From problem to solution: A guide on architecture, design and evaluation of an injury surveillance and workload monitoring app for cricket

Najeebullah Soomro\textsuperscript{1,2,3}, Meraj M. A. Chhaya\textsuperscript{4}, Mariam Soomro\textsuperscript{5}, Naukhez Asif\textsuperscript{3}, Emily Saurman\textsuperscript{1}, David Lyle\textsuperscript{1}, Ross Sanders\textsuperscript{2}

1. Broken Hill University Department of Rural Health, Faculty of Medicine, The University of Sydney, Broken Hill, NSW 2880
2. Discipline of Exercise and Sport Science, Faculty of Health Sciences, The University of Sydney, Lidcombe, NSW 2141
3. Adelaide Rural Clinical School, University of Adelaide, SA 5005
4. Academy of Computer Science and Software Engineering, University of Johannesburg, Gauteng, South Africa
5. School of Public Health and Community Medicine, University of New South Wales, NSW 2052

Word count = 4704
Abstract word count = 253
Number of Tables = 1
Number of Figures = 6
Abstract

Introduction:
Injury surveillance and workload monitoring is long associated with professional sports, including cricket. However at the community level, there is a dearth of accessible and intelligent surveillance tools. Mobile apps are an accessible tool for monitoring cricket related injuries at all levels.

Objectives:
This paper will share the novel methods associated with the development of the free TeamDoc app and provide evidence from an evaluation of the user experience and perception of the app, its functionality, utility, and design.

Methods:
TeamDoc mobile App for Android and Apple smartphones was developed using three languages C++, Qt Modeling Language (QML) and JavaScript. For server-side connectivity, PHP: Hypertext Preprocessor (PHP) was used as it is a commonly-used cross-platform language. PHP includes components that interacts with popular Database Management Systems (DBMSs), allowing for secure interaction with databases on a server-level. Evaluation of the app was done by administrating a modified user version of Mobile Application Rating Scale (uMARS).

Results:
TeamDoc is the first complimentary, standalone mobile app that records cricket injuries through a smartphone. It can also record cricketing workloads, which is a known risk factor for injury. The app can be used without the need of supplementary computer devices for synchronization. The uMARS scores showed user satisfaction (overall mean score = 3.5/5, SD=0.5), which demonstrates its acceptability by the cricketers.
Conclusions:

Electronic injury surveillance systems have been shown to improve data collection during competitive sport. Therefore, TeamDoc may assist in improving injury reporting and may also act as a monitoring system for coaching staff to adjust individual training workloads. The methods described in this paper provide a template to researchers to develop similar Apps for other sports.

Keywords:

Cricket; injury surveillance; mobile application; app; TeamDoc
Introduction

Emerging technologies are enabling new opportunities for science and medicine within high performance sports (HPS)\[1\]. Performance in HPS benefits from application of sciences such as physiology, psychology, monitoring injury patterns, recovery, and using technology to improve performance\[2, 3\]. In terms of technology, an emerging domain is mHealth which involves mobile computing by the use of apps on smartphones to improve health\[4\]. mHealth to monitor an athlete’s health has also been identified as an area that can revolutionize Sports Medicine\[5\]. Electronic injury surveillance and monitoring tools (including mobile apps) are being used to monitor and predict injuries for sports including athletics, football, handball\[6-8\]. However, their use in cricket is limited to elite players with limited or no availability at the community level.

Cricket Australia (CA) uses the Athlete Management System (AMS) for workload monitoring and injury reporting of their contracted players\[9\]. This system allows coaches and medical staff to monitor individual workloads which may reduce the occurrence of overuse injuries. CA’s ten-year injury report (2005-2014) indicated that the 2013-14 season had the lowest prevalence of injury (10.8%) compared to the ten-year average of 11.9\%\[10\]. One factor contributing to the lower injury prevalence during the 2013-14 season was the introduction of mandatory use of AMS. Mandatory reporting by players on variables such as sleep and workload may have helped them adhere to the recommendations of the team’s medical staff and thereby minimize reportable injuries.

