Clinical validation of footprint analysis using the low cost Photo-podoscope JHECA NAWE

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RESUMEN

Un foto-podoscopio es una herramienta útil parla evaluación de la huella plantar, que se realiza mediante la observación de las áreas de apoyo al ponerse el paciente totalmente de pie. Esta evaluación diagnóstica la realiza generalmente un especialista, sin dejar registro de evidencias médicas para comparaciones futuras. Generalmente, esta evaluación se hace sobre la base de la forma de la huella plantar mediante el uso de un Podoscopio tradicional o siguiendo un proceso rudimentario, el cual acarrea una gran cantidad de desventajas. En este trabajo, presentamos un equipo alternativo llamado foto-podoscopio JHECA NAWE. Este equipo permite la evaluación de la huella plantar de una forma rápida, eficaz y ofrece un diagnóstico más preciso, incluyendo el registro de la huella plantar para futuras evaluaciones y a un costo menor comparado a los equipos comerciales. Los equipos comerciales suelen ser costosos, por lo que los especialistas médicos prefieren utilizar los procesos rudimentarios. Con el fin de evaluar clínicamente la eficacia de JHECA NAWE, en este estudio hemos analizado a un grupo de pacientes que fueron evaluados usando este equipo y los resultados fueron evaluados a ciega por los especialistas.

Palabras clave: Análisis de la huella plantar, foto-podoscopio de bajo costo, procesamiento de imágenes.

ABSTRACT

A photo-podoscope is a useful tool for assessing a footprint; it is performed by observing the supporting areas of the foot in standing position. This evaluation and diagnosis generally is made by a specialist, and without leaving medical evidence for future comparisons. Generally, this evaluation is made based on the form of the footprint by using a traditional podoscope or rudimentary process which carries several disadvantages. We present, a medical alternative equipment called JHECA NAWE photo-podoscope. This equipment allows assessment of a footprint in a fast an effective way with accurate diagnoses, including a record for future evaluations. Commercial equipment is expensive, reason why medical specialists prefer to use rudimentary processes. In order to evaluate clinically the effectiveness of JHECA NAWE, we analyzed a cross-sectional of attended patients by using this equipment in comparison with different medical specialist opinion.

Keywords: Footprint analysis, photo-podoscope, image processing.

1.   INTRODUCTION

The human skeleton is composed of a number of bones, together with joints, ligaments and muscles supporting the whole body weight (Voegeli, 2003). This weight is distributed in three main supporting points called foot tripod (see Fig. 1a), similar to a camera tripod (see Fig.1c), forming three arch (see Fig.1b), which are: the anterior transverse arch, the lateral longitudinal arch and the medial longitudinal arch (Gray, 1918; Álvarez Camarena & Palma Villegas, 2010). Being the medial arch the part that supports most of the weight and the longitudinal arch is in charge of the balance keeping. One of the main arches who suffer morphological changes is the medial longitudinal arch due to the muscle weakness caused by overstretching of the ligament.

