2 Discussion

The mobile application's evaluation results show both its general effectiveness and user satisfaction, as well as areas where improvements could be made.

The usability of the application was rated by participants across the various pages of the mobile application. Both the account creation and login processes were deemed very easy, showing that the initial interaction with the application is positive, simple, and user-friendly, which is crucial for user retention.

The mobile application should offer a quick, practical, and user-friendly way of recording and monitoring players, exposures, and injuries, allowing clinics to perform epidemiological surveillance on the teams they are registered in. These processes were found by the participants to align with those requirements, who considered them as very easy, their information clearly displayed,

and the content very appropriate. Along with this, all the users performed the tasks requested in the cognitive walkthrough very easily, meeting the requirements of the mobile application and reflecting its intuitive design. Furthermore, the particular process of closing an injury, along with searching for the injury to close, was found to be very easy to perform, providing a vital functionality for injury monitoring.

The application's user interface was generally well-received. Participants considered it very appropriate and visually appealing, where the high scores for the clarity and organization of the UI components reflect a user-friendly design. The high interactivity score also shows that the application provides adequate feedback, engagement, and fault tolerance, enhancing the user experience. The clear and consistent design of the user interface components ensures that users can navigate between pages and perform tasks efficiently, without much effort or time spent.

Participants found the content of the application to be highly relevant and correct. The statistical data displayed in the application was also considered very relevant and clear, providing an overview of the data collected. This shows that the application effectively presents complex data in a user-friendly manner, and provides valuable insights on the epidemiological situation of a team. The consistency in high scores for content correctness, relevance, and clarity across different sections of the application underscores the importance of well-organized and concise information presentation. The participants' unanimous agreement on recommending the application for epidemiological surveillance in football reinforces the application's utility and effectiveness.

While the evaluation results are positive, the issues faced by two participants during the data export process highlight the need to address compatibility with older Android versions. Ensuring that the application supports a wider range of devices will improve its accessibility and usability, as well as having more users to collect more epidemiological data, vital for assessing injury prevention measures.

6.3 Summary

This chapter detailed the evaluation process and results for the mobile application developed for epidemiological surveillance in football. The evaluation involved seven participants, including one technical staff member and six medical staff members, who had also participated in the initial user interface evaluation. The evaluation process comprised a cognitive walkthrough followed by a questionnaire to assess the application's usability, functionality, aesthetics, and content relevance.

The cognitive walkthrough revealed that participants found most tasks, including account creation, login, and managing player information, exposures, and injuries, to be very easy to perform. However, two participants encountered issues with exporting data due to compatibility problems with older Android versions, highlighting a need for broader device support.

The questionnaire results indicated high user satisfaction with the application, who highly rated the usability of the application, finding it easy to use, with clear and appropriate content. The user interface was considered visually appealing, well-organized, and interactive, showing the focus on developing a simple, practical, and fault-tolerant mobile application. The statistical

data presentation was also deemed relevant and clear, providing valuable insights into the epidemiological data collected.

Despite the positive feedback, the evaluation identified areas for improvement, particularly in ensuring compatibility with older Android devices to enhance accessibility and usability. Overall, participants unanimously recommended the application for recording and monitoring injury incidence and prevalence among football players, affirming its utility and effectiveness for epidemiological surveillance in football.

Chapter 7

Conclusions

This chapter presents this work's main conclusions and proposes future steps to improve epidemiological surveillance in football.

7.1 Accomplishments

In the literature review process several problems were identified regarding epidemiological surveillance in football. From the lack of injury surveillance solutions to inconsistencies in injury reporting and definition methods, epidemiological surveillance has been hard to perform by clinicians in football, hampering the development and assessment of injury prevention programs. Currently, this process is mostly done with pen and paper, offering many difficulties in accessibility, data completeness, and correctness.

As a solution, the presented work aimed to provide a quick, practical, accessible, and user-friendly injury registry software to record and monitor injury incidence and prevalence among football players by developing a mobile application. As an end goal, this tool also aimed to provide meaningful data on injury epidemiology to, in the future, feed predictive systems that inform about players at increased risk of injury and help to assess the effectiveness of preventive measures. It was possible to identify the mobile application as an impactful and positive solution for epidemiological surveillance from the evaluation questionnaires performed, where people considered that the mobile application would have a positive impact on recording and monitoring epidemiological data in football, performing epidemiological surveillance and, in the future, to improve injury prevention in football.

To reach this solution, a user-centered methodology was followed, consisting of four main phases: (i) Problem Identification, where the problem is identified and previous attempts to solve it are studied, as a result of the literature review process; (ii) Requirements Gathering, where the user groups and the requirements of the system were defined and validated; (iii) Design Phase, where the user interfaces of the mobile application were designed and validated and, consequently, the architecture of the system was defined; (iv) Development phase, where the server and the mobile application of the system were developed and, in the end, the mobile application was evaluated.

The intermediate and final evaluation steps to, respectively, assess the design of the user interfaces and content of the mobile application, and evaluate the final developed solution, were done by performing cognitive walkthroughs, where the users were requested to perform some actions, followed by a questionnaire. As a result, the participants identified the mobile application as easy to use, with a clear and appealing design solution for clinicians to quickly register meaningful and appropriate epidemiological data from their teams, adding value by centralizing clinical data and providing real-time feedback and data while allowing them to build epidemiological overview in football, leveraging epidemiological surveillance in football.

7.2 Limitations and Future work

While the current version of the mobile application has proven to be effective and easy for injury recording and monitoring, there are several areas for future enhancement. Addressing the compatibility issues with older Android devices is crucial for broadening the application's user base and ensuring accessibility. Expanding the application's compatibility to include both iOS and Android devices is crucial for broadening its user base and ensuring accessibility across different devices and operating systems.

Another limitation identified is the participation rate in the evaluation questionnaires, particularly the second and third ones that followed the cognitive walkthroughs. Low participation rates can skew the results and may not provide a fully accurate representation of the application's effectiveness and areas needing improvement. Future efforts should focus on strategies to increase engagement and participation in these evaluations, as it would lead to more accurate conclusions and opinions regarding the application's design and effectiveness.