The statistics for cricket injuries at the junior level tell a different story; a five-year investigation of injuries in elite junior cricketers in South Africa indicated that 27\% of the cricketers sustained injuries\[11\]. Whereas in Australia the injury incidence in under 14 and under 16 players at the club level was 14.2\%\[12\]. Other studies show the injury incidence ranges between 15-49\%, and cricket-related musculoskeletal pain was reported by 80\% of school-aged cricketers in a season\[13-17\]. However, injury burden may be greater than reported as most cricket injury reports discount the burden of non-time loss injuries, where the player continues to play despite the injury. Recording non-
time loss injuries is now considered essential according to injury epidemiologists in other sports[7].

Therefore, in 2016, the new consensus statement for injury surveillance in cricket included the reporting of non-time loss injuries[18].

Adolescent athletes are susceptible to injuries due to rapid bone growth and musculoskeletal immaturity[19]. Evidence shows that increasing cricket related workload increases injury risk[15]. To tackle this problem, international cricket associations have proposed workload guidelines[20, 21]. But these are not being extensively followed at the junior level and may be due to the lack of support staff to keep track of the bowling and batting workloads and injuries[22].

Monitoring training workload by using subjective measures from an athlete is an effective way to address the issue of training loads in sports such as cycling, athletics, and football[23-25]. If cricket players can similarly record their bowling and batting workloads with a user-friendly mobile app, they will have better workload monitoring which may reduce the burden of overuse injuries. Currently, there are no free-to-download Mobile Health (mHealth) apps available that can record cricket related injuries and monitor workload. Given that elite cricketers emerge from junior cricket, it would be logical to implement such a system at the junior or amateur level. This would have several benefits, first, it could reduce the possibility of talented cricketers being ‘lost’ from player pool due to injury. Second, it could provide exposure and experience with reporting injuries and workload for those cricketers who progress to the elite levels, where reporting is mandatory. Finally, reporting injuries may enable players to seek timely medical advice and minimize injury effect.

The primary aim of the paper is to outline the methods for app development used to design TeamDoc, a free mHealth app, providing paperless, user-friendly solution for monitoring injuries and workloads in junior cricket. The sharing of novel methods associated with the development of TeamDoc will act as a foundation for future app developments in the area of injury surveillance and workload monitoring. The secondary aim of the paper is to provide evidence from an evaluation of the user experience and perception of the app, its functionality, utility, and design. The results of the evaluation will assist in improvement of future apps in this domain.
2. Methods

2.1 Software System Development

When designing the app, there were several important considerations. First, it should ensure confidentiality of the data provided by the players. Second, the system needed to be user-friendly with ease for quick data entry (not exceeding more than 2 minutes). Third, there needed to be a back-end server that stores the data for future analysis. Fourth, it should be useable and adaptable for common operating systems. Finally, the injury and workload data must be presented in a way that is easily read and interpreted.

The TeamDoc software system design was divided into three components: player interface, coach interface, and a back-end system to securely store the data. The player and coach interfaces are completely separate. This design protects player privacy as the player interface only permits authorized players to log the data. Similarly, the coach interface only allows authorized coaching staff access to the data. The design of the software relies on client-server architecture, with the player and coach interfaces operating as clients (resource and service requesters) and the back-end system operating as the server (resource and service provider) (Figure 1).
2.2 Tools and Languages

2.2.1 Client-side software

The client-side software used was an open-source software development platform, Qt 5.3 (Qt Company Ltd. Finland 2014). This platform was chosen because of its cross-platform compatibility (ability to work on multiple operating systems; for example, it supports Windows, Mac OS X and Linux for desktops and Android, iOS and Windows Phone for mobile phones)[26]. This meant that even though the initial release was compatible only with Android, the source code can be ported to 15 other operating systems with relative ease[27]. It also allows developers to programme software using a range of different programming languages. Three languages – C++, QML, and JavaScript – were used because they are well-documented and supported by Qt 5.3.

The chosen platform and languages simplify the construction of custom user-interfaces and provide the opportunity to augment user-interface components with high-level logic. The Qt SDK (Software...
Development Kit) was used to develop the client-side software. This Integrated Development
Environment (IDE) had a compiler for the C++ language and a Graphical User Interface (GUI)
designer, allowing for rapid prototyping of user-interfaces.

2.2.2 Server-side software

The most important considerations for designing the server-side software were data security and
cross-platform connectivity. PHP scripting language was used as it allows cross-platform server-side
connectivity and is commonly used in website development. PHP includes components that interact
with popular database management systems (DBMS) and provides protection against certain
malicious attacks, such as Structured Query Language (SQL) injections, which is a technique used to
exploit data from servers (although this must be explicitly instructed in source code), allowing for
secure interaction with databases on a server-level.