Furthermore, a common pathology is the high instep caused by shortening of extensor muscles and ligaments. An individual footprint study allows correcting any early alteration, thus, prescribing an appropriate and effective treatment or recommending the right type of footwear. Therefore, it is important to diagnose any footprint disorder in children at an early age, thus, preventing changes that might cause futures implication. Rudimentary processes normally consist of using techniques like stamp ink, modeling clay, plaster and talc. Actually, the specialists are still using these rudimentary processes, which are subjective, time consuming and uncomfortable for the patient and the specialist as well. Nowadays, more sophisticated methods of footprint evaluation exist already. Even more, computer-assisted systems have been created by using the latest technology, such as photo-podoscope, where the plantar pressure can be evaluated, studied and analyzed. Combining lighting techniques, the effects of ambient light on images are reduced and the final image of the footprint is improved (Crisan *et al.*, 2011). However those equipments are very expensive, in our case we are using simple low cost homemade photo-podoscope, connecting to an application where a semi-automatic process is performance and the footprint is evaluated and a diagnosis is obtained as a result, which can be approved by the specialist.
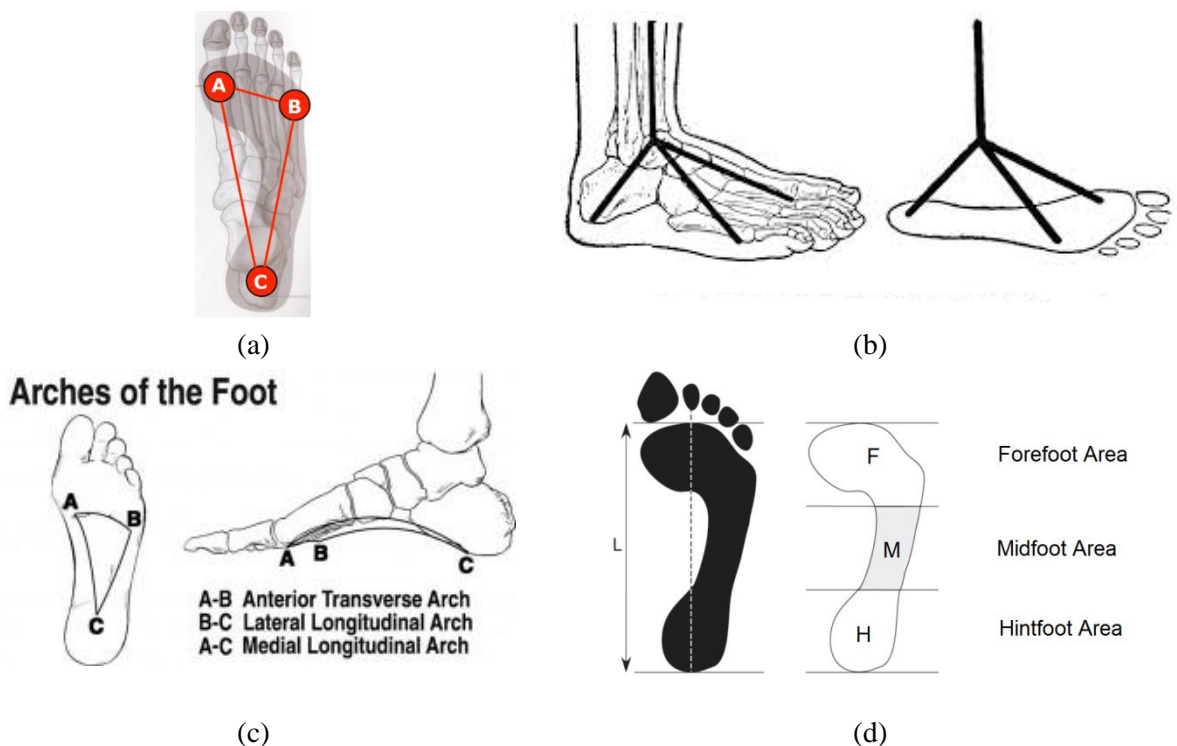

(a)   (b)

(c)   (d)

Figure 1. Foot anatomy (a); supporting points of the human foot, forming a tripod (b); and different arches (c). Anatomically, the footprint may be divided in three areas: the hindfoot, midfoot and forefoot area (d).

The footprint can be divided into three regions (see Fig. 1d): the hindfoot, the midfoot and the forefoot area. These areas serve as guides to analyze the footprint of the subject by calculating the Arch Index of Hernández Corvo (AI-HC) (Lara Diéguez *et al.*, 2011) or the Arch Index of Cavanagh and Rogers (AI-CR) (Lara Diéguez *et al.*, 2011), which determine the type of the footprint depending on some measurement performed based on the image from the footprint. We took the footprint by means of the box of JHECA NAWE for a later image processing. We have designed a tool using a free software for analyzing the footprint by obtaining the profile of the footprint and tracing a semi-automatically reference points and lines to facilitate the estimation of the AI-HC.