Moreover, the definition of injury based on the time-loss criterion may also present a limitation. While this definition is widely used and facilitates consistency in injury reporting, it may not capture the full spectrum of injury severity and its impact on players, as it may overlook minor injuries or physical complaints that do not lead to missed training or matches but could still affect performance and player well-being.

Future work should also focus on improving the scope of data collected. Expanding data points to include, for example, detailed player performance metrics, more details on meteorological conditions during exposures, and precise injury diagnoses will provide the epidemiological analysis performed and, consequently, the development of effective injury prevention strategies. Additionally, improving the statistical data shown by the application can enhance its utility in identifying players at increased risk of injury and evaluating the effectiveness of preventive measures.

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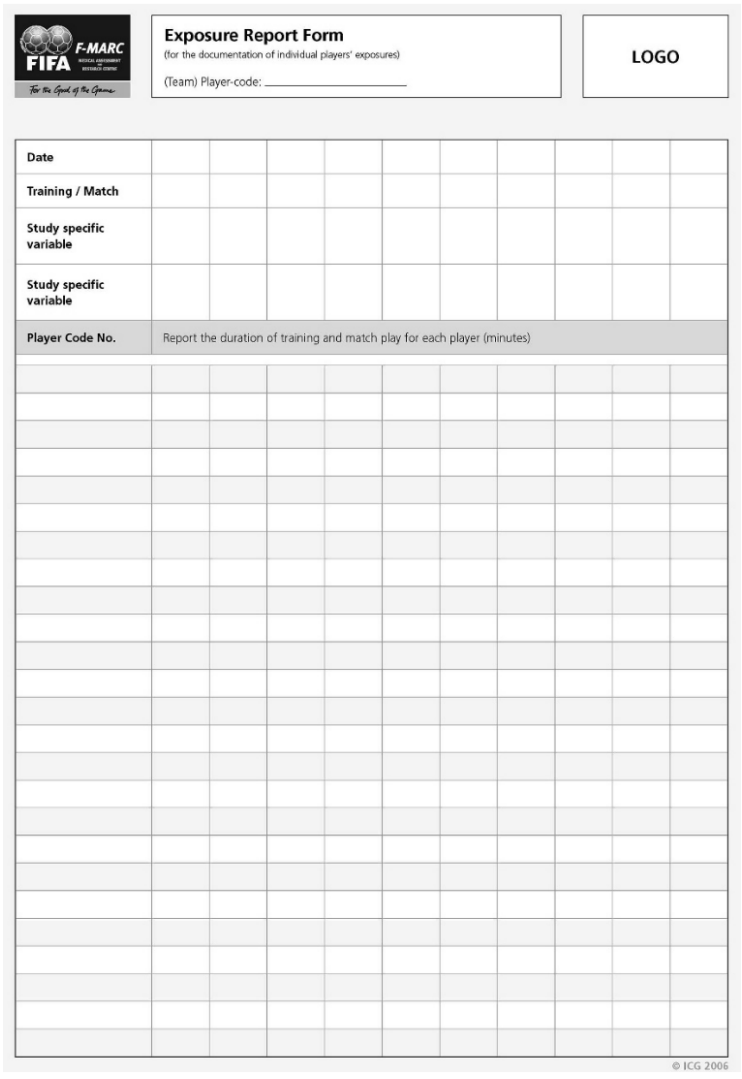
Appendix A

Literature Review

A.1 UEFA Data Collection Forms



FIFA F-MARC

Exposure Report Form

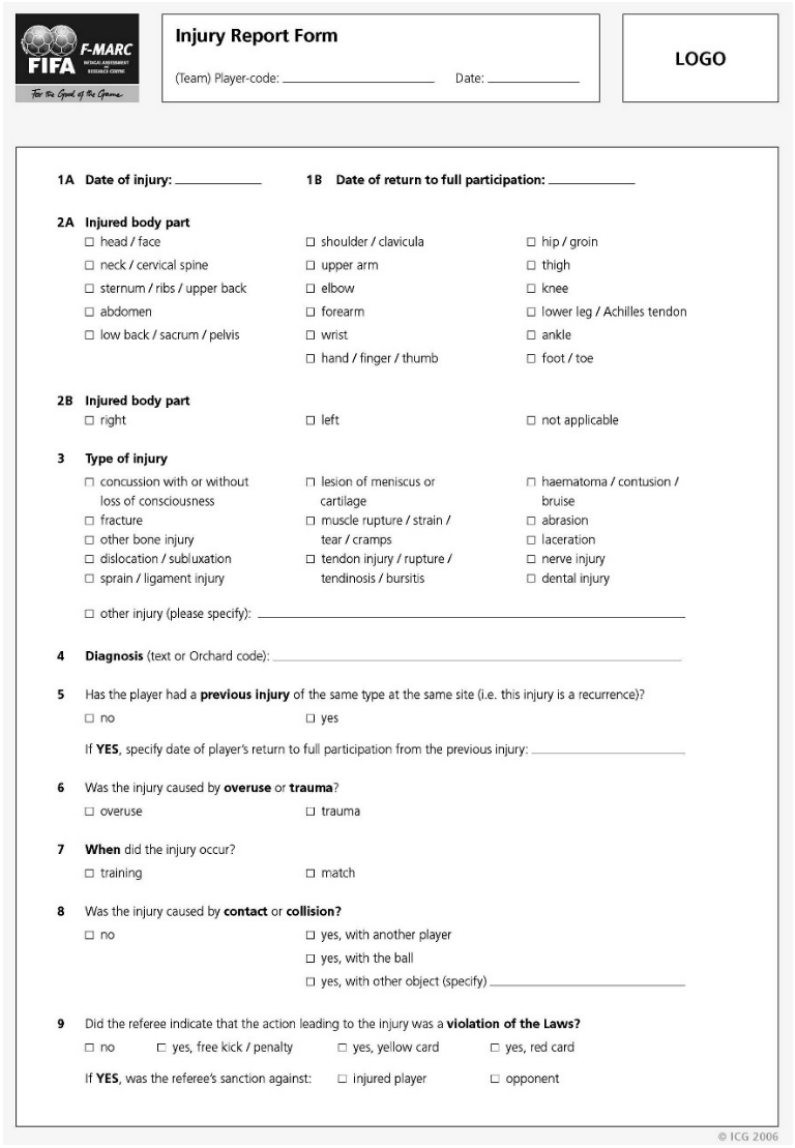
(for the documentation of individual players' exposures)

