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RESEARCH ARTICLE

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## CREATION OF AN APPLICATION THAT USES THE CORRELATION BETWEEN STATURE AND PLANTAR ANTHROPOMETRIC MEASUREMENTS FOR FORENSIC PURPOSES

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### ABSTRACT

This research was developed based on the idea that human stature is a set of linear dimensions and that there are significant associations between it and various body segments. By associating this concept with mobile device technology, criminal experts can do their work quickly and easily, anywhere. The main objective of this study is to report the steps of creating and developing an application that uses the correlation of height with plantar anthropometric measurements for forensic purposes. The methodology used was the product analysis for assembly, design making, creation and development, calculation of the stature, application availability. As a result, the application "Foot Height" was obtained, available free of charge, in Portuguese, for tablets and smartphones with the Android operating system. Conclusively the Foot Height application can serve as an aid in criminal investigation cases and that further studies are needed to validate its functions. Furthermore, this research reinforces the importance of a theoretical and practical background to establish the content and function of the application, in order to search for programs that fit the established requirements.

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## INTRODUCTION

Criminal forensics generally aims at analyzing traces, being indispensable for the elucidation of crimes.

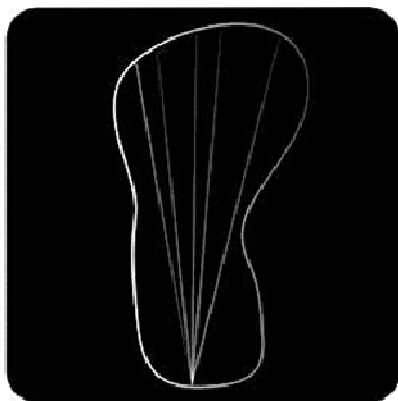
In this context, human footprints left at crime scenes can be a clue to find the victim or suspect. The feet can provide an estimate of the individual's height, facilitating the beginning of identification. Within this context, human footprints left at crime scenes can be a clue to find the victim or suspect (REEL *et al.*, 2012). Stature is one of the components of biological profiling in evaluations of skeletal remains for paleoanthropology and osteoarchaeology (DE GROOTE; HUMPHREY, 2011), as well as being applied in the anthropology of the living. The height of an individual can be estimated by the dimensions of the feet, which makes it an important factor to aid in the identification of victims (PAWAR; PAWAR, 2012). At crime scenes, the presence of footprints or shoeprints is not an uncommon finding.

For this reason, it is assumed that footprints can have important value during a criminal investigation, as they can help establish a relationship between the suspect and the crime (FAWZY; KAMAL, 2010). Technological advances have made it possible to offer a wider range of services to perform personal and professional functions in a easier, faster, and more simplified ways. This is the case with smartphones, which run on an operating system that offers the user remote access to various technologies that are constantly being updated. The applications available for smartphones and tablets have numerous features: calculator, photo and video editor, online games, message exchange, scanner, file editor, and much more. Anywhere, with just one click, the people can access information from the other side of the world. In this context, in order to assist forensics in crime scenes involving human footprints and to keep up with technological advances, this study had as its main scope the development of an application that uses the correlation of plantar anthropometric measurements with height.

## MATERIALS AND METHODS

**Product Analysis for Assembly:** Android and IOS operating systems were designated as deliverables, with free access to the application. It was defined that the application would function as a calculator and have a scanning function to estimate height from plantar anthropometric measurements using feet or shoes.

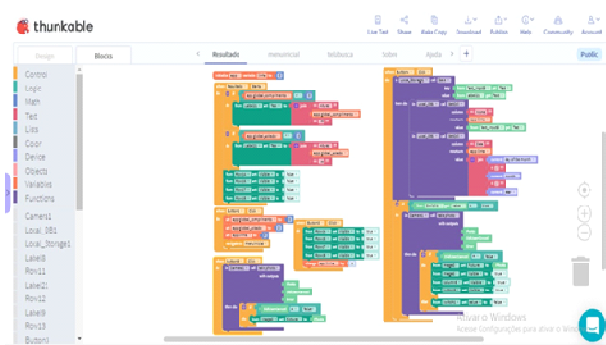
**Design making:** The design of the logo (Figure 01) was based on a relationship not only of the shoe and the foot, but also of the measurements obtained through them. The diagonally traced rays simulate the tracing of the lengths from toe to heel, referring to the plantar anthropometric measurements. In the free Adobe Illustrator® program, the figure was created. In order to establish a visual harmony within the functionalities of the application, the colors in neutral tones of the design were chosen based on the logo. The chosen name was in English language "Foot Height", which means "Pé Altura" in Portuguese, seeking to establish a relationship between plantar anthropometric measurements and height.



