Prediction of clinical foot characteristics using quantitative features from different measurement setups

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Introduction

The clinical assessment of feet is mostly based on the experience of foot experts, and varies with their clinical background.

To assess feet, experts typically use different techniques and equipment, such as podoscopes, blueprints, pressure plates, or goniometers.

To reach a better consistency among experts, it is necessary to compare their results to accurate, quantitative measurements.

Purpose of the study

This study aims to identify which clinical feet characteristics can be measured robustly visually, and which ones benefit from adding specific equipment in the measurement procedure.

As a first step, we want to identify which foot characteristics can be accurately predict-ted from the quantitative data from different measurement setups.

Methods

We measured 77 healthy subjects without major foot deformities. They were all clinically assessed by 10 experts (orthopedic technologists, podiatrists, and one orthopedic surgeon), hence a total of 770 assessments. Furthermore, an anamnesis was conducted, and gait of all subjects was quantitatively measured using 3D motion analysis (Codamotion), dynamic pressure plate (RSScan International), a dynamic 3D scanner (ViALUX) and a force plate (AMTI).

To identify those clinical characteristics, which are robust over the different experts, we conducted a 2-agreement weighted kappa analysis which is an extension of Cohen's kappa for multiple raters (Warrens 2012). Furthermore, we included both the popularity and the discriminative power of a characteristic (i.e. how many experts scored it and how diverse are the scores, resp.). We included these last two elements because if either popularity or discriminative power are low, we cannot say much about a certain feature, e.g. if it is evaluated by only one or two experts, or if all subjects get the same score.

In a second part we used the quantitatively extracted features (from the pressure plate, 3D motion analysis, dynamic 3D scanner and force plate) to predict the average expert scores, for each clinical characteristic individually. To determine the best feature subset, we carried out a feature selection using the Lasso technique in a 10-fold cross validation. The feature subset was then fed to a support vector machine (SVM) classifier which trained a prediction model using a leave one out cross validation.

Lastly, from these data we can give an indication which hardware is best to predict foot characteristics. To this end we built the SVM model only including features from one or a limited set of measurement equipment. In this abstract we highlight 3 cases: prediction of the resting calcaneal stance position (RCSP), pressure of the midfoot during stance, and the ratio of the forefoot/heel width.

Results

12 foot characteristics were identified as being robust over all experts, including pressure of the midfoot during static measurements, the longitudinal foot arch height, the ratio of the forefoot/heel width, foot flexibility, midfoot during midstance (supination/ pronation). Furthermore 9 characteristics were considered to be moderately robust. In the rest of the study, we only consider these 21 (12+9) characteristics.

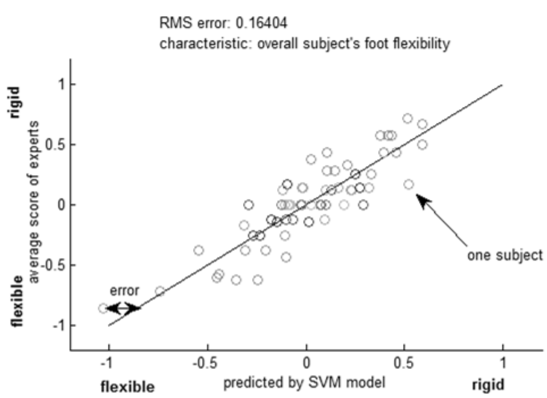

Figure 1: comparison of prediction of model and the score of the experts.

Figure 1 shows the prediction of the SVM model for foot flexibility. Each dot represents one subject's score of this feature. In the ideal case, when the SVM prediction is perfect, the dots will lie on the diagonal. We standardized the range from -1 to 1, which corresponds to the case where all experts score the foot as flexible or rigid, respectively. The root mean square error is 0.164 which means that the model can give a good prediction of the experts' scores.

Of the 21 foot characteristics we took into account, 15 of them scored a RMS lower than 0.2 with the lowest being 0.124, and 6 were higher than 0.2, with a maximum of 0.449.

As expected the prediction of the midfoot pressure was best using the pressure plate and was slightly improved when combining the pressure plate with a 3D scanner or 3D motion analysis. RCSP was best predicted using the 3D measurement system, or the 3D measurement system combined with the pressure data. Lastly, the forefoot/heel ratio showed the best results combining 3D scanner data and pressure data.

Discussion and conclusion

We revealed some of the relationships between the clinical analysis of feet by experts and the measurements using specialized equipment.

The prediction using the quantitative features is dependent on the extracted features, so future work should focus on the foot characteristics that are difficult to predict, and extract better features for it.

References

Warrens, M. J. (2012) Stat Methodol 9 **(3)**, 407-4