IX Reunión del Capítulo Español de la Sociedad Europea de Biomecánica (ESB)
24 - 25 de octubre 2019, Las Palmas de Gran Canaria

Integration of OpenCV in an Android app to measure antero-posterior knee translation

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Introduction

The knee anterior cruciate ligament (ACL) rupture is a common knee injury. Between 3 and 4 out of 1000 people have to be intervened every year [1,2]. There are some "standard" tests to perform the clinical evaluation, such as the Lachman and Pivot-Shift tests. However, the process could be quite subjective. Despite there are multiple devices to measure the instability of the knee [3], the measurement could be difficult to perform, not repeatable, or expensive. For example, the most common device to measure anterior-posterior (AP) translation is the arthrometer KT-1000, which is not practical to be used in the operating room since it must be sterilized every time of use. Kira accelerometer is used to measure the instability during a Pivot-Shift test; it actually measures the absolute acceleration of the tibia with respect to the ground, and the evaluation of the results is not obvious.
Hoshino et al. [4] proposed an image-based method to measure the AP translation of the knee, one of the most reliable indicators of the knee instability. They also showed that differences in AP translation during Pivot-Shift tests (with movement outside the sagittal plane) could be identified using this method.
In this study, we created an Android application to measure the AP translation in a user-friendly, low-cost and fast way. The application was developed using Android Studio, and it relies on the open-source computer vision OpenCV libraries [5]. The application was tested in five ACL-deficient subjects.

Methods

Lachman and Pivot-Shift tests were performed by a knee surgeon on five ACL-deficient subjects (gender: women, 30 ± 9.1 years-old), while videos were captured with a smartphone. Three of the subjects were under anesthesia. The process only consists of 1) the placement of three green round stickers at the fibula head, Gerdy's tubercle and lateral epicondyle of ACL-deficient subjects; 2) the recording of the videos while the surgeon is performing the tests; 3) the postprocessing of the videos (stored in the phone) using the mobile application.
In order to run the application, the user first needs to introduce the experimental distance between the Gerdy's tubercle and the fibula head (tibia's markers), and choose the left or the right leg. The user also has the possibility to save the results as a .txt file. Second, the video is loaded in the application from the phone gallery, and the user just run the algorithm and the results of the AP translation are shown on the screen (Figure 1).
The Android application, developed in Android Studio 3.1.3, relies on the computer vision open-source library OpenCV 4.1.0. This library is used to convert each RGB (red, green, blue) image to HSV (hue, saturation and value scale) image, then to a binary image at the same time that the markers at each frame (as green circles) are detected. After that, the algorithm maps each detected point with the three mentioned landmarks.
These points are used to calculate the knee AP translation. This distance was defined as the segment between the Gerdy's tubercle and the pivot point, which is the intersection between the tibia's markers line and the perpendicular of the tibia's markers line crossing the lateral epicondyle (see Figure 2).
The range of the AP translation was calculated for each movement of the test. AP translations from the ipsilateral and the contralateral legs were compared, and they were assumed to be significantly different when $p<0.05$.

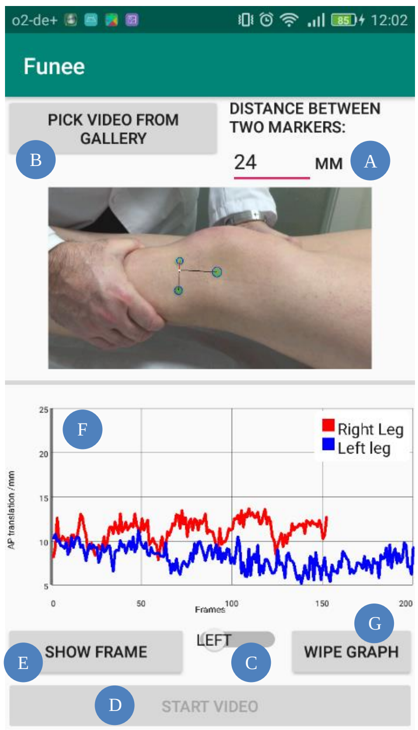

Figure 1. Main screen of the Android application. A: introduction of the distance between both tibia's markers. B: search and load of the video with the performed test. C: choice of the left or right leg. D: start of the video processing. E: visualization of the frame image. F: box showing the plot of the AP translation. G: refreshing the image.