Source: Personal collection.

**Figure 01. Application icon**

**Creation and Development:** The data used for the base equation and for the development of the scanner function were obtained through research by Plácido et al. (2021) developed in the Master's Program in Forensic Sciences at FOP/UPE. For this process, the Thinkable® platform was chosen. The decision to use it took into account its ease of handling, good results, no additional costs required, fast operation and development of a mobile tool for AppStore® and PlayStore®. In Thinkable®, the construction of the planned project and the production of the content of the interfaces was carried out, through the codes and functions that the application will perform. (Figure 02).



Source: Personal collection.

**Figure 02. Software coding process**

The scanning software was developed through the CustomVision® platform. This platform uses an artificial intelligence, which, after a 24-hour training with images in a database, can estimate height based on the same linear equation as the calculator. The database included 1,233 images of the right and left feet, in different rotations, to

improve the scanner's ability to identify the images. In order to analyze the functions of the app afterwards and to group the data in a way that was most appropriate for the platform, the statures were separated by ranges and each range was embedded in a tag. The tags were organized according to the shoe sole numbers corresponding to the plantar anthropometric measurements.

**Calculation of the Stature:** The application has two methods for calculating height and it is up to the user to choose the best option for him. If he wants to use the plantar measurements, he must fill in the fields corresponding to D1, D2, D3, D4 and D5 (distance from the most posterior point of the heel to the most prominent point of each right and left toe), and then, after the user's confirmation, the calculation will be done based on Plácido et al. (2021) research:

Estimated height =  $50.297 + 5.17 \times \text{mean footprint length (cm)}$ , because this is the formula of the footprint;

If you choose the sole of the shoe, you must fill in the corresponding field and after confirmation, the calculation will be performed. The equation adapted for these cases used the values from ISO/TS 19407/SC Footwear (2015) as reference:

Estimated height =  $41.294 + 3.208$  (multiplied by the sole of the shoe)

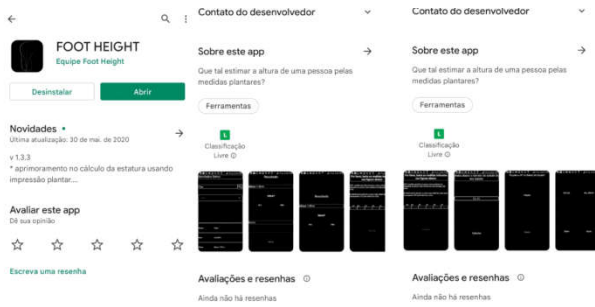
The shoe number must be in the European standard, if the Brazilian standard is used, an addition of 6.408 cm must be considered in the final result. In the equations, the measurements are in centimeters, but the application will automatically convert the height to meters.

**Application Availability:** To make an application available on the PlayStore®, one must register with a Google (Gmail)® account and pay \$25 dollars, which grants the developer account unlimited time to publish any application. In the AppStore®, the registration is done with IDApple and the fee is \$99 dollars, which extends only for one year for this account. For both providers, the developer is required to submit information such as: credit card data for payment of each store's fees; cell phone number; address; full name; e-mail account. During the process of sending the app to these platforms, the PlayStore® proved to be much more flexible, having in just one non-business day, all the necessary steps performed, including making the app available itself. The AppStore® only works during business days, and for each step to be performed, it is necessary to wait an average of 2 business days to move on to the next phase. To send the application to the stores, screenshots were taken of each interface of the service provided, so that people can see what the application has to offer and how it works. Unlike the screenshots made for the Google® service, at Apple® it was necessary to take screenshots of various screen sizes, referring to the iPhone® models, which required more time to convert the images from one model to another. Establishing a privacy policy for the application data proved to be necessary and so it was prepared in a specific and free site.

**Ethical Considerations:** For this study, data from projects already approved by the Research Ethics Committee of the University of Pernambuco, numbers 1,577,911, from the research by Plácido et al. (2021) and 4,276,967 from the current survey, were used. The related research followed in accordance with resolution number 466/2012 of the National Health Council and the Helsinki VI declaration, promulgated in 1964, regarding ethics in research involving human subjects.