(Team) Player-code: _____

LOGO

Date										
Training / Match										
Study specific variable										
Study specific variable										
Player Code No.	Report the duration of training and match play for each player (minutes)									

Figure A.1: UEFA Exposure report form



Injury Report Form

(Team) Player-code: _____ Date: _____

LOGO

1A Date of injury: _____ **1B Date of return to full participation:** _____

2A Injured body part

- ☐ head / face
- ☐ neck / cervical spine
- ☐ sternum / ribs / upper back
- ☐ abdomen
- ☐ low back / sacrum / pelvis
- ☐ shoulder / clavicula
- ☐ upper arm
- ☐ elbow
- ☐ forearm
- ☐ wrist
- ☐ hand / finger / thumb
- ☐ hip / groin
- ☐ thigh
- ☐ knee
- ☐ lower leg / Achilles tendon
- ☐ ankle
- ☐ foot / toe

2B Injured body part

- ☐ right
- ☐ left
- ☐ not applicable

3 Type of injury

- ☐ concussion with or without loss of consciousness
- ☐ fracture
- ☐ other bone injury
- ☐ dislocation / subluxation
- ☐ sprain / ligament injury
- ☐ lesion of meniscus or cartilage
- ☐ muscle rupture / strain / tear / cramps
- ☐ tendon injury / rupture / tendinosis / bursitis
- ☐ haematoma / contusion / bruise
- ☐ abrasion
- ☐ laceration
- ☐ nerve injury
- ☐ dental injury
- ☐ other injury (please specify): _____

4 Diagnosis (text or Orchard code): _____

5 Has the player had a **previous injury** of the same type at the same site (i.e. this injury is a recurrence)?

- ☐ no
- ☐ yes

If **YES**, specify date of player's return to full participation from the previous injury: _____

6 Was the injury caused by **overuse** or **trauma**?

- ☐ overuse
- ☐ trauma

7 When did the injury occur?

- ☐ training
- ☐ match

8 Was the injury caused by **contact** or **collision?**

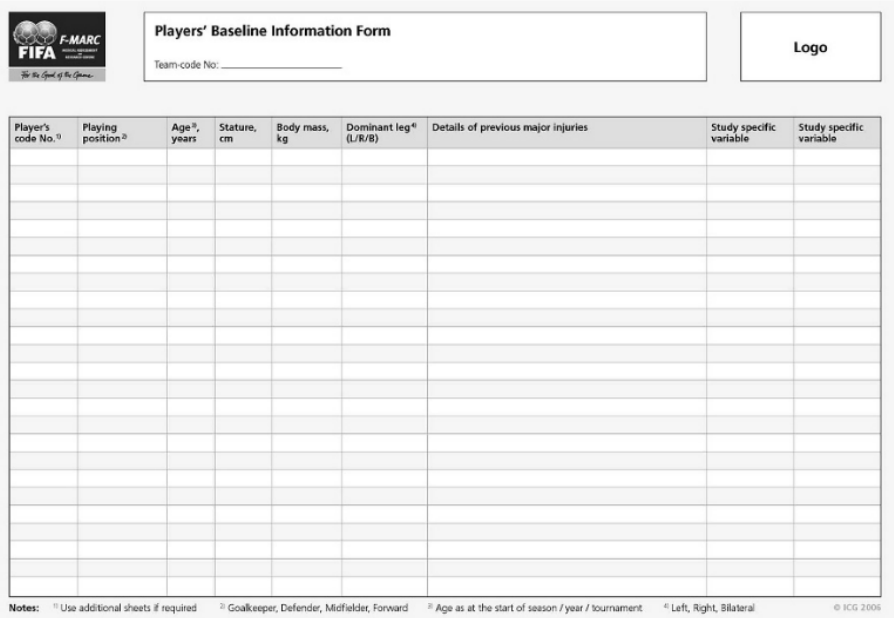
- ☐ no
- ☐ yes, with another player
- ☐ yes, with the ball
- ☐ yes, with other object (specify) _____

9 Did the referee indicate that the action leading to the injury was a **violation of the Laws?**

- ☐ no
- ☐ yes, free kick / penalty
- ☐ yes, yellow card
- ☐ yes, red card

If **YES**, was the referee's sanction against: ☐ injured player ☐ opponent

Figure A.2: UEFA Injury report form



Players' Baseline Information Form

Team-code No: _____

Logo

Player's code No.[1]	Playing position[2]	Age[3], years	Stature, cm	Body mass, kg	Dominant leg[4] (L/R/B)	Details of previous major injuries	Study specific variable	Study specific variable

Notes: [1] Use additional sheets if required [2] Goalkeeper, Defender, Midfielder, Forward [3] Age as at the start of season / year / tournament [4] Left, Right, Bilateral © ICG 2006