The data entry required to compile injury reports was quite simple and this led to TeamDoc being
built with a thin-server architecture, which is a type of architecture that is suitable for systems where
the majority of the computation occurs in the client-side, as opposed to fat-server architecture, which
requires higher computational resources on the server-side. PHP was chosen instead of native
executable code, as it is more suitable given this thin-server architecture. Alternatively, with native
executable code, TCP (Transmission Control Protocol) server sockets would have to be implemented
and socket communication handled, which would have increased the complexity of this system.

2.2.3 Software architecture

There were three components of the system:

1. Player App; a write-only function permits only data entry and restricts access to individual
output data thereby ensuring data privacy. Players can submit information that will be
compiled into the Daily Fitness Tracker and Injury Report System.
2. Coach App; a read-only function limits data access so that no amendment can be made by the coaching staff after the data has been recorded by the player. This ensures data security and authenticity as multiple people may be involved in a team’s coaching staff. Only coaching staff (including doctors) are able to visualize the collected information both graphically within the app and in tabular form [via a CSV (Comma-Separated Values) file compatible with Microsoft Excel and other spreadsheet applications] see Figure 2.

3. Server-side operations; both players and coaches/doctors are able to login and register, and if necessary, reset their password.
Figure 2 – Screenshot from server interface showing data view available to the coaching staff
The interaction of a design-focused language, QML, and two logic-focused programming languages, C++ and JavaScript, allowed for the use of the Model-View-Controller (MVC) software architectural pattern. MVC supports the user-interface, internal data representation, and logic of the project to be independent so that a change in one component does not directly affect the next one. This architectural pattern also ensured that team members involved in the project design were able to engage with the project from their preferred aspect – design, logic, or database management – and minimized delay with parallel, rather than sequential development and implementation.

2.2.4 Database implementation

To improve cross-platform connectivity in the future, a popular and robust open-source DBMS called MySQL, was used to capture, query, and administer the data collected by the TeamDoc app. The database is comprised of five tables that store raw and processed data:

- The **Users table** contains information about every user, including user-identification and password.

- The **ResetPasswords** table is an administrative table that stores computer-generated temporary passwords for users who have forgotten their passwords.

- The **DailyFitnessTracker** table stores processed final scores as well as the raw values input by players.

- The **InjuryReport** table collects the players’ responses and can be accessed by coaches and affiliated medial staff.

- The **Attendance** table stores player attendance and injury details for a 40-week season, each week includes three practice sessions and one match. These variables may be adjusted as needed.
The information for each table is linked to each player via a user-ID and time-stamp of submission. The values in the tables can be queried manually via SQL or through the interfaces available to coaches and doctors.

2.3 User Interface Design

The user interface (UI) of TeamDoc was designed to be user-friendly with little-to-no training time. The login and player and coach interfaces are illustrated in Figures 3. The player interface provides forms with text-input-boxes, numeric sliders, check-boxes and radio-buttons to make data input quick and simple (Appendix 2).
2.3.1 Injury reporting

The injury reporting in the UI was based on the standard injury reporting form developed by Finch et al. and used by Sports Medicine Australia[29, 30]. The form had questions on the activity at the time of injury, reason for presentation, site of injury, nature and mechanism of injury, initial treatment given, action taken after the injury, referral etc. The site of injury function uses a ‘branching’ logic, which means that when a specific body region was indicated as injured, only questions related to that region were displayed.
region would appear. For example, if Knee / Lower leg was selected, then options such as calf muscles, knee joint etc. came up. Injury reporting forms in the player’s interface are shown in Figure 4; refer to Appendix 2 for all UI in the player’s app and Appendix 3 for the video run-down of the app.

Figure 4 User interfaces for the injury reporting tab in the TeamDoc player app.

2.3.2 Workload reporting
Workload monitoring was designed for batting and bowling. For batting, the number of balls batted was the primary input and the number of balls bowled for bowling. Cricket Australia’s fast bowler workload guidelines were used to determine if a fast bowler over-bowls or under-bowls[20]. These guidelines are part of the coach training programmes and are standard to monitor the training of fast bowlers. All input from the player is stored on the server and is accessible for the coach at any time.

