Concussion Management Application for Amateur Sports

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Concussion management has become one of the most popular topics in sports medicine. Significant resources are being invested in developing protocols for professional sport associations such as the NFL and FIFA. These protocols are often expensive and require substantial resources to implement. The problem, however, runs much deeper than just professional sports. Currently there exists little infrastructure to effectively manage concussion in amateur settings such as high school, club and university sport. A more holistic approach is required to ensure that the same standard of concussion management is being implemented across the board, regardless of the available medical and financial resources. An application was developed that will allow for easily accessible baseline testing and access to a player's concussion history from anywhere in the world. The application will be used to monitor players from the day they start playing sport until they potentially become professional sport players.

I. Introduction

Biomechanically, concussion is due to rotational or angular acceleration forces applied to the brain that cause neuronal shearing [1]. This leads to neuronal depolarization, neurometabolic derangements, and decreased blood flow [21]. It is the combination of neuronal injury and the neurometabolic dysfunction that gives rise to the common signs and symptoms associated with concussion [3, 4]. Concussions cause micro-architectural changes in white matter integrity [5-7] and subsequently alters the way a brain functions.

The exact incidence rate of concussion remains unclear, however, estimates puts the incidence at more than 3.8 million sport-related cases annually in the United States alone [3, 8, 9]. The true incidence is likely much higher, as many individuals fail to report concussion. This is often because they are athletes who want to remain in play [10] or due to the false perception that concussion is benign [4, 11, and 12]. It is further estimated that concussion accounts for between 75% - 90% of all traumatic brain injuries with an annual economic burden in the US of $22 billion [13, 14]. After sustaining one concussion, an individual is three times more likely to have another concussion in the same season [1]. This places athletes at risk of developing the very rare second impact syndrome (SIS), which can be severely disabling or even fatal due to brain swelling after the second concussion [1, 15, and 16]. Repeated mild head trauma has also been thought to potentially be associated with the long-term development of neurodegeneration [17–19]. It is evident that concussion is a very troublesome injury for the sport medicine professional due to the individualized nature of the injury and therefore raises the need for adjunct measures of assessment to evaluate [7,20]. Shuttleworth-Edwards et al. suggest that management programs should include baseline testing and be available from at least age 13 [21]. It is clear that there is a definite need for a standardized concussion management protocol that incorporates computerized assessment tools in the monitoring and management of concussion, especially at nonprofessional settings. Such a protocol must be easy to administer and involve a multidisciplinary team which includes parents, teachers, athletic personnel, primary care providers and specialists. Due to the abundant negative long-term effects of repetitive concussive injuries, it is deemed necessary to monitor and manage any player throughout his sports participating career from as early as the age of 13 [21]. Access to a complete medical and concussion history can be highly advantageous in the management of concussion and the Return-To-Play (RTP) decisions that needs to be made. Such a proposed system lends itself perfectly to the many advantages of conducting baseline testing on each individual. This will ensure optimal management to each individual injury. Baseline and historical data is critical to ensuring that correct diagnoses are made.

Due to the availability of players in South-Africa and since rugby has the highest incidence of concussion of any team sport [1], this study has focused on high school rugby in South-Africa. Research suggests that 13-15% of all sport-related injuries sustained by high school athletes are due to concussions [2]. The burden of care is typically spread between primary care including nurse practitioners and specialist providers [2, 22]. Primary care providers are estimated to manage about 60% of concussion patients [2] although it has been noted that many nurse practitioners may lack adequate education or training required to diagnose and manage concussion [22]. Another study conducted in South

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Africa, found that there was minimal infrastructure in place in amateur rugby teams to manage concussions [21]. Owing to these limitations, a substantial number of rugby players at school, club, and university level, may receive inappropriate medical management which raises significant health concerns [21]. This study developed an application that will allow quality concussion management at all sporting events, regardless of available resources.

II. Head Injury Assessment Protocol

The Head Injury Assessment (HIA) protocol was designed by the World Rugby Association and is based on the Sports Concussion Assessment Tool 3 (SCAT3) [24]. It consists of three tests. Each test has been specifically designed for each stage of the concussion management process. The three stages are; the immediate RTP during a game, concussion diagnoses post game and the rehabilitation of an injured player until the player is ready for RTP.

The protocol has been designed specifically for the professional setting and requires a medical doctor with experience in concussion management to conduct the test and interpret the results. As eluded to in the introduction, it is not possible to implement this protocol in the amateur setting. In the amateur setting, it is common practice to have one doctor at a sporting event with as many as 36 participating teams as opposed to three doctors for two teams as often seen in professional matches.