In previous work we have presented the design of a low cost photo-podoscope (Campoverde *et al.*, 2014), which capture an image of a footprint and evaluate it using an application for image processing. In this paper, we present a clinical evaluation of 2 groups of patients, evaluated at three different times. A first group of 30 patients were evaluated using a traditional podoscope (see Fig.2) by a specialist. A second group of 40 patients were evaluated by the specialists by visual observation of the footprint using the image generated by our photo-podoscope JHECA NAWE. Both groups were compared with the semi-automatic result obtained by our software connected to the photo-podoscope, in order to validate clinically our device.
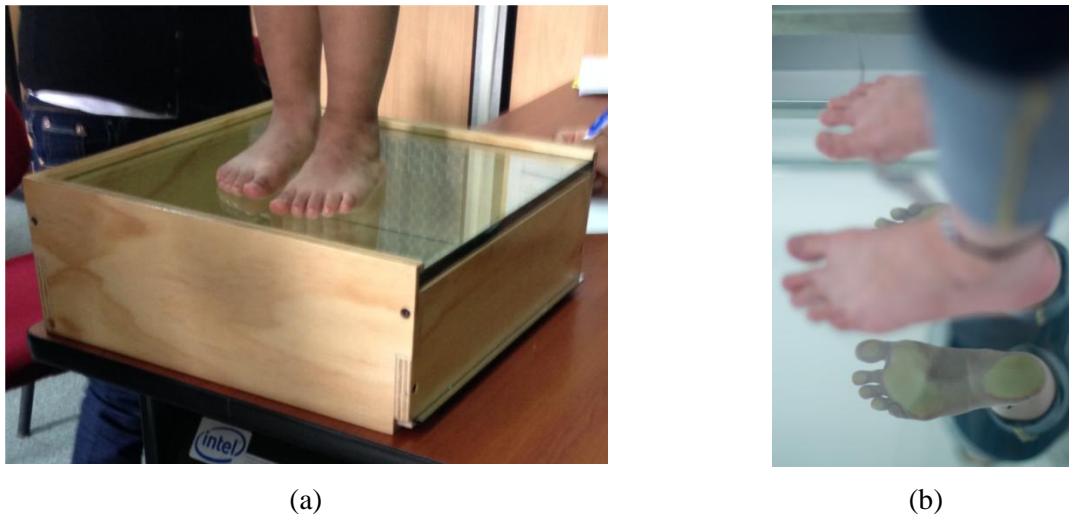

(a)   (b)

Figure 2. (a) A traditional podoscope; (b) the view for the specialist accomplish a diagnosis.

2.   MATERIALS AND METHODS

The study population consisted of children aged 3-6 years old, patients from the Integrated Development Center of University of Cuenca (CEDIUC) in the city of Cuenca, Ecuador. Children were evaluated, prior to the Center permission and their parents' consent. The medical record of every child was evaluated to check whether they presented a register of previous evaluations of their footprint. This first analysis allows us to realize that not all of them had previously their footprint evaluation, however after footprint evaluation; an alarming number of children presented some footprint disorder (90%). For every footprint evaluation, the child should stand on the photo-podoscope for five seconds to capture the image. A technician should control the position of the foot on the platform of the photo-podoscope in order to prevent sliding and get an optimal and effective image for further evaluation. The image generated with the photo-podoscope is sent to an application, where the image is preprocessed and in a semi-automatic way the AI-HC is estimated for clinical evaluation and validation of the photo-podoscope JHECA NAWE.