2.4 Mode of availability of software

The client-side was built to simplify porting it to diverse smartphone operating-systems, the initial release for the Android platform. The server-side of TeamDoc was also implemented to be compatible with various server operating systems in order to avoid dependence on a single technology. This consideration made the release to Apple’s iOS platform.

2.5 App evaluation

A modified user version of the Mobile App Rating Scale (uMARS) was used to critically appraise the app[31]. uMARS is derived from MARS which a validated mobile apps evaluation tool and has been used extensively to rate the quality of medical based apps[32-34]. It has 31 questions mostly using a Likert-type rating scale to evaluate an app on three domains, 1) Quality score examines engagement, functionality, aesthetics, and content information provided in the app; 2) Subjective quality questions likelihood of recommending the app to others, use in future, overall rating etc.; and 3) Behavior change which assesses the perceived impacts on knowledge, attitude, awareness, and behavior. The internal consistency (α = 0.90) and inter-rater reliability (ICC = 0.79) for MARS is acceptable[32].

The MARS was modified by excluding 7 questions on information content of the app. These questions are only relevant for apps which provide content to the users. The 24 questions
relevant to assess TeamDoc app were used (see Appendix 1). Field testing and validation of the app was conducted during the initial phase of development by collecting informal user reviews from twenty players on the University of Sydney Cricket team. After the final launch of TeamDoc on the Android and iOS app stores, eight registered cricket clubs in New South Wales and Victoria, Australia were invited to use the app during the 2017-2018 season by using convenience sampling.

270

2.6 Procedure for uMARS administration

The modified uMARS was administered through a web-based survey using the Research Electronic Data Capture (REDCap) Survey instrument. REDCap is a secure, web-based application for building, disseminating, and managing online surveys and complies with Health Insurance Portability and Accountability Act (HIPAA) regulations. Participant information was secure and only available to the authors through the use of both server authentication and data encryption using secure web authentication, data logging, and Secure Sockets Layer (SSL). The survey was available online and an invitation with the survey link was sent to the registered users.

280

2.7 Data analysis

The survey results were exported to Microsoft Excel v2013 and basic calculations were performed to report standard descriptive statistics. For qualitative data, content analysis was performed by categorization of the content into themes. Top three themes from each category were reported.

3. Results

3.1 Description of participants
Three of the eight club teams agreed to participate in the app testing and evaluation. Each club team had an average squad size of 14 players. In total, 42 club cricketers (14x3) registered and used the app. The data collected by the app was verified with the data stored on the server by the developers and the results indicated 100% data accuracy.

App review with the modified uMARS was completed by 16 cricketers, 38% of the app user-base. All the respondents were current club cricketers with mean age 27.4 (16-42). Nine users were running the app on Android smartphones and seven on Apple iOS, six used an iPhone and one used an iPad.

3.2 uMARS ratings

The mean app quality score was 3.6/5 [standard-deviation (SD) = 0.6], this was compiled from the mean scores on app functionality, engagement and aesthetics. The mean subjective quality score was 3.3/5 (SD=0.7). Behavior change, which included assessment of the perceived impacts on knowledge, attitude, awareness, and behavior, had a mean score of 3.8/5 (SD = 0.5). The overall mean uMARS score was of 3.5/5 (SD = 0.5), and the scores ranged from 2.9 - 4.8 out of 5 (Table 1 and Figure 5).

- Engagement. This score ranged from 2 to 4.4 (Mean = 3.3, SD = 0.7). Engagement scores were compiled from five questions on entertainment, interest, customization, interactivity, and appropriateness for target audience. Appropriateness for target group was rated highly among the ‘engagement’ questions, with an average score of 3.8. However, customization received the lowest score (M=2.94).

<table>
<thead>
<tr>
<th>Subject</th>
<th>Engagement</th>
<th>Functionality</th>
<th>Aesthetics</th>
<th>Sub-Qual / Satisfaction</th>
<th>Behaviour Change</th>
<th>Overall Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

17
Table 1 MARS ratings for TeamDoc app

- **Functionality** score ranged from 2.3 to 5 (Mean=3.9, SD=0.7). Functionality scores were compiled from four questions on performance, ease of use, navigation, and gestural interactivity. Ease of use scored highly within the category (Mean=4.1) while gestural interactivity was the lowest rated category with a mean score of 3.8.