Figure A.3: UEFA Player baseline information form

A.2 LKIS System

A.2.1 LKIS Flow Chart

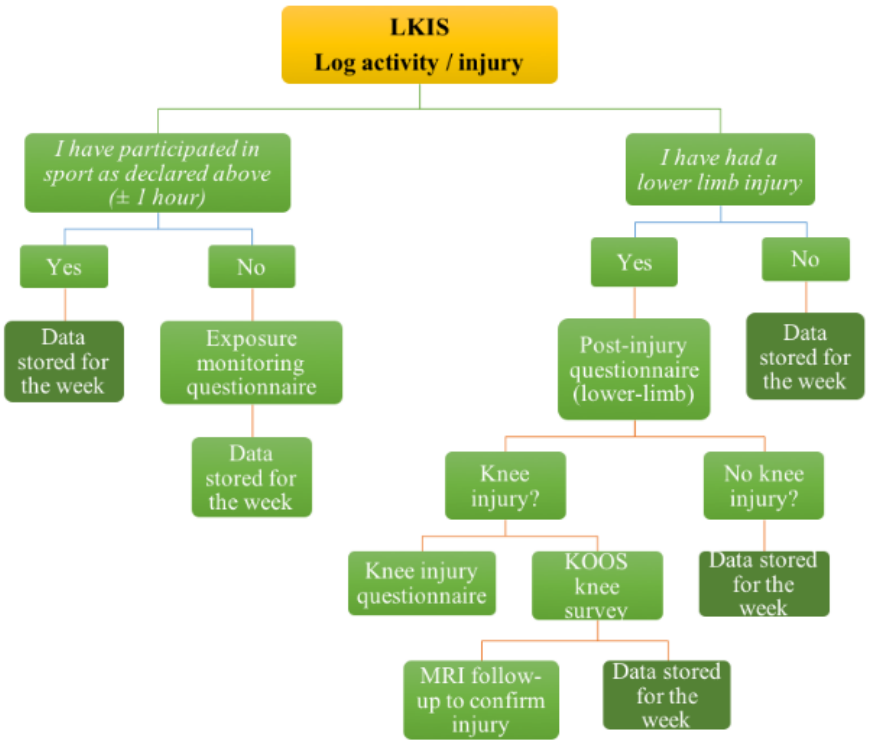


Figure A.4: A flow chart describing the follow-up process and questionnaires provided by LKIS app.

A.2.2 LKIS System Architecture

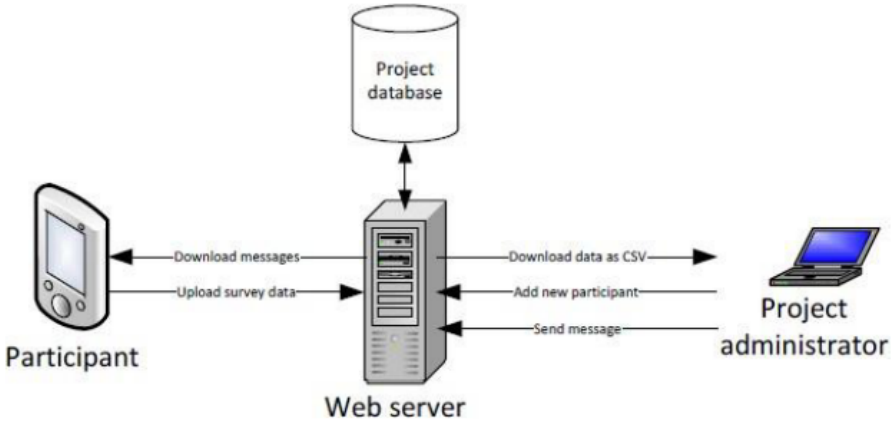


Figure A.5: Architecture of the LKIS application.

Appendix B

Evaluation Questionnaires

B.1 Requirements Gathering Evaluation Questionnaire

Table B.1: Questionnaire 1 - Mobile Application for Epidemiological Surveillance in Football

Questionnaire 1 - Mobile Application for Epidemiological Surveillance in Football
Tese de Mestrado - Aplicação Móvel para Vigilância Epidemiológica no Futebol Este formulário desenvolve-se no âmbito da dissertação de mestrado "Aplicação Móvel para vigilância epidemiológica no futebol", sendo que as suas respostas são de total relevância para o estudo e desenvolvimento de uma ferramenta eficiente para recolha e análise de dados epidemiológicos no futebol. O objetivo principal do formulário é receber feedback acerca da usabilidade de uma aplicação móvel para a recolha de dados epidemiológicos, com foco nas preferências, expetativas e requisitos que os utilizadores considerem relevantes para a aplicação. A participação é totalmente voluntária, sendo que as respostas serão guardadas de forma confidencial e anónima. Ao proceder com este formulário, tem o consentimento na recolha e análise das respostas dadas. O tempo esperado para completar este formulário é de aproximadamente 3 minutos. Fico agradecido pelo tempo dispendido e pelas respostas, que me irão ajudar no desenvolvimento desta tese. Obrigado!
* Indica uma pergunta obrigatória
Secção 1: Contexto Pessoal

1	**Qual é a sua profissão ou papel atual num contexto futebolístico?** • Equipa Médica (Médico, Enfermeiro, Fisioterapeuta, Outro) • Equipa Técnica (Treinador, Treinador-Adjunto, Preparador Físico, Recuperador Físico, Analista de dados, Cientista de dados, Outro) • Organizações de Regulamentação (FPF, Associações de futebol...) • Jogador de futebol • Outro: _____
2	**Quantos anos de experiência tem, no total, no futebol?** • < 1 ano • 1-5 anos • 6-10 anos • Mais de 10 anos • Nenhuma experiência no futebol
3	**Se é afiliado a um clube de futebol, selecione a categoria que melhor descreve esse clube:** • Amador (participantes têm outra profissão a tempo integral) • Semi-profissional (segundo emprego, sendo o futebol um emprego de "part-time") • Profissional (futebol como profissão a tempo integral)
4	**Alguma vez teve contacto com alguma ferramenta para gestão de dados epidemiológicos no futebol?** • Sim • Não Se sim, por favor descreva a sua experiência com a ferramenta e indique o seu nome: _____
Secção 2: Expetativas e Requisitos	

5	**Numa escala de 1 a 4, quais são as expetativas acerca do impacto da aplicação móvel para a gestão de dados epidemiológicos no futebol?** • 1 (Sem Impacto) • 2 • 3 • 4 (Muito Impacto)
6	**Numa escala de 1 a 4, quais são as suas expetativas acerca do impacto da aplicação na vigilância epidemiológica no futebol e na prevenção de lesões?** • 1 (Sem Impacto) • 2 • 3 • 4 (Muito Impacto)
7	**Numa escala de 1 a 4, qual é a probabilidade de usar uma aplicação móvel para recolha e visualização de dados epidemiológicos?** • 1 (Nada Provável) • 2 • 3 • 4 (Muito Provável)