2.1. *Photo-podoscope JHECA NAWE*

The photo-podoscope used in this study was designed to evaluate the footprint statically using an image captured by a webcam, which is located at the internal base of the photo-podoscope. The first design was presented in (Campoverde *et al.*, 2014). In this work we presented an improved design of JHECA NAWE, and a study of evaluation of footprint disorder using our photo-podoscope for clinical validation. The improved design includes a fixed camera, and a fancy design for the box (see Fig.3a). The webcam used is a Logitech R HD webcam, up to 3 megapixel photos and hi-speed USB 2,0, focus type fixed, field of view of 600 and an optical resolution of 1280x960 1,2 MP.
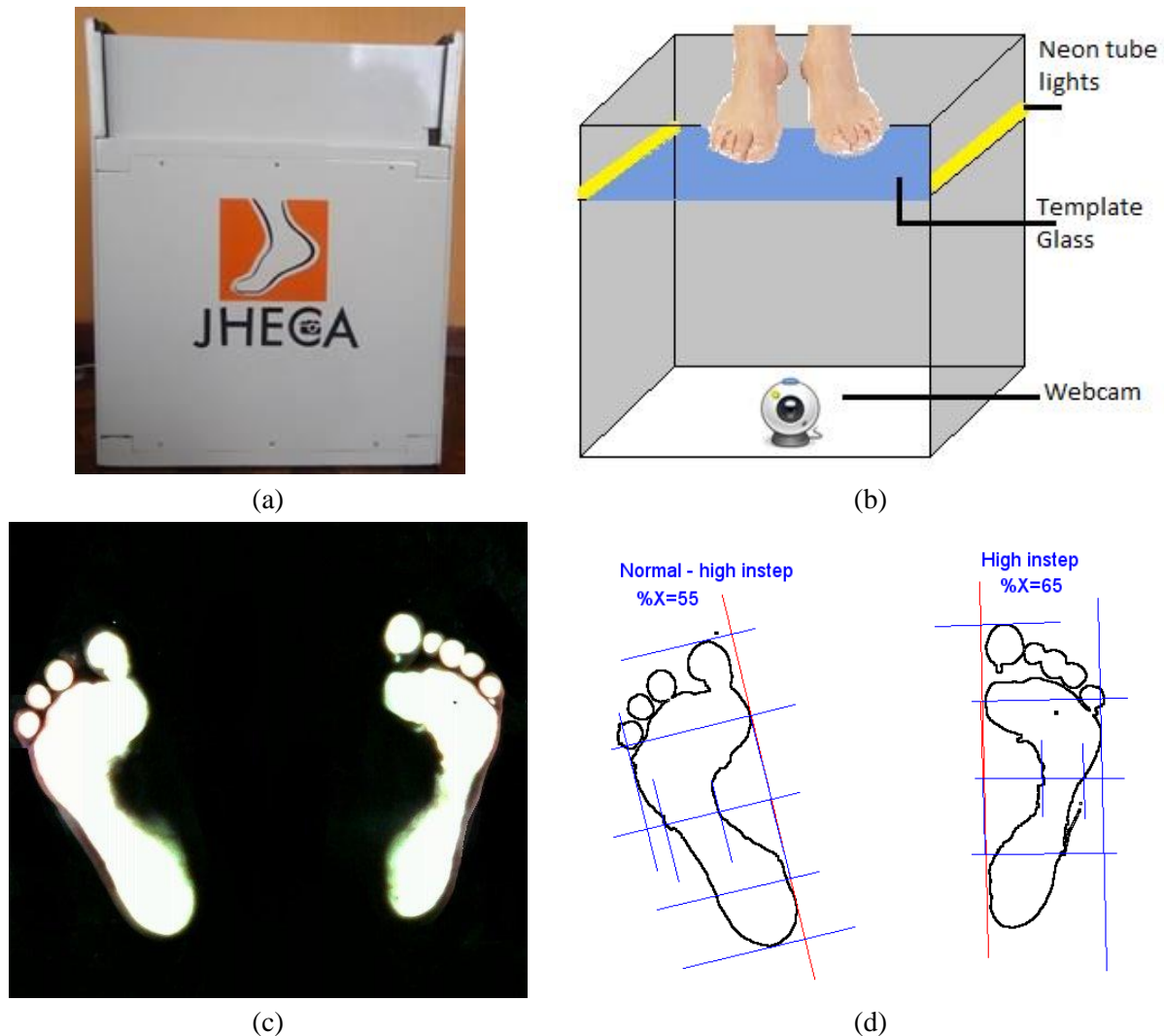

(a)   (b)

(c)   (d)

Figure 3. Footprint evaluation process and the components of the JHECA NAWE box (a) and the equipment components (b). The captured image (d) is sent to an application for further processing, and finally we the result of estimating the AI-HC is gotten (d).

2.2. *Image processing tool used for JHECA NAWE*

The image captured by JHECA NAWE (see Fig. 3c) is sent to a program called Fiji (ImageJ; http://fiji.sc/Fiji), where the image is preprocessed. A plugin added to Fiji were designed for edge detection of a footprint (MAKE FOOT) and by using the graphics tool of Fiji the specialist is able to trace manually the reference lines for estimation of the AI-HC. Then, the AI-HC value is shown over the pre-processed image (see Figs. 3d and 4b).