- **Aesthetics** scores ranged from 2.3 to 4.3 (Mean=3.5, SD=0.6) and were for questions on the app's layout and graphics to visual appeal. The layout of the app had the highest score (mean=4.2) and visual appeal had the lowest score (mean=3.2).

- **Subjective Quality / Satisfaction.** This score ranged from 2.25 to 4.75 (Mean=3.14, SD=0.7). These scores were for questions on recommendation to others, use in the next 12 months, overall star rating, and paying for the app. Recommendation to others received the highest score (mean=3.75), while paying for the app received the lowest score with a mean of 2.75.

<table>
<thead>
<tr>
<th></th>
<th>3.6</th>
<th>4</th>
<th>3.3</th>
<th>4</th>
<th>3.7</th>
<th>3.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>4.2</td>
<td>5</td>
<td>4.3</td>
<td>2.8</td>
<td>4.2</td>
<td>3.8</td>
</tr>
<tr>
<td>3</td>
<td>4.4</td>
<td>4</td>
<td>4.3</td>
<td>3.8</td>
<td>4</td>
<td>4.0</td>
</tr>
<tr>
<td>4</td>
<td>2.6</td>
<td>4</td>
<td>3.3</td>
<td>2.8</td>
<td>2.7</td>
<td>2.9</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>2.3</td>
<td>2.3</td>
<td>2.8</td>
<td>3.5</td>
<td>2.9</td>
</tr>
<tr>
<td>6</td>
<td>2.8</td>
<td>3.5</td>
<td>3.7</td>
<td>2.3</td>
<td>3</td>
<td>2.9</td>
</tr>
<tr>
<td>7</td>
<td>2.6</td>
<td>2.8</td>
<td>2.7</td>
<td>4</td>
<td>4</td>
<td>3.6</td>
</tr>
<tr>
<td>8</td>
<td>4.4</td>
<td>4.8</td>
<td>4.3</td>
<td>4.8</td>
<td>5</td>
<td>4.8</td>
</tr>
<tr>
<td>9</td>
<td>3.4</td>
<td>4.8</td>
<td>3.7</td>
<td>3.3</td>
<td>4</td>
<td>3.8</td>
</tr>
<tr>
<td>10</td>
<td>3.8</td>
<td>3.5</td>
<td>3.3</td>
<td>3</td>
<td>4</td>
<td>3.5</td>
</tr>
<tr>
<td>11</td>
<td>3.6</td>
<td>4</td>
<td>4</td>
<td>3.3</td>
<td>3.8</td>
<td>3.7</td>
</tr>
<tr>
<td>12</td>
<td>2.6</td>
<td>4</td>
<td>3.7</td>
<td>2</td>
<td>3.7</td>
<td>3.0</td>
</tr>
<tr>
<td>13</td>
<td>2.8</td>
<td>4.5</td>
<td>2.7</td>
<td>3.8</td>
<td>3.8</td>
<td>3.6</td>
</tr>
<tr>
<td>14</td>
<td>2</td>
<td>4</td>
<td>3.3</td>
<td>2.3</td>
<td>3.3</td>
<td>2.9</td>
</tr>
<tr>
<td>15</td>
<td>3.6</td>
<td>4.3</td>
<td>3</td>
<td>2.8</td>
<td>3.5</td>
<td>3.3</td>
</tr>
<tr>
<td>16</td>
<td>3.2</td>
<td>3.5</td>
<td>3.3</td>
<td>3</td>
<td>3.8</td>
<td>3.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mean</th>
<th>3.3</th>
<th>3.9</th>
<th>3.5</th>
<th>3.2</th>
<th>3.8</th>
<th>3.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Std-Dev</td>
<td>0.7</td>
<td>0.7</td>
<td>0.6</td>
<td>0.7</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Behavior Change scores ranged from 2.7 to 5 (Mean=3.6, SD=0.5). These scores were from six questions about awareness, knowledge, attitudes, intention, behavior to change, and help seeking. The question on behaviour change, describing the likelihood of the app in improving the understanding of injury and seeking help for it, received the highest score, mean=3.9. Conversely, the question on the role of app to improve the knowledge about injuries received the lowest score, mean=3.6.

![Mean domain scores for MARS](image)

**Figure 5:** Mean domain scores for MARS with SD

### User perceptions

3.3 User perceptions
User perceptions were collected with two open-ended questions: a) If you decide/decided not to use this app, what will be the possible reasons for it? b) What improvements do you want to see in the future versions of the app?