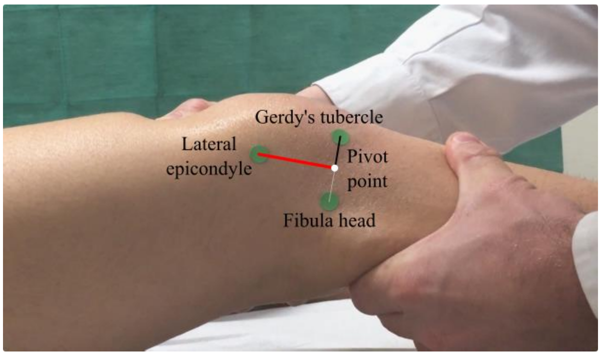

Figure 2. Position of the three green stickers. Black line is the AP translation.

Results

Mean and standard deviation values of the AP translation of five Lachman and Pivot-Shift test trials were calculated for all five subjects (Figure 3). The results showed that the AP translation were higher at the ipsilateral leg in all subjects and both test trials, being significantly different in four subjects (S2 to S5) during the Lachman tests and in three subjects during the Pivot-Shift tests (S3 to S5).

It is worth to mention that one video of about 10s takes about 5s to be processed. The results were obtained in a regular mobile phone (Huawei Ch2-L11 Android 6.0, API 23).

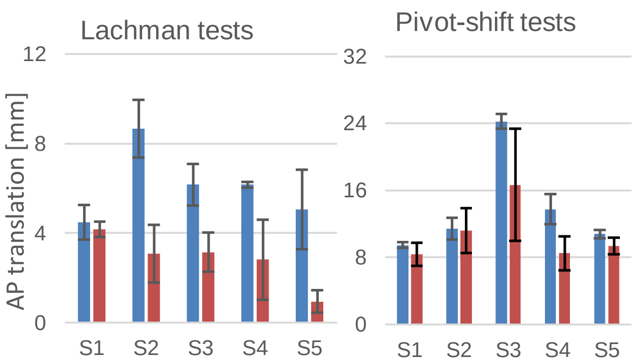

Figure 3. AP translation / projection of the AP translation in Lachman and Pivot-Shift tests respectively. Note that the vertical scale of the plots is not the same.

Discussion

In this study we presented how the integration of open-source OpenCV libraries can be used to create an Android application for orthopedic purposes. This application represents a low-cost method (only three adhesive markers and an Android mobile phone are needed) to estimate the AP translation of the tibia with respect to the knee, one of the main indicators of the knee instability. This method is fast and easy to use, since no special sterilization is required of any bulky device. This fact allows its use in both the clinics and the operating room. Moreover, the results are also easy to interpret, since the application reports the projection of the knee AP translation along the time. The application will be freely available (likely in Google Play).

We showed that significant differences can be observed between the ipsilateral and the contralateral leg in ACL-deficient subjects. In addition, we also identified that the subjects with the highest AP translation differences were those ones who were under anesthesia (S3 to S5). This is in agreement with the literature [6], which suggests that muscle forces may not be null when ACL-deficient subjects are not under anesthesia, despite being requested not to perform any force in passive movements.

As Hoshino et al. [4] reported, this image-analysis-based method allows to identify the differences in knee instability for both Lachman and Pivot-Shift tests, although in the latter we only measure the projection of the AP translation to the camera plane. Another potential limitation is that the markers are affected by the skin movement. Therefore, the user must pay attention to this effect when analyzing the results. The future work will be focused on comparing the results obtained with this application and fluoroscopy data, and on integrating this measurement in a computer musculoskeletal application to predict knee instability *in-silico*.

Conclusion

The developed Android application represents an open-source and objective indicator to evaluate the knee instability, through the measurement of the AP translation. The use of this application does not require neither expensive equipment nor a sophisticated training.

References

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