The plugin MAKE FOOT executes three processes from Fiji in this order: Enhance Contrast to reduce the illumination effects, Binarize the image by thresholding and the Edge Detection processes. Finally, the foot silhouette is obtained (see Fig. 4b). From this silhouette, the user traces the reference lines and points used for the method of estimation of the AI-HC (see Fig.4b).

3.   RESULTS

We accomplished two experimental evaluations, with different group of patients. Both groups were a population of children aged 3-6 years old; Group A: 30 patients evaluated by the specialist using a traditional podoscope as they normally do at the Center; Group B: 40 patients evaluated by three specialists and using only the image generated by our device JHECA NAWE. Also, it is important to point out that the evaluation was conducted by feet (left and right) independently and not per patient. The specialist describes the type of footprint for every foot, for the left foot and for the right foot.
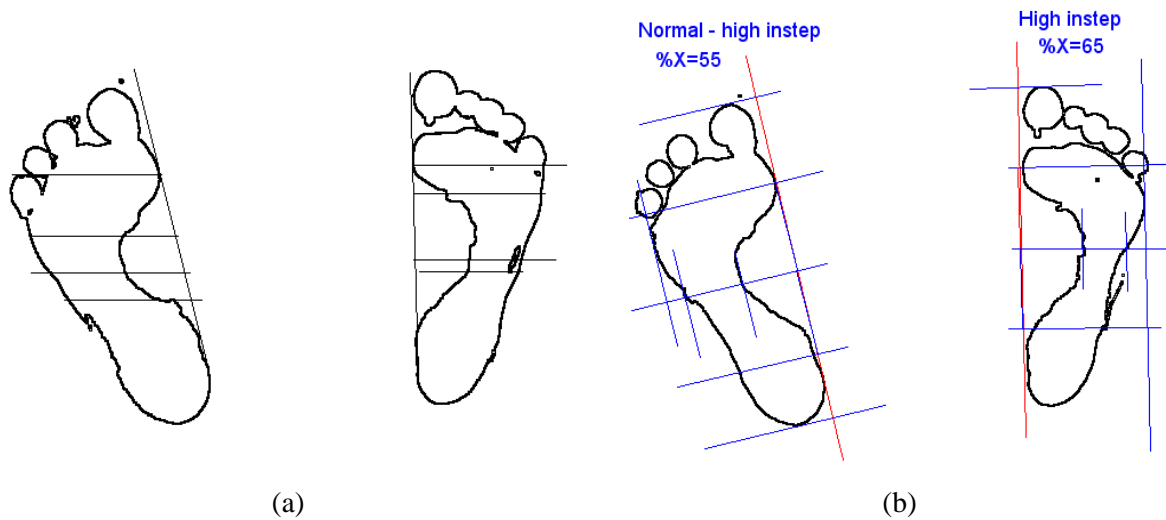

(a)   (b)

Figure 4. Example of calculating the Arch Index Hernández Corvo (AI-HC). Tracing reference lines by manual interaction with the application (a) and the estimation of the percentage of AI-HC(b).

3.1.   *Evaluation of Group A*

This first evaluation was carried out in order to evaluate clinically our device. In this study, a population of 30 children aged 3-6 years old, 19 boys and 11 girls were analyzed. Five of them had difficulties to keep in a standing position for the time required for taking a good footprint. Children taken for the study, had previously foot assessments made by the specialist of the CEDIUC, using a traditional podoscope to establish a diagnosis (see Fig.2). The result of this evaluation is presented below in Table 1.

Table 1. Evaluation of Group A by the specialist using a traditional podoscope.

Foot Type	Right Foot	Left Foot
Flat	21	21
Normal	8	9
High instep	-	-
Non Testable	1	-

The same group of patient was evaluated using our device JHECA NAWE and using the AI-HC for classifying the foot type, and the result is presented in Table 2.