Majority of the respondents (n=10) were not currently using the app (non-users). The main reasons for not using the app were user-interface (UI), time consumption and forgetfulness. Users expressed importance of functional design improvement of the app which may have made them feel they were spending too much time on filling out information. Several users expressed that the app lacked the graphic interface and breadth of content to engage them for regular use.

“I like using this app, however, I need more interactive options in it such as scores and health tips etc.”

“Lack of feedback, unable to enter data in days after activity”

“Time consuming”

Most of the current users (n=6) mentioned that the reasons for future disuse will be if they didn’t get injured, stopped playing cricket or forgot using it.

“Due to no injuries”

“If I don’t play in the future”

“The only reason I wouldn’t (use the app) would be forgetting to”
On the question regarding future improvements in the app. The main reasons cited by current non-users (n=10) were linked to lack of feedback, UI, User experience (UX).

“Being able to see how the data is collated and be able to refer back to this data would help with the information entered. Entering data two days after activities by putting in date (not rely on entering data immediately after activity) would allow more entries to be input. Workload app would consider multiple activity types for example, running while not playing cricket, gym time etc.”

“No graphics or engaging content”

Reviews of current app users (n=6) identified two main themes where improvements in the future versions could be made i.e., improvement of the interactivity and content in the app, improvement of UI.

“injury reports should be graphically displayed rather than plain text”

“user-design can be improved my making the content more interactive,”

“I would like to see more information diet, such as calorie tracker, dietary recommendations before and after the game etc.”

3.4 Validation of design considerations

First, data confidentiality was assured because none of the test users were able to access the other player’s records without validated authentication details. Second, the system’s user-
friendliness was validated with high mean ‘functionality’ and ‘ease of use’ scores of 3.9 and 4.1 respectively. However, on average users took 3 minutes to fill out the injury and workload entries so time efficiency for data entry did not meet the aim of 2 minutes per entry. Future versions should reduce the number of data entry fields and make the entry more engaging to enhance user compliance and entry efficiency. The third consideration was data storage for future analysis. The testing and validation showed that data output via the server was 100% accurate and could be retrieved instantaneously, this was tested by the investigators by asking the players to enter data on the player app, and then was cross verified with the player after downloading the information from the server. The fourth consideration was app’s cross platform availability and the app was made available for both Android and iOS operating systems. Finally, the UI for injury and workload data entry was to be presented in a way that was easy to input and interpret. This was validated during user-rating functionality and had an overall mean uMARS score of 3.8/5. Most features of the app scored more than 3 out of 5 on uMARS domains, showing an over-all end-user satisfaction.

4. Discussion

It is commonly perceived that cricket is a non-impact sport with fewer injuries compared to other sports. However, literature shows that when injuries are measured in terms of injury rates (i.e. per hour of athletic exposure), junior and amateur cricketers have higher rates than professional cricketers[35], and injury rates are comparable to other non-contact or quasi-contact team sports such as soccer, basketball and tennis[36]. In recent times, the use of mHealth and online technology to monitor an athlete’s health is becoming an important component of Sports Medicine[5]. The development of the TeamDoc app was inspired by this concept and is the first standalone mobile app that can record injuries in cricket through a
smartphone without the need for connectivity from parent software on computers. The injury questionnaire was tailored to effectively cater for cricket-related injuries, for example, a finger injury while catching the ball.

The benefits of using electronic injury surveillance systems have been extensively documented by Karlsson[6]. It identifies the advantages of using such systems compared to a paper-based system as having less risk of error while transcribing and minimal to no logistic issues. TeamDoc provided the functionality to store the injury data on the server, thereby delivering a paperless solution for tracking injuries and providing ease of access for the team’s coaching staff to track injury profiles of the players. Yet, 63% (n=5) club teams declined to participate when invited to use and evaluate the app. The two main reasons cited by the team coaches or captains for not participating were ‘time commitment’ and ‘injury not a major for the team.’ To change these perceptions educating the players and coaches about cricket related injuries, injury prevention strategies and the role of technology to prevent future injuries is important.