8	**Quais são os fatores que influenciam maioritariamente a sua decisão de usar a aplicação? (Selecione até 3 fatores)** • Interface amigável • Acesso em tempo real aos dados • Facilidade de introdução de dados • Centralização dos dados clínicos • Integração com aplicações existentes • Informação estatística das lesões e atletas • Visualização gráfica dos dados • Outro: _____
9	**Quais são os tipos de dados epidemiológicos que considera mais essencial recolher para uma eficiente gestão de lesões? (Selecione até 3 dados)** • Tipo de lesão • Gravidade/Severidade da lesão • Localização da lesão • Burden (quantidade de jogos perdidos) • Detalhes específicos do jogador (condições médicas pré-existentes, lesões anteriores, carga de treino, níveis de fadiga, etc.) • Outro: _____

10	**Quais são as funcionalidades que considera fundamentais na aplicação para a recolha de dados epidemiológicos? (Selecione até 3 funcionalidades)** • Introdução de dados simples e rápida • Importação/Exportação de dados (usando, por exemplo, QR Code ou outra metodologia) • Funcionamento da App em modo "offline" • Sincronização automática de dados • Outro: _____
11	**Considera importante a aplicação associar de forma eficiente clubes e jogadores através da integração com bases de dados ou sistemas existentes?** • Sim • Não Porquê? _____
12	**Considera que a aplicação a desenvolver devia ter algum nível de customização para alinhar os requisitos de cada um dos clubes?** • Sim • Não Se sim, que tipo de customização? _____
13	**Há algum requisito ou funcionalidade específica que considera importante para o sucesso desta aplicação?** Especifique: _____
14	**Há algum tipo de dados (e.g., certas classificações de lesões) que considera que devia ser integrado na aplicação para assegurar a sua conformidade?** Especifique: _____
Secção 3: Agradecimentos Agradeço sinceramente o seu tempo e contribuição valiosa para a pesquisa sobre a aplicação de registo e vigilância epidemiológica em futebol, que é fundamental para a validação e desenvolvimento desta tese de Mestrado. Uma vez que é necessária uma posterior validação dos requisitos e interface da aplicação, gostaria de saber se tem interesse e disponibilidade para contactos futuros, de forma a contribuir e ajudar-me ainda mais neste desenvolvimento. Se sim, por favor deixe o seu e-mail no campo em baixo.	

15	**Gostaria de ser contactado futuramente para contribuir e ajudar no desenvolvimento da aplicação?** Se sim, por favor deixe o seu e-mail no campo em baixo: _____

B.2 Mobile Application User Interface Evaluation Questionnaire

Table B.2: Questionnaire 2 - Mobile User Interface Evaluation

Questionnaire 2 - Mobile User Interface Evaluation	
Aplicação Móvel para Vigilância Epidemiológica no Futebol Este formulário desenvolve-se no âmbito da dissertação de mestrado "Aplicação Móvel para vigilância epidemiológica no futebol", sendo que as suas respostas são de total relevância para o estudo e desenvolvimento de uma ferramenta eficiente para recolha e análise de dados epidemiológicos no futebol. O objetivo principal do formulário é receber feedback acerca da interface gráfica, usabilidade e experiência do utilizador na utilização de aplicação móvel para a recolha de dados epidemiológicos, em sequência da semi-entrevista efetuada com o utilizador. A participação é totalmente voluntária, sendo que as respostas serão guardadas de forma confidencial e anónima. Ao proceder com este formulário, tem o consentimento na recolha e análise das respostas dadas para fins académicos. O tempo esperado para completar este formulário é de aproximadamente 5 minutos. Fico agradecido pelo tempo dispendido e pelas respostas, que me irão ajudar no desenvolvimento desta tese. Obrigado!	
Secção 1: Contexto Pessoal	
1	**Qual é a sua profissão ou papel atual num contexto futebolístico?** • Equipa Médica (Médico, Enfermeiro, Fisioterapeuta, Outro) • Equipa Técnica (Treinador, Treinador-Adjunto, Preparador Físico, Recuperador Físico, Analista de Dados, Cientista de Dados, Outro) • Organizações de Regulamentação (FPF, Associações de Futebol...) • Jogador de Futebol • Outro: _____

2	**Quantos anos de experiência tem no futebol?** • < 1 ano • 1-5 anos • 6-10 anos • Mais de 10 anos • Nenhuma experiência no futebol
3	**Se é afiliado a um clube de futebol, selecione a categoria que melhor descreve esse clube:** • Amador (os participantes têm outro emprego a tempo integral) • Semi-profissional (futebol é um trabalho a tempo parcial) • Profissional (futebol como profissão a tempo integral)
Secção 2: Autenticação Nesta secção, o foco é na autenticação. Como tal, pretende-se analisar a facilidade de utilização e consistencia da aplicação nos vários processos de autenticação.	
4	**Numa escala de 1 a 4, o quão fácil considera ser criar uma conta?** • 1 (Muito Difícil) • 2 • 3 • 4 (Muito Fácil)
5	**Considera que a informação pedida no processo de criação de conta clara e adequada?** • Sim • Não Se não, porquê? _____

6	**Numa escala de 1 a 4, o quão fácil considera ser autenticar-se na sua conta?** • 1 (Muito Difícil) • 2 • 3 • 4 (Muito Fácil)
7	**Alguma sugestão em relação às páginas de autenticação?** _____
Secção 3: Dados Demográficos Nesta secção, o foco é a inserção, visualização e edição dos dados demográficos de um jogador. Como tal, pretende-se analisar a facilidade de utilização e consistencia da aplicação nos vários processos de manipulação dos dados demográficos de um jogador na equipa na qual o utilizador está registado.	
8	**Numa escala de 1 a 4, o quão fácil é o processo de inserção dos dados demográficos de um jogador?** • 1 (Muito Difícil) • 2 • 3 • 4 (Muito Fácil)
9	**Acredita que informação diferente ou adicional devia ser recolhida na inserção dos dados de um jogador numa equipa?** • Sim • Não Se sim, qual? _____
10	**Numa escala de 1 a 4, o quão clara é apresentada a informação demográfica de um jogador?** • 1 (Nada Clara) • 2 • 3 • 4 (Muito Clara)