III. Aims & Objectives

The primary project aim, shown in blue on Figure 1, was to design an Android smartphone based sports concussion management application that will enable the same quality of concussion management in an amateur rugby setting as in professional rugby. The aim of this project however, is not only to bridge the gap in quality of care between amateur and professional sports, but also, to increase the current quality of care across the board, towards an acceptable standard. This secondary aim is illustrated in red on Figure 1.

Three subsequent objectives were designed for this purpose. Firstly, to design an application framework that will allow for easily accessible baseline testing and access to a player's concussion history from anywhere in the world. Secondly, to enable the first responder to gain an indication of a player's concussion status when no concussion specific medical advice is immediately available. To accomplish this, the tests the application uses, must be designed to be objective and intuitive to use. Lastly, to improve the concussion protocol implemented in professional leagues, using the on-board sensors of the smartphone.

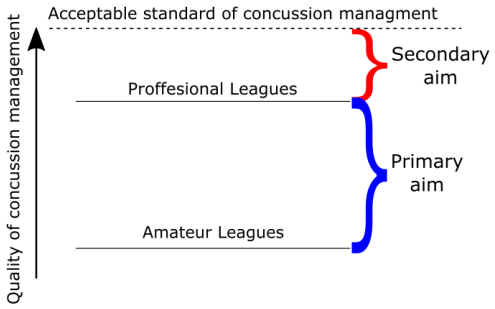


Figure 1: Aims

IV. Application

The need for quick access to baseline and historical data facilitates the need for a player database and a digitized version of the HIA protocol, rather than the pen and paper approach of the current HIA protocol.

A. Player Database Management

Access to the database is password restricted. This means for example, that parents can be restricted to access only the information of their children or that team doctors are restricted to view only the information of the teams they have been granted access to.

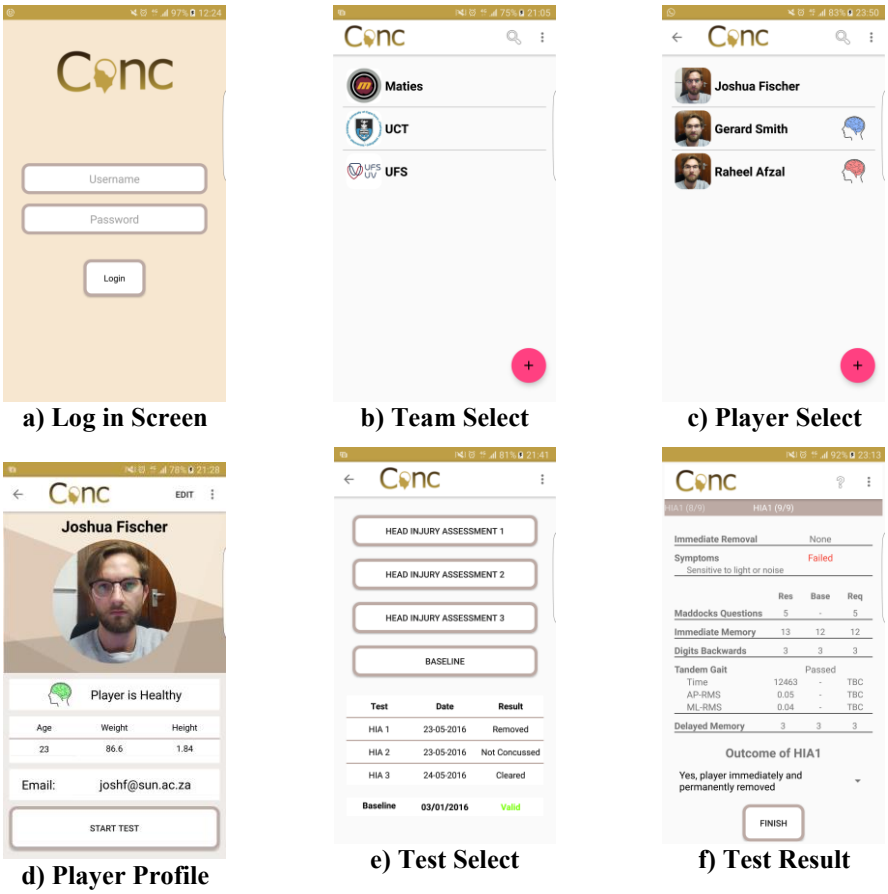
The application flow is detailed in Figure 2. The user must log in every time the application is used (Figure 2a). After log in the user choses a team to access (Figure 2b), and then a player in the team (Figure 2c). Teams and players can only be added by users with sufficient administrative clearance.

