

Development and Evaluation of a Custom Mobile Application for Prospective Injury and Exposure Monitoring

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Abstract—Advancement in information technology have created opportunities for the use of mobile applications (app) for activity monitoring. This study aims to observe the feasibility of using mobile app for monitoring ACL injuries during dynamic sporting activities in a two-year prospective cohort study. This study developed a bespoke mobile app, to be used by the participants as a weekly-basis monitoring platform. 104 injury- free participants were monitored for one-season. Participant’s compliance in reporting their activities and/or injury each week was assessed. Participants’ anticipated time of exposure was declared upon installation of the app. The incoming data from the app was stored in an allocated web server and checked weekly by the researcher. At the end of the season, 93 participants were analyzed. Forty-seven participants completed the monitoring requirement of 36 weeks, while thirteen comply <4 weeks. The highest declared weekly exposure was 20 hours (n=3) and the lowest was 2 (n=4). Sixteen participants declared 6 hours of exposure per week. Direct application of mobile app in monitoring injury still faces many hurdles. In order to result in optimal participant compliance, findings from this study shows that total reliance on the mobile app alone may not be sufficient.

Keywords— *injury monitoring, ACL injury risk, mobile app*

I. INTRODUCTION

Typically, a prospective study requires the researcher to observe a large number of uninjured athletes and then monitor their injury status over a period of time. Over-time, if the researcher is lucky enough, few of those monitored athletes becomes injured and can then be compared to the uninjured group in an attempt to identify disparities with a predictive value commonly called risk factors. However, part of the known challenges in conducting a large-scale prospective studies are the drop in response rate i.e. dropouts. Monitoring hundreds of participants for a

prospective study by letters, phone calls, emails and managing excel sheets takes a lot of time and can be very tedious as well as challenging. As high-quality data on the occurrence of an injury is dependent on the quality of the monitoring process [1], improved monitoring system should be implemented.

Recent advances in information technology have have also created opportunities and transformed many parts of daily- living, education and communication. These advancements included the opportunity for the use of mobile app as a way to monitor or follow-up participants. The use of specific mobile application software (app) and programs in clinical practice has been commonly practiced by health care professionals in supporting better clinical decision-making outcomes and monitoring [2, 3]. Mobile access to information made possible by these devices has the potential to change how one monitors their participants. This present study ought to test the feasibility of using mobile app for the monitoring ACL injuries during dynamic sporting activities in a two-year prospective cohort study. The primary focus of this study was the compliance and feasibility of the mobile app for monitoring participants for one whole season.

II. MATERIALS AND METHODS

A. Study Design and Participants

The prospective cohort study was known as the Liverpool Knee Injury Study (LKIS) and the study was conducted between September 2014 and September 2016. Informed consent was obtained prior to testing. The Liverpool John Moores University Ethics Committee approved the study. Prior to testing, participants were given a Sports and Injury History questionnaire, Exercise Readiness Questionnaire and a consent form. 104 participants who were free from lower-limb injuries for at least 12 months and who regularly participated at least twice

a week in highly dynamic sports such as football, handball, field hockey, basketball and netball were eligible to participate i.e. recreational/amateur athletes, beginner or university athletes.

B. Injury and Exposure Monitoring - Development of the Liverpool Knee Injury Study mobile application

A one-season follow-up was conducted. In order to ease the follow-up procedure, a mobile phone application (iOS and Android) was created to monitor participant’s activity and injury exposure. The mobile application was developed with the assistance of Liverpool John Moores University’s staff, Dr Chelsea Dobbins and Dr Martin Hanneghan from the School of Computer Sciences. The researcher, colleague and the researcher’s supervisory team designed all aspects of the mobile application and layout (Fig. 1).

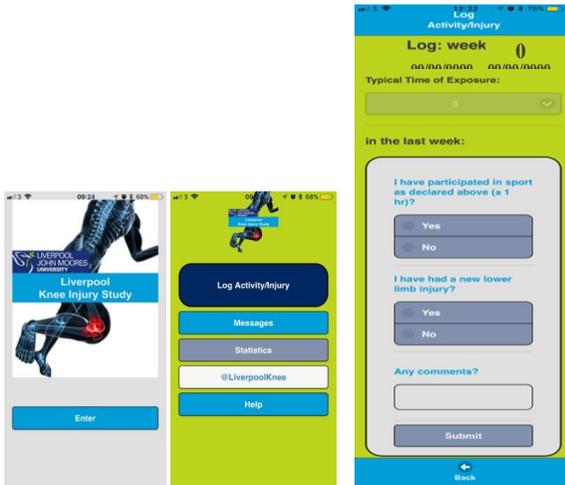


Fig. 1. (Left to right) LKIS mobile application welcome page, menu page and log activity / injury page.