11	**Encontrou alguma dificuldade no processo de inserção/edição da informação demográfica de um jogador?** • Sim • Não Se sim, quais e porquê?? _____
12	**Alguma sugestão em relação às páginas de visualização, adição e edição dos dados demográficos dos jogadores de uma equipa?** _____
Secção 4: Dados de Exposição de uma Equipa Nesta secção, o foco é a inserção, visualização e edição dos dados de exposição de uma equipa. Como tal, pretende-se analisar a facilidade de utilização e consistencia da aplicação nos vários processos de manipulação dos dados de exposição da equipa na qual o utilizador está registado.	
13	**Numa escala de 1 a 4, o quão clara é a informação apresentada acerca de uma exposição?** • 1 (Nada Clara) • 2 • 3 • 4 (Muito Clara)
14	**Encontrou alguma dificuldade no processo de inserção/edição de uma exposição de uma equipa?** • Sim • Não Se sim, quais e porquê? _____
15	**Alguma sugestão em relação às páginas de visualização, adição e edição das exposições de uma equipa?** _____
Secção 5: Episódios de Lesão de uma Equipa Nesta secção, o foco é a inserção, visualização e edição dos dados acerca das lesões de uma equipa. Como tal, pretende-se analisar a facilidade de utilização e consistência da aplicação nos vários processos de manipulação (inserção/edição) dos dados de lesões de uma equipa. Nesta secção, é apresentado um design relativo aos episódios de lesão. O design apresentado nesta página centra-se na lesão, que incorpora toda a informação relativa à mesma. Na próxima secção, um design alternativo será apresentado, de forma a serem comparados.	

16	**Numa escala de 1 a 4, o quão adequados considera os campos que descrevem uma lesão?** • 1 (Nada Adequados) • 2 • 3 • 4 (Muito Adequados)
17	**Numa escala de 1 a 4, o quão clara é a informação apresentada acerca de uma lesão?** • 1 (Nada Clara) • 2 • 3 • 4 (Muito Clara)
17	**Numa escala de 1 a 4, o quão fácil é encontrar a informação relativamente a uma lesão?** • 1 (Muito Difícil) • 2 • 3 • 4 (Muito Fácil)
18	**Numa escala de 1 a 4, o quão fácil é o processo de dar alta a um jogador?** • 1 (Muito Difícil) • 2 • 3 • 4 (Muito Fácil)
19	**Encontrou alguma dificuldade no processo de inserção/edição de uma nova lesão?** • Sim • Não Se sim, quais e porquê?? _____

20	**Qual o significado das cores vermelho e verde no contorno dos componentes com a informação de uma lesão? Considera as cores adequadas para o objetivo pretendido?** _____
21	**Alguma sugestão em relação às páginas de visualização, adição e edição das lesões de uma equipa?** _____
Secção 6: Eventos de Lesão de uma Equipa Como explicado na secção anterior, esta secção representa uma alternativa ao design da interface gráfica em relação às lesões de uma equipa. O design apresentado nesta página centra-se em eventos, dos quais podem advir mais do que uma lesão.	
22	**Numa escala de 1 a 4, o quão fácil é o processo de inserção de um novo evento e respetivas lesões?** • 1 (Muito Difícil) • 2 • 3 • 4 (Muito Fácil)
23	**Numa escala de 1 a 4, o quão adequados considera os campos que descrevem um evento e respetivas lesões?** • 1 (Nada Adequados) • 2 • 3 • 4 (Muito Adequados)
24	**Numa escala de 1 a 4, o quão clara é a informação apresentada acerca de um evento e respetivas lesões?** • 1 (Nada Clara) • 2 • 3 • 4 (Muito Clara)

25	**Numa escala de 1 a 4, o quão fácil é encontrar a informação relativamente a uma lesão em específico?** • 1 (Muito Difícil) • 2 • 3 • 4 (Muito Fácil)
26	**Encontrou alguma dificuldade no processo de inserção/edição de um novo evento e respetivas lesões?** • Sim • Não Se sim, quais e porquê? _____
27	**Alguma sugestão em relação às páginas de visualização, adição e edição de eventos de uma equipa?** _____
Secção 7: Comparação de Designs Nesta secção, seguem-se questões relacionadas com a comparação dos dois designs apresentados nas secções anteriores (5 e 6). Nesta secção, a letra A e B serão usadas para referenciar cada um dos designs: A - Design da secção 5 onde a informação das lesões está toda nos Episódios de lesão B - Design da secção 6 onde a informação das lesões está incorporada em Eventos, que podem conter uma ou mais lesões.	
28	**Você acha mais fácil navegar e usar algum dos designs em relação ao outro para gerenciar lesões? Se sim, qual e porquê?** _____
29	**Você encontrou alguma dificuldade em entender como inserir ou atualizar informações acerca de uma lesão específica em qualquer um dos designs? Se sim, por favor, especifique.** _____
30	**Qual design oferece uma organização mais clara dos dados acerca das lesões? Porquê?** _____
31	**Em termos de capturar todas as informações relevantes sobre lesões, qual design você considera mais eficaz e porquê?** _____

32	**Com base na sua experiência e comparando os dois designs, qual deles preferia usar para registar e monitorizar?** • A • B
33	**Há melhorias específicas que sugeriria para qualquer um dos designs para atender melhor às suas necessidades e preferências?** _____
34	**Por favor, compartilhe quaisquer outros comentários, sugestões ou observações que você tenha sobre a comparação entre os dois designs para o gerenciamento de episódios de lesão.** _____
Secção 8: Avaliação Geral da Aplicação Nesta secção, pretende-se avaliar a apreciação da aplicação num todo em termos de envolvimento, funcionalidades, estética e informação	
35	**A aplicação é interessante e mantém o seu interesse durante a sua utilização?** • 1 (Discordo Totalmente) • 2 • 3 • 4 (Concordo Totalmente)
36	**Numa escala de 1 a 4, o quão fácil é navegar pela aplicação?** • 1 (Muito Difícil) • 2 • 3 • 4 (Muito Fácil)