There are three options for the concussion status icon next to the player's name. Firstly, if there is no icon, it indicates that the player is not injured. A blue, brain icon indicates that the player's baseline scores require an update. The period between updates depends on the protocol of the setting that the application is being used in. For this final application submission, the period has been set as 365 days. Ideally this period should be set as to ensure that baseline scores are updated before the start of every season, A red brain icon indicates that the player is currently either, suspected of concussion, a concussion has been confirmed or that the player is currently undergoing rehabilitation for a concussion injury.

If a player is selected, it will open the player profile screen (Figure 2d). The player information shown can be tailored to fit the requirements of the user. To start the test procedure the user selects the start test button

B. Test Data Recording

The testing procedure starts with selecting which test to perform in the test select screen (Figure 2e). Using the information about the previous tests conducted, the test administrator must select the appropriate test to conduct on the player. The recommended test, according to the HIA protocol will be highlighted. There is also an indication of whether the baseline is still valid for performance comparison.



a) Log in Screen b) Team Select c) Player Select

d) Player Profile e) Test Select f) Test Result

Figure 2: Application flow

Each test is a digitized version of the corresponding HIA test. Test result interpretation is done automatically. According to the HIA protocol each category score must be compared to a protocol specified minimum based on normative data and the player's baseline. If the player's performance falls below either, it facilitates a failed test. After a test has been conducted, the results will be displayed in the test result screen. Figure 2f depicts the result screen of the HIA 2 test. A diagnosis can then be chosen if the current user is a medical doctor with the authority to make diagnoses. All test scores and results are stored in the database.

C. Balance Assessment

The digitization of the HIA protocol allows a vast improvement of the balance assessments of the HIA protocol. Currently, the HIA protocol uses the Balance Error Scoring System (BESS) test. This test requires the player to complete a number of balance tasks. These tasks are static; single, double and tandem leg stances and a tandem gait test. The test administrator would then be required to subjectively quantify the number of balance errors the player makes during these task. The test was improved by using the on-board inertial sensors of smartphone are used to determine balance efficacy during various stances and tandem gait test.

The smart phone is inserted in a custom manufactured casing, as shown in Figure 3. The use of smartphone ensures that the balance examinations are inherently more objective than before. During the test, torso tilt and acceleration in mediolateral (ML) and anteroposterior (AP) axis are recorded. In current the application, the RMS of the ML and AP torso tilt is used to identify differences in the baseline balance ability and the results of HIA test. Likewise, during the tandem gait test, the RMS of ML torso tilt and peak-to-peak ML acceleration of torso are calculated to find differences in balance at baseline and during a HIA test. In future work, the balance data can be used to identify more accurate markers of torso tilt disturbance after a concussion.

Figure 3: Smartphone, torso mount

V. Conclusion

The digitization of the HIA tests, facilitates quick and effective testing. Test data is then also automatically recorded, and can be accessed from anywhere in the world, using the application. Test digitization also allows for randomization of tests, such as the numbers the player is required to memorize during the immediate memory recall test. This significantly decreases the learning effect and will contribute to the sensitivity of repeated use.

Ethical approval has been granted to test the accuracy and repeatability of the application on a healthy population mid-2017. The will then be tested on a concussed population in 2018.

Management of concussion is most important when evaluating when a player is ready to RTP. This is a critical decision in order to prevent the dangers of repeated head trauma and SIS [23]. RTP should not be considered unless an athlete is completely void of any symptoms, meaning when assessment scores of an athlete returns to baseline or normative values. The application will streamline this comparative process, allowing for quick testing in any setting, without the need for acute medical training in concussions. In future, new tests can be developed and included in the application. The application has been developed in a modular manner, so that new tests can easily be added to the applications protocol. The application has not been used to gather test data yet. In 2017 the application will be included in University of Stellenbosch's rugby concussion management protocol. This study will test the reliability of the application, by comparing the result of the application to currently used pen and paper methods.

The data gathered will be invaluable to future concussion research. As mentioned before, the balance data will be used to identify better markers of concussion during balance tests. Longitudinal studies could potentially observe a correlation between academic performance and the number of concussions during adolescence. The data will be invaluable to understanding concussions.

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