## RESULTS

The "Foot Height" application with the calculator version was made available for free and in Portuguese on the PlayStore® platform for all users of the Android® operating system (Figure 03). The availability on the AppStore® platform was not successful due to maintenance fees.



Source: Personal collection.

**Figure 03. Application available at PlayStore in Portuguese**

For the app to fulfill its objectives, 8 interfaces were created: initial menu, footprint or shoe selection, foot measurements, shoe measurements, results, search area for saved files, information about the application and help. In addition to these interfaces, a video can also be opened by the user if he or she has any doubts about how to measure the plantar measurements. The storage capacity depends on the overall memory of the device, while the stability of the function depends on the RAM memory. The version with the scanning function showed average results, according to the evaluation on the CustomVision® platform (Figure 04). These results are divided into 3 points:

**Accuracy:** The chance that a tag detected and predicted by the model is correct.

**Recall:** The chance that a tag is right and is the most relevant among the others suggested.

**Level of apprenticeship:** Overall summary of accuracy and recall in different situations.



Legend: Precisão (Accuracy) Lembrar (Recall) and AP (Level of apprenticeship). Source: Personal collection.

**Figure 04. Scanning results on the CustomVision® platform**

The scanning has not yet been implemented in the version of the app available on PlayStore® due to the instability of the function on some devices and the need for a validation study.

## DISCUSSION

In this study, the formula included in the code of the application was based on the research by Plácido et al. (2021) with the population of the state of Pernambuco, Brazil, where the measurements of the length of the foot and toes showed a greater relationship with height. The research was carried out with a sample of 450 people, of both genders and with ages ranging from 18 to over 60 years old. The calculator version of "Foot Height" offers the advantage of not requiring an Internet connection, which is very useful when the operator's signal is not available. In addition, the calculator and scanner versions do not require payment for the download. The code developed to make the app was simple, with the amount of memory of less advanced smartphones in mind. The importance of having an application that can be accessed by a large part of the population was

a concern in this research, and that is why the Google® Android system was chosen. This operating system is present in both mobile phones and tablets. The smartphone is accessible at any time and place, being carried exclusively by its user and represents a great advantage when it comes to transport and storage of information. By working as a calculator and scanner, which use the plantar anthropometric measurements to establish height, the results are generated more quickly and estimated automatically, since the software is the one that will perform the operation. Also, because it offers a search tool, access to the files is not time-consuming. At crime scenes, footprints are often left behind and can exclude or make someone a suspect. According to Reel *et al.* (2012) footprints can be left on a surface and marked by various types of substances, such as oil, dust, mud, and paint, which can preserve a footprint and make it evidence. Thus, by preserving the shape of the printout, it is possible to use the anthropometric measurements and put them into the application to calculate the height, as well as scanning the printout and letting the software do the estimation automatically. The app can be useful in missing persons cases, however, some issues must be taken into consideration. As Hemy *et al.* (2013) explain, *ante-mortem* height data are often obtained subjectively and not through professional measurements. The absence of information regarding the stature of the person in life also becomes a limiting factor for anthropological comparison of stature. As the study carried out to make the formula used in the application was in the metropolitan region of Recife, in the state of Pernambuco, and as stated by authors such as Fawzy and Kamal (2010) and Caplova *et al.* (2018), the populations present diverse measures among themselves, and therefore the data found cannot be used as a basis for the whole world, there may be errors in the measures achieved by the calculation in different places. Therefore, population studies on this topic need to be encouraged.

Some difficulties regarding AppStore®, are also worth mentioning. Getting available on this platform requires many steps, resulting in the process taking longer, and the code created by the Thinkable® platform had a clash in relation to what was requested by Apple®, leading to the delay in delivering the application to the service for free download. No applications with the same objective as "Foot Height" were found in the literature or in the mobile download store discussed in this project (PlayStore®). An important issue is that, when acquiring the application, because it is associated with a cell phone, if this device is stolen or stolen, the case information contained therein will be lost. However, this can be solved if the professional writes down all the data obtained in another tool, such as pen-drives or some computer program. Analyzing the applicability and ease of use of the application proposed here, it is thought that this becomes a possibility of choice for criminal investigations, taking into account the advantages presented in this study. Further research will be conducted to confirm the efficiency of this tool in obtaining results. Conclusively the Foot Height application can serve as an aid in criminal investigation cases and that further studies are needed to validate its functions. Furthermore, this research reinforces the importance of a theoretical and practical background to establish the content and function of the application, in order to search for programs that fit the established requirements.

## ACKNOWLEDGEMENTS

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