37	**A navegação entre as diferentes páginas faz sentido?** • 1 (Discordo Totalmente) • 2 • 3 • 4 (Concordo Totalmente)
38	**Numa escala de 1 a 4, o quão intuitivas são as funcionalidades da aplicação?** • 1 (Nada Intuitivas) • 2 • 3 • 4 (Muito Intuitivas)
39	**As interações com os diferentes componentes da aplicação fazem sentido?** • 1 (Discordo Totalmente) • 2 • 3 • 4 (Concordo Totalmente)
40	**Numa escala de 1 a 4, o quão atrativa é a aplicação visualmente?** • 1 (Nada Atrativas) • 2 • 3 • 4 (Muito Atrativas)

41	**Numa escala de 1 a 4, o quão agradáveis são as cores e o layout da aplicação?** • 1 (Muito Desagradáveis) • 2 • 3 • 4 (Muito Agradáveis)
42	**A disposição e o tamanho dos botões, ícones, menus e conteúdo na tela é apropriado?** • 1 (Discordo Totalmente) • 2 • 3 • 4 (Concordo Totalmente)
43	**Numa escala de 1 a 4, o quão apropriado é o conteúdo visual e o design da aplicação para o público-alvo?** • 1 (Nada Apropriado) • 2 • 3 • 4 (Muito Apropriado)
44	**O conteúdo do aplicativo está correto, bem escrito e é relevante para o objetivo da aplicação?** • Irrelevante/inadequado/incoerente/incorreto • Pouco relevante/apropriado/coerente/pode estar incorreto • Relevante/apropriado/coerente/correto • Altamente relevante, apropriado, coerente e correto

45	**Recomendaria esta aplicação a alguém?** • Sim • Não

B.3 Mobile Application Evaluation Questionnaire

Table B.3: Questionnaire 3 - Mobile Application Evaluation

Questionnaire 3 - Mobile Application Evaluation
Aplicação Móvel para Vigilância Epidemiológica no Futebol Este formulário desenvolve-se no âmbito da dissertação de mestrado "Aplicação Móvel para vigilância epidemiológica no futebol", sendo que as suas respostas são de total relevância para o estudo e desenvolvimento de uma ferramenta eficiente para recolha e análise de dados epidemiológicos no futebol. O objetivo principal do formulário é receber feedback acerca da usabilidade e experiência do utilizador na utilização de aplicação móvel para a recolha de dados epidemiológicos. A participação é totalmente voluntária, sendo que as respostas serão guardadas de forma confidencial e anónima. Ao proceder com este formulário, tem o consentimento na recolha e análise das respostas dadas para fins académicos. O tempo esperado para completar este formulário é de aproximadamente 5 minutos, após a previa utilização da aplicação por parte do utilizador. Fico agradecido pelo tempo dispendido e pelas respostas, que me irão ajudar no desenvolvimento desta tese. Obrigado!
Secção 1: Contexto Sócio-Demográfico Nesta secção alguns dados sócio demográficos do utilizador serão registados de forma a poder estudar os resultados obtidos. Note que a sua identidade permanecerá anónima independentemente das respostas colocadas.

1	**Qual é a sua profissão ou papel atual num contexto futebolístico?** • Equipa Médica (Médico, Enfermeiro, Fisioterapeuta, Outro) • Equipa Técnica (Treinador, Treinador-Adjunto, Preparador Físico, Recuperador Físico, Analista de Dados, Cientista de Dados, Outro) • Organizações de Regulamentação (FPF, Associações de Futebol...) • Jogador de Futebol • Outro: _____
2	**Quantos anos de experiência tem no futebol?** • < 1 ano • 1-5 anos • 6-10 anos • Mais de 10 anos • Nenhuma experiência no futebol
3	**Se é afiliado a um clube de futebol, selecione a categoria que melhor descreve esse clube:** • Amador (os participantes têm outro emprego a tempo integral) • Semi-profissional (futebol é um trabalho a tempo parcial) • Profissional (futebol como profissão a tempo integral)
Secção 2: Autênticação Nesta secção, o foco é na autenticação. Como tal, pretende-se analisar a facilidade de utilização e consistencia da aplicação nos vários processos de autenticação.	
4	**Numa escala de 1 a 4, o quão fácil considera ser criar uma conta?** • 1 (Muito Difícil) • 2 • 3 • 4 (Muito Fácil)

5	**Numa escala de 1 a 4, o quão fácil considera ser autenticar-se na sua conta?** • 1 (Muito Difícil) • 2 • 3 • 4 (Muito Fácil)
Secção 3: Dados Demográficos Nesta secção, o foco é a inserção, visualização e edição dos dados demográficos de um jogador. Como tal, pretende-se analisar a facilidade de utilização e consistência da aplicação nos vários processos de manipulação dos dados demográficos de um jogador na equipa na qual o utilizador está registado.	
6	**Numa escala de 1 a 4, o quão adequada considera ser a informação a recolher acerca de jogador?** • 1 (Nada Adequada) • 2 • 3 • 4 (Muito Adequada)
7	**Numa escala de 1 a 4, o quão fácil é o processo de inserção dos dados demográficos de um jogador?** • 1 (Muito Difícil) • 2 • 3 • 4 (Muito Fácil)

8	**Numa escala de 1 a 4, o quão clara é apresentada a informação demográfica de um jogador?** • 1 (Nada Clara) • 2 • 3 • 4 (Muito Clara)
9	**Acha que algum aspeto deveria ser melhorado ou modificado acerca dos dados demográficos de um clube? Qual/Quais e porquê?** _____
Secção 4: Dados de Exposição de uma Equipa Nesta secção, o foco é a inserção, visualização e edição dos dados de exposição de uma equipa. Como tal, pretende-se analisar a facilidade de utilização e consistência da aplicação nos vários processos de manipulação dos dados de exposição da equipa na qual o utilizador está registado.	
10	**Numa escala de 1 a 4, o quão adequados considera ser os dados a recolher acerca de uma exposição?** • 1 (Nada Adequados) • 2 • 3 • 4 (Muito Adequados)
11	**Numa escala de 1 a 4, o quão fácil é o processo de registo da adição de uma exposição da equipa?** • 1 (Muito Difícil) • 2 • 3 • 4 (Muito Fácil)

