Utilization of Artificial Intelligence in the Diagnosis of Pes Planus and Pes Cavus with a Smartphone Camera

Samir Ghandour, Anton Lebedev[1], Wei Shao Tung[2], Konstantin Semianov[1], Artem Semjanow, Mohamad Al Masri, Christopher W DiGiovanni[3], Soheil Ashkani Esfahani[4], Lorena Bejarano-Pineda
[1]Foot and Ankle Surgery, [2]University of Sheffield, [3]Mass General/Newton-Wellesley, F&A Ctr, [4]Massachusetts General Hospital

INTRODUCTION:

Pes planus (flatfoot) and Pes cavus (high arch foot) are common foot deformities, often requiring clinical assessment and radiographic imaging for diagnosis and potential subsequent management. The Foot Posture Index (FPI) is a standardized diagnostic clinical tool used to evaluate the multidimensional aspects of the foot, which scores feet along a spectrum of cavus to planus features. While not commonly used, weightbearing computed tomography (WBCT) or plain radiographs are diagnostic or adjunctive assessment modalities for foot arch deformities. Nevertheless, these modalities are costly, expose the patient to radiation, and may not be accessible to the general population, especially in underserved communities. With the advent of artificial intelligence (AI) and its integration into mobile cameras, this study aims to evaluate the efficacy and utility of a CNN algorithm for detecting and classifying foot arch deformities using smartphone cameras in comparison to traditional clinical assessment using the FPI. We hypothesize that our model can detect the presence of deformity, particularly when subtle, with high accuracy, using standardized phone camera images of the medial foot.

METHODS:

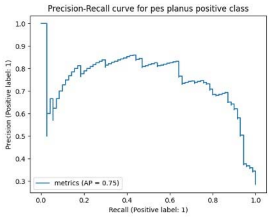
An algorithm that integrated a deep convolutional neural network (CNN) into a smartphone camera was utilized to detect Pes planus and Pes cavus deformities (link to mobile application tool: https://medlab.neatsy.ai/registration/c8875a56-0e9a-4c31-a114-7df739956a23/). This prospective study was conducted at a tertiary hospital with participants recruited from two orthopaedic foot and ankle clinics. Participants included subjects with standard foot alignment, Pes planus, or Pes cavus determined by an expert clinician using the Foot Posture Index (FPI). Feet that were deemed as having pes planus or pes cavus deformity by a foot and ankle surgeon were labeled as cases, while feet that did not have any arch deformity were labeled as normal controls. The inclusion criteria for the recruited individuals in this study were 1) adults aged ≥ 18 years old, 2) experiencing foot pain, 3) being able to ambulate and bear weight on their feet, and 4) having the capacity to provide informed consent for participation. The exclusion criteria were 1) the presence of fractures in the foot, including stress fractures and traumatic injuries, 2) the presence of peripheral neuropathy, neurological injuries, or structural deformities related to chronic diseases (i.e., Charcot's foot), 3) the inability to stand on one foot, and 4) structural deformities in the toes (mainly the first ray). The CNN was trained and tested using photographs of the medial aspect of participants' feet, taken under standardized conditions. The model's performance was assessed in comparison to clinical assessment and radiographic measurements, specifically lateral tarsal-first metatarsal angle (LTMA) and calcaneal inclination angle (CIA) for correlation with radiographic deformity severity.

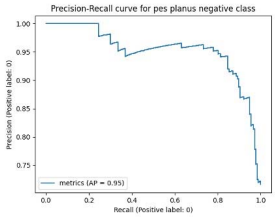
RESULTS:

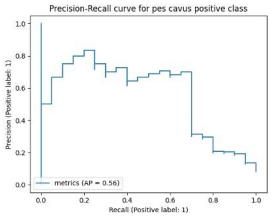
Within the testing set, 70 feet were labeled and identified as pes planus (28.4%), and 20 feet (8.1%) were labeled and identified as pes cavus. There were 156 healthy feet (normal) in the testing set. A total of 36 lateral weightbearing radiographs were available for LTMA and CIA measurements. The developed CNN model demonstrated high accuracy in diagnosing both pes planus and pes cavus. with an optimized area under the curve (AUC) of 0.90 for Pes planus and 0.90 for Pes cavus. It showed a specificity and sensitivity of 84% and 87% for Pes planus detection, respectively; and 97% and 70% for Pes cavus, respectively. For the Pes Planus model, The PR-AUC for the positive class was 0.75 and 0.95 for the negative class, as shown in **Figure 1**. for the Pes Cavus model, the PR-AUC for the positive class was 0.56 and 0.99 for the negative class, as shown in **Figure 2.** The LTMA and CIA were derived from these radiographs and showed a correlation of -0.65 (95% CI: [-0.81, -0.41]; $p < 0.001$) for LTMA and -0.23 (95% CI: [-0.52, 0.09]; $p = 0.16$) for CIA with the neural network output score.

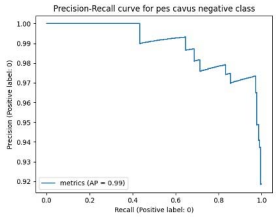
DISCUSSION AND CONCLUSION:

This study showed that a deep learning CNN algorithm using smart device cameras can identify foot arch deformities by analyzing photos of the medial foot reliably, accurately, and independently of clinical examination, which is especially beneficial for underserved communities and patients with pain generated by subtle foot arch deformity. Patients might experience remarkable pain and associated symptoms from subtle, not readily recognizable foot arch deformities. Therefore, remotely utilizing this algorithm as a prescreening tool prior to any clinical encounter to identify suspected foot arch deformities in the setting of pain may prompt physicians to pursue more conservative management pathways to address a pain-generating yet subtle foot arch deformity. Future efforts should enhance this technology for pediatric use and improve severity differentiation, paving the way for more personalized and inclusive healthcare solutions.


Precision-Recall curve for pes planus positive class
Precision (Positive label: 1)
Recall (Positive label: 1)
metrics (AP = 0.75)


Precision-Recall curve for pes planus negative class
Precision (Positive label: 0)
Recall (Positive label: 0)
metrics (AP = 0.95)


Precision-Recall curve for pes cavus positive class
Precision (Positive label: 1)
Recall (Positive label: 1)
metrics (AP = 0.56)


Precision-Recall curve for pes cavus negative class
Precision (Positive label: 0)
Recall (Positive label: 0)
metrics (AP = 0.99)