Participants were granted access to the mobile app at the end of the testing session. Participants’ anticipated time of exposure was declared upon installation of the LKIS mobile application. Data concerning sports exposure and dynamic-loading-related injuries were collected weekly and at the time of exposure and verified with individual players if necessary through an online injury registration system. On a weekly basis participants were notified by the app to respond to two primary questions concerning their declared sporting exposure and current injury status in the form of a simple yes/no response to the questions;

- (i) *I have participated in sport as declared above (± 1 hour)*, and
- (ii) *I have had a lower limb injury*. During the monitoring period, follow-up questionnaires were administered if the participant’s sport participation changed or they declared an injury (Fig. 2).

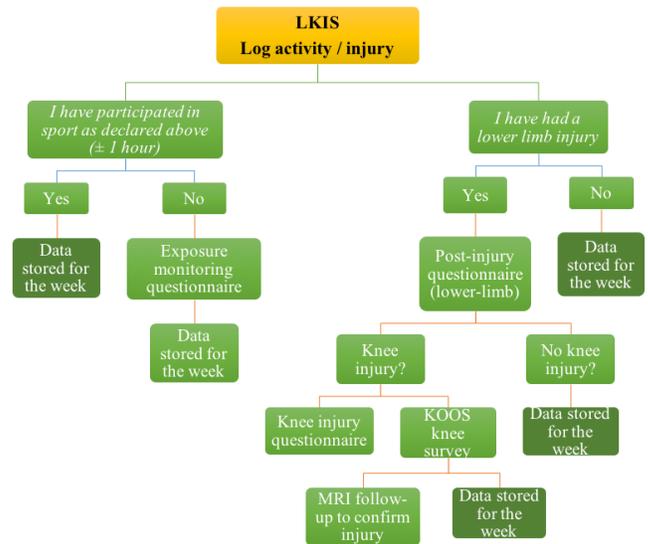


Fig. 2. A flow chart describing the follow-up process and questionnaires completed when relevant.

The mobile app sent notifications to the participants for 36 weeks (1 season). If participants missed the first notification, another alert for the week was sent automatically the next day. The incoming data from the mobile application was stored in an allocated web server and checked weekly by the researcher (Fig. 3). For participants who did not own a smart phone, the injury monitoring procedure was conducted through email.

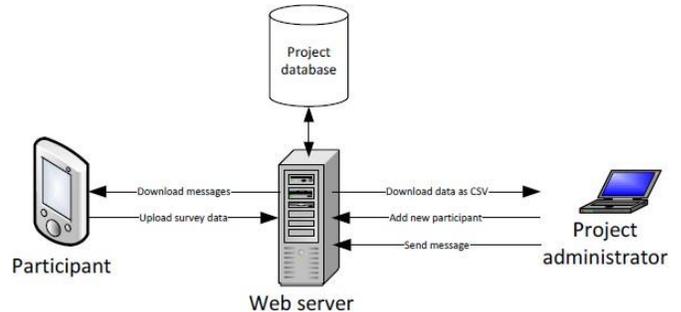


Fig. 3. The system composed of two distinct entities – the LKIS mobile application and a web server administration interface. The collected questionnaire was stored remotely on the web server, where it was available for the researcher to download.

II. RESULTS AND DISCUSSION

Eleven pilot participants had no LKIS mobile application registered therefore they were excluded from this study. Forty- six females (mean ± SD: age, 21.97 ± 3.98 years; height, 170.04 ± 9.85 cm; mass, 69.92 ± 12.15 kg) and forty-seven males (mean ± SD: age, 21.83 ± 3.91 years; height, 170.24 ± 9.69 cm; mass, 69.94 ± 12.13 kg) participated in the study. Participants were involved in highly-dynamic sports such as football (n=38), netball (n=11), field hockey (n=10), basketball (n=9), rugby (n=7), handball (n=6), volleyball (n=6), badminton (n=4), squash (n=1), tennis (n=1). The

participant compliance in reporting their activities and injury through the LKIS mobile application is illustrated in Fig. 4. Out of 93 participants, 51% of the participants finished the monitoring requirement of 36 weeks. Though 14% of the participants only managed to comply for 0 to 4 weeks.

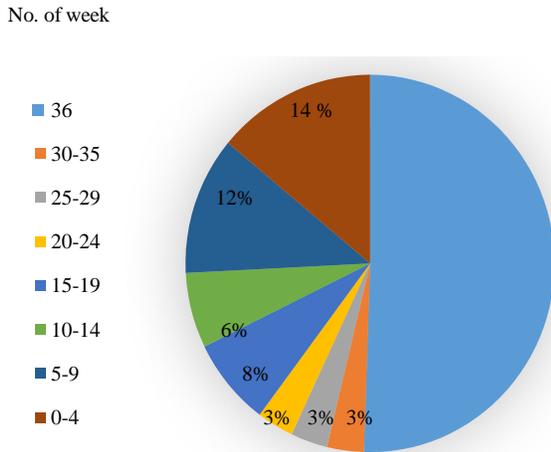


Fig. 4. Participants compliance through self-reporting LKIS mobile application (n=93)

The highest declared weekly exposure was 20 hours and the lowest was 2. Most of the participants had declared 6 hours of exposure per week while only three participants declared 20 hours (Fig. 5). During the 36 weeks of follow-up, no ACL injuries were reported, though a few other injuries were seen. Injuries were recorded and verified through the LKIS mobile application log, in the “injury comments” section and also through the Post-injury Questionnaire for the lower limbs (Figure 4.4). Common lower limb injuries reported were hamstring or quadriceps strain/pull (n=7), lateral collateral ligament strain (n=1), ankle sprain (n=4) and muscle/ligament soreness around the foot and knee (n=6).