12	**Numa escala de 1 a 4, o quão clara é apresentada a informação de uma exposição?** • 1 (Nada Clara) • 2 • 3 • 4 (Muito Clara)
13	**Numa escala de 1 a 4, o quão adequados considera ser os aspetos visuais da informação de uma exposição?** • 1 (Nada Adequados) • 2 • 3 • 4 (Muito Adequados)
14	**Acha que algum aspeto deveria ser melhorado ou modificado acerca dos dados de exposição de um clube? Qual/Quais e porquê?** _____
Secção 5: Episódios de Lesão de uma Equipa Nesta secção, o foco é a inserção, visualização e edição dos dados acerca das lesões de uma equipa. Como tal, pretende-se analisar a facilidade de utilização e consistência da aplicação nos vários processos de manipulação (inserção/edição) dos dados de lesões de uma equipa.	
15	**Numa escala de 1 a 4, o quão adequados considera os campos que descrevem uma lesão?** • 1 (Nada Adequados) • 2 • 3 • 4 (Muito Adequados)

16	**Numa escala de 1 a 4, o quão fácil é encontrar a informação relativamente a uma lesão?** • 1 (Muito Difícil) • 2 • 3 • 4 (Muito Fácil)
17	**Numa escala de 1 a 4, o quão fácil é o processo de registar uma lesão de um jogador?** • 1 (Muito Difícil) • 2 • 3 • 4 (Muito Fácil)
18	**Numa escala de 1 a 4, o quão fácil é o processo de dar alta a um jogador?** • 1 (Muito Difícil) • 2 • 3 • 4 (Muito Fácil)
19	**Acha que algum aspeto deveria ser melhorado ou modificado acerca das lesões de um dado jogador? Qual/Quais e porquê?** _____
Secção 6: Dados Estatísticos Nesta secção, o foco é a informação estatística disponibilizada pela aplicação. Como tal, pretende-se analisar a relevância da informação mostrada e também a sua facilidade de compreensão	

20	**Numa escala de 1 a 4, o quão relevantes considera os gráficos mostrados na página de estatísticas de um clube?** • 1 (Nada relevantes) • 2 • 3 • 4 (Muito relevantes)
21	**Numa escala de 1 a 4, o quão claros considera os gráficos mostrados na página de estatísticas de um clube?** • 1 (Nada Claros) • 2 • 3 • 4 (Muito Claros)
22	**Considera essencial existir a possibilidade de visualizar a distribuição de lesões, por mês?** • Sim • Não
23	**Acha que algum aspeto deveria ser melhorado ou modificado acerca das estatísticas de um clube? Qual/Quais e porquê?** _____
Secção 7: Aspetos Gerais Nesta secção, pretende-se avaliar a experiência do utilizador na utilização da aplicação.	
24	**Numa escala de 1 a 4, o quão apropriado considera ser a aplicação e o seu conteúdo (visual, linguístico e de design) no contexto inserido?** • 1 (Nada Apropriado) • 2 • 3 • 4 (Muito Apropriado)

25	**Numa escala de 1 a 4, o quão ajustados estão os diversos componentes nas páginas?** • 1 (Nada ajustados (Mau design, dificuldade na seleção de certas opções)) • 2 • 3 • 4 (Muito ajustados (design profissional, claro, ordenado e logicamente organizado))
26	**Numa escala de 1 a 4, o quão apelativa considera a aplicação em termos visuais?** • 1 (Nada Apelativa (gráficos amadores, mau e inconsistente design visual)) • 2 • 3 • 4 (Muito Apelativa (qualidade visual apropriado e consistente em toda a aplicação))
27	**Numa escala de 1 a 4, o quão interativa com o utilizador considera ser a aplicação?** • 1 (Sem interatividade e sem resposta às interações do utilizador) • 2 • 3 • 4 (Grande nível de interatividade com funcionalidades interativas, feedback e opções de introdução do utilizador)
28	**Numa escala de 1 a 4, o quão adequadas estão as funcionalidades e os componentes para as respetivas funcionalidades?** • 1 (Nada Adequados) • 2 • 3 • 4 (Muito Adequados)

29	**Numa escala de 1 a 4, o quão fácil considera ser aprender a usar a aplicação?** • 1 (Muito Difícil) • 2 • 3 • 4 (Muito Fácil)
30	**Numa escala de 1 a 4, o quão claros considera ser as descrições dos menus, botões, ícones, e instruções?** • 1 (Nada Claros) • 2 • 3 • 4 (Muito Claros)
31	**Como considera ser a navegação entre as diversas páginas da aplicação? A aplicação tem todos os links necessários entre as páginas?** • 1 Sem lógica entre as páginas / Navegação Difícil • 2 A navegação é compreensível após muito time/esforço • 3 A navegação é compreensível após algum time/esforço • 4 Fácil de compreender/navegar • 5 Navegação perfeitamente lógical, fácil, clara e intuitiva
32	**Numa escala de 1 a 4, o quão adequados e consistentes são as interações (cliques, scrolls,...) com os diversos componentes das páginas** • 1 (Completamente Inconsistentes/Confuso) • 2 • 3 • 4 (Perfeitamente Consistente/Intuitivo)

33	**Numa escala de 1 a 4, como considera o conteúdo da aplicação?** • 1 (Nada correto/relevante) • 2 • 3 • 4 (Muito correto/relevante)
34	**Numa escala de 1 a 4, considera a informação da aplicação compreensível e concisa?** • 1 (Nada compreensivel, Insuficiente ou excessiva) • 2 • 3 • 4 (Compreensível e concisa)
35	**Numa escala de 1 a 4, o quão clara considera a informação visual dos conceitos da aplicação?** • 1 (Nada Clara) • 2 • 3 • 4 (Muito Clara)
36	**Recomendaria esta a aplicação a alguém inserido no contexto da mesma?** • Sim • Não
Secção 8: Agradecimentos Muito obrigado pela participação neste questionário. Todos os dados serão usados unicamente para estudo académico no âmbito da dissertação de mestrado "Aplicação Móvel para Vigilância Epidemiológica no Futebol". Caso tenha algum detalhe extra a apontar ou queira discutir algo acerca da aplicação, não hesite em contactar-me através do meu email.	