The overall mean uMARS score was of 3.5/5, this is comparable to other health related surveillance apps, for instance, a review of seven app for prostate cancer risk calculation apps had a mean quality score of 3.75[33]. Similarly, a review of 20 epilepsy self-management apps found a mean quality score of 3.25[34]. The results indicated that only 6 of 16 respondents (38%) were current users. The high rate of attrition may be linked to the low scores on satisfaction on subjective quality of the app (3.14/5) and engagement (3.3/5). The main reasons for low score on engagement were half of the users rated the app having no or very basic interactive features, and a quarter rated the app as boring. Escoffery et al (2018)
advocated that for apps targeting behavioral change, developers work with behavioral scientists to improve the engagement features within the app and encouraged the use of theoretical strategies for behavior change during conceptualization and design phases of app development[34].

The mandatory reporting of injuries and workload by the players may be another reason for high attrition rate from regular use of the app. Medical professionals often use the terms ‘compliance’ and ‘adherence’ to describe rate at which patients follow their ‘requests, commands, orders or rules’[37, 38]. These rules and orders can range from following the advice on talking medications, performing investigations, to engaging in physical activity etc. When a patient fails to perform the required tasks they are deemed to have poor compliance or adherence. More recently, ‘concordance’ rather than compliance or adherence has been proposed to be a better alternative when dealing with certain populations[37]. ‘Concordance’ in medicine is defined as ‘a state of agreement’ between the patient and the physician[39]. Similarly in sports, concordance can be inferred as a state of agreement between the player and the coach. In medicine, low concordance has been shown to have poor outcomes in patient satisfaction and perception of care[39]. Therefore, before introducing mandatory reporting or asking players to report their injuries and workload, educating them on the benefits of reporting may improve concordance and improve the uptake of the app in the future.

The reason for the low mean subjective quality score (3.18/5) can be attributed to a low score (2.8/5) on “would you pay for this app?” Only two users indicated they would be willing to pay for the app in the future. The app was not designed for commercial use, but user
inclination to pay for it may be a surrogate for their perception about the value of the app.

‘Lack of feedback’ to the users may be another issue for the low ratings. This is associated with the design constraints of the app which only allows the coaches to view the data entered by players. In future versions, it may be prove useful to allow players to view their own data so they can track their activity levels and setup goals. Another feature that may be useful to improve user experience is the inclusion of ‘gamification’ and ‘social media plugins’.

Gamification features may include features such as players setting up weekly targets for their activity and getting rewards if they achieve their target. Social media and sports news plug-ins may improve user experience and encourage regular use of the app.

There were multiple limitations within the current version of the app. For example, there was no mechanism for alerting fast bowlers or coaches if a player exceeded age related bowling workload recommendations nor mechanisms for delivering reminder alerts if players forgot to key in their workloads. However, important design considerations, such as security and confidentiality of data, were ensured by designing the app on PHP which provided protection against malicious attacks by hackers and by designing separate app interfaces for players and coaches. Another consideration during development was cross-platform connectivity with other eHealth platforms the client-side of the app was developed to simplify porting it to diverse operating-systems.

5. Conclusions

The use of mHealth in Sports Medicine can assist in wireless data capture that can be used to make informed, evidence-based decisions. TeamDoc follows this concept by allowing the coaching staff and the players to record data on injury and workload on the go. The app may
assist coaches to make informed decisions in real-time during match conditions. TeamDoc is available for free which means that community-based clubs can access and use it. This manuscript provides a guide to the architecture and framework for developing an injury surveillance and workload monitoring mobile app, which can be applied to design similar systems for other sports. The results from the user survey indicate that future versions of the app should have improved user-interface and interactivity features.

Practical implications

● The ease to use the app ‘on the go’ may mean better reporting of injuries at junior level.

● The app can act as a monitoring tool for the coaching staff to adjust individual training loads for players which may assist in reducing injuries.

● The methods of development used for this app can be applied by researchers and developers to introduce similar apps for other adolescent team sports.

● In the future, surveillance apps should focus on improved UI and interactivity to attract and retain users.

Conflict of interest statement and competing interests

The authors declare that there are no conflicts and competing interests.
Acknowledgements

The authors are grateful to Dr. René Ferdinands, Mr. Gary Whittaker and players from The University of Sydney Cricket team for their assistance in testing of the app. We would also like to thank James Alexander and Shane Herft from Incubate Hub University of Sydney Union for their assistance in the development and promotion of the app.


6232018.
632
633