Note that the assessment by the photo-podoscope JHECA NAWE uses the AI-HC method, which presents a more specific classification of footprint, giving us good diagnoses for the patient. JHECA NAWE provides a more accurate classification, considering the experts use a rudimentary method or a traditional podoscope and the evaluation is done per person and not individually per foot. The assessment by the photo-podoscope JHECA NAWE is performed independently on each foot (left and right), allowing classification of foot diseases as: Flat feet, Flat Feet - Normal, Normal, Normal - High Instep, High Instep, Strong High Instep and Extreme High Instep, and that allow the specialist to provide a better treatment.

Table 2. Evaluation of Group A by the specialist using a traditional podoscope.

Foot Type	Right Foot	Left Foot
Flat	21	21
Normal	8	9
High instep	-	-
Non Testable	1	-

Concordance Evaluation between the Expert and JHECA NAWE

We carried out an evaluation of concordance between evaluation results from experts and the photo-podoscope JHECA NAWE, in order to evaluate clinically our device. It should be noted that the diagnosis provided by the specialist and the photo-podoscope were conducted in an independent way, without seeing each other the data or images. We use the statistical Kappa to evaluate the concordance between the evaluation of the expert and the evaluation result from our device. Resulting a k = 0:63 (substantial concordance). This result indicates a high degree of agreement between expert assessment and the result obtained with JHECA NAWE photo-podoscope. We conclude that the photo-podoscope JHECA NAWE is suitable for footprint evaluation clinically.

3.2. *Evaluation of Group B*

This second evaluation was carried out in order to evaluate the concordance between observers. In this study, a population of 40 children aged 3-6 years old, 29 boys and 11 girls were analyzed. Three of them were not considered for testing due they presented other lower extremity abnormalities.

Concordance between observers

An evaluation inter expert was made using a triple-blind study, were three experts evaluated every patient based on the image captured by the photo-podoscope, without seeing the patient. They classified every foot (left and right) as: normal, flatfoot or high instep. Therefore, concordance evaluation between experts was needed. In this case the statistical measure called Fleiss Kappa (Fleiss, 1973) was used. Fleiss Kappa (k) is a measurement of agreement that can be used when the numbers of evaluators are three or more, which is the case. Resulting a k = 0:42 evaluating the left feet and k = 0:36 evaluating the right foot, considering as fair to good agreement evaluating the left feet and poor agreement evaluating the right feet, between observers. This result confirms the subjectivity of the testing. Considering evaluators are using the image captured by our device which introduces a new way to analyze the footprint to the evaluators.

4.   DISCUSSION

This study took two groups of children for evaluation: a first group of 30 children and a second group of 40 children. All of them from different therapy areas at CEDIUC such as: Speech Therapy, Early

Stimulation, Physical Therapy and Psychology, by reviewing the medical records of every child we found that not all of them had a pediatric evaluation. Normally, only patients who attend the physical therapy have their footprint evaluated. However, because in the study, children attending from different therapy were evaluated, we realized that a lot of them presented a feet disorder. At the beginning of this study we started applying the method of Arch Index Cavanagh and Rodgers (Lara Diéguez *et al.*, 2011), but during the evaluation we note this method was not applicable to children because they had errors in determining the surface of the foot and prevented us from obtaining correct results. In this situation, after some testing we applied the protocol of Hernández Corvo to evaluate the arch index, resulting be an effective method for our study.

5.   CONCLUSION

As a result of the study, we demonstrated that our device JHECA NAWE is suitable for the assessment of footprint, allowing capturing an accurate image of footprint for further processing and medical record of every patient. This study allows evaluating two groups of patients from a specialized center (CEDIUC) in Cuenca, Ecuador. The results obtained after applying the photo-podoscope helped us to realize that there is a high percentage of children with flatfoot pathology at early ages (90%). Besides, we may say that there is a marked difference between the assessments made by using JHECA NAWE, experts and diagnosis already given earlier in the center. Since, the classification by experts implementing the rudimentary process are just flat feet, normal or high instep for both feet, meanwhile using the image capture by the device and further processing, the classification is more precise, and may be useful for building a more suitable orthopedic insole. As a future work, it is possible to automate the estimation of the arch index, reducing the evaluation time per patient.

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