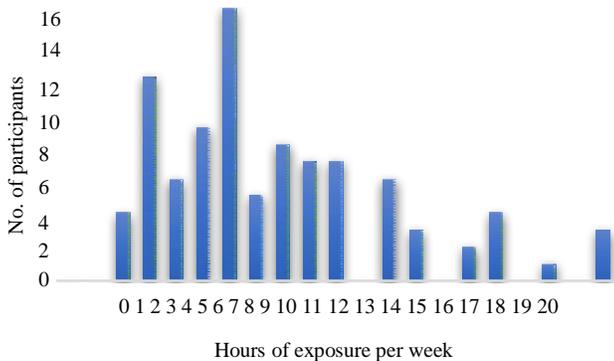


Fig. 5. Participants' declared exposure on average (per week)

IV. DISCUSSION

As previous prospective study only observed 9 ACL injuries in a sample of 205 participants [4], therefore a bigger sample size was needed to observe bigger number of injuries. As the calculated incidence are 0.17 and 0.23 per 1000 hours for male and female [5], in order to observe higher number of injuries, a bigger sample size and longer exposure time was needed. Despite the extensive recruitment effort and outreach, this study only manage to recruit 104 participants. This may be due to several causes, though the problem that mainly effected the recruitment number was due to the university's semester break. As our participants were mainly university athletes, this means that recruitment were only most efficient during term times.

Unfortunately, this study did not observe any ACL injuries. The 93 participants in this study was monitored based on selfdeclared exposure which adds up to 26,064 hours of exposure over the full testing period. Typical ACL injury incidence rates are 0.10 (females) and 0.057 (males) per 1000 hours of athlete exposure during active sport participation [6]. With the above incidence rates, monitoring males and females and this study's total hours of exposure, we might have expected to see at the very least one or two injuries in our cohort. According to a more recent study [5] with incidence rates of 0.17 and 0.23 per 1000 hours for male and females respectively, we might have expected to observe at least 4 to 5 injuries, which would approach the number of injuries in a previously reported study [4]. Our participants were athletes who participated in high-risk dynamic sports in which ACL injury commonly occur in [7-10]. One characteristics of our cohort is that everyone was aged above 18 years old and injury incidence is higher in younger adolescents (aged 13-18) and late childhood (aged 10-12) [7, 11, 12].

The timing of when the participants were recruited and assigned to the LKIS mobile app may also affect the study's outcome. In a study of injury reporting by short messaging service (SMS) [13], it was seen that throughout the season the number of injuries dropped. Our participants were recruited at the beginning of their season, they therefore during the monitoring period may have become better adapted to the training and competition's needs of their sports [14, 15]. As the participants mostly came from the university sports teams, in addition to training sessions they were often also receiving strength and conditioning training perhaps making them less susceptible to injury. The timing of this study was restricted by the availability of students during the academic year as this was the most feasible time for the monitoring to occur.

Many different methods have been used to monitor exposure and injury [13, 16, 17] though none had used a bespoke mobile application. Forty-seven participants from this study managed to complete the LKIS monitoring for

the whole monitoring period while 13 of the 93 participants completed the monitoring for less than 4 weeks. The LKIS mobile application was developed to lead to a high compliance during follow-up as previous studies had seen increased response rates in novel injury surveillance methods [13, 16]. However, only 51% of the participants in our study completed the 36 weeks monitoring. This may be due to several possible causes such as changing to a new mobile phone, starting new employment or lack of interest. Some of these causes has also been seen by Hanauer, Wentzell, Laffel, and Laffel [18] in their study on the Computerized Automated Reminder Diabetes System (CARDS) where they saw a decline in response rates throughout their 3-month study. They also assumed that despite the advance reminder system, over time it became laborious and participants lose interest [18]. This perhaps, may explain some of the causes of our monitoring responses. Although monitoring compliance was mixed, we are confident that no ACL injuries were sustained or remained unreported. In summary, we were confident that the LKIS mobile monitoring app was fit for purpose and it is likely that other reasons such as self-reporting more substantially influenced monitoring success.

A self-reported follow-up system which requires the participant to respond independently means that it is not possible for the researcher to track their actual training and exposure hours throughout the 36 weeks. We therefore acknowledge the limitations that come with this type of monitoring system including a reliance on the integrity of the participants. An extreme solution to this could be hiring research assistants or creating a larger interdisciplinary team to rigidly enforce injury reporting e.g. Padua, 2010 [19], or using wearables that track the activity levels of participants.

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