DETERMINATION OF FUNCTIONAL GROUPS IN DIFFERENT LEVELS IN RUNNING GAIT; LOWER LIMB MECHANICAL ENERGY ANALYSIS

Mansour Eslami[1], Esmaeil Hosseininejad[1], Fatemeh Salari Esker[1], Rohollah Yousefpour[2], Afshin Fayyaz Movaghar[2] and Heydar Sadeghi[3]
Faculty of Sport Science, University of Mazandaran, Babolsar, Iran[1]
Faculty of Mathematics and Statistics, University of Mazandaran, Babolsar, Iran[2]
Faculty of Sport Science, Kharazmi University, Tehran, Iran[3]

The purpose of this study was to determine the functional groups in different levels during stance phase of running. 118 students (58 males and 60 females) ran in two footwear conditions (Nike free5 and Vibram FiveFingers shoes) and barefoot. Mechanical energy of pelvic, thigh, leg and right foot were calculated. Functional groups were determined using principal component analysis, self-organizing maps, k-means clustering and support vector machine methods based on lower limb mechanical energy. Five first level functional groups were defined in barefoot, Nike and FiveFinger running conditions with accuracy of 95.80%, 91.60% and 91.60%, respectively. 41 subjects were identified as the third level functional groups. According to our results, the functional groups were well recognized with the use of dimension reduction and unsupervised clustering methods.

KEY WORDS: functional groups, principal component analysis (PCA), self-organizing maps (SOM), support vector machine (SVM), k-means clustering.

INTRODUCTION: Subject-dependent responses to biomechanical interventions have been considered as a major challenge in predicting the effect of these interventions. Determination of functional groups (FGs) and their features is a best solution for this problem. A FG is a collection of individuals that response to a specific intervention in a similar way (Nigg, 2010). However, for comprehensive predictions in subject response to a specific intervention and task, FGs must be determined in different levels. To our best acknowledge, no investigations have determined FGs based on footwear interventions and running gait task.
The perpose of this study was to determine FGs in different levels (e.g. first, second or third level) based on lower limb mechanical energy. Each level indicates the number of interventions that subjects have same responses to them. For example, those subjects who are in the third level, they respond similarly to three interventions in a running gait task.

METHODS: 118 subjects (58 males and 60 females) ran in two footwear conditions (Nike free5 and Vibram FiveFingers shoes) and barefoot. Mechanical energy of pelvic, thigh, leg and foot was calculated during stance phase of running. In each running condition the principal components that accounted for 95% variance of data were used as inputs for Self-Organizing Maps (SOM) technique (Hoerzer, von Tscharner, Jacob, & Nigg, 2015). Size of output matrices from SOM was 118×1600 that again reduced dimensionality by PCA. The first two principal components of barefoot running condition were imported to a K-means clustering method, and respect to neighborhood distance plot that achieved by SOM, subjects were classified into four different number of groups (5-8 groups). Because the outputs of K-means are slightly different for a same collection of data, so clustering was performed 10 times for each group number. The classification rates were determined with support vector machine (SVM) and a fivefold cross-validation technique.
Best group number (five groups) was determined and best classification rate result was used to train a SVM. In the next step, subjects were classified in two remaining conditions (two shod running) using this trained SVM so the first-level FGs were determined in three conditions. In order to detection of second-level FGs, two running conditions must be considered together (barefoot-FiveFinger, barefoot-Nike and FiveFinger-Nike). If more than

five first-level FG subjects in one condition (e.g. barefoot) were still in same group in second condition (e.g. FiveFinger), these subjects were considered as a second-level FG. At last, third-level FGs were determined in three conditions of this study.

RESULTS: Classification rate results showed that best group number with accuracy of 94.58% was five group. Five first-level FGs were defined in barefoot, Nike and FiveFinger running conditions with accuracy of 95.80%, 91.60% and 91.60%, respectively. From 118 subjects, 85, 82 and 84 subjects were in second-level FG in barefoot-FiveFinger, barefoot-Nike and FiveFinger-Nike conditions, respectively. Finally, 41 subjects were identified as the third-level FGs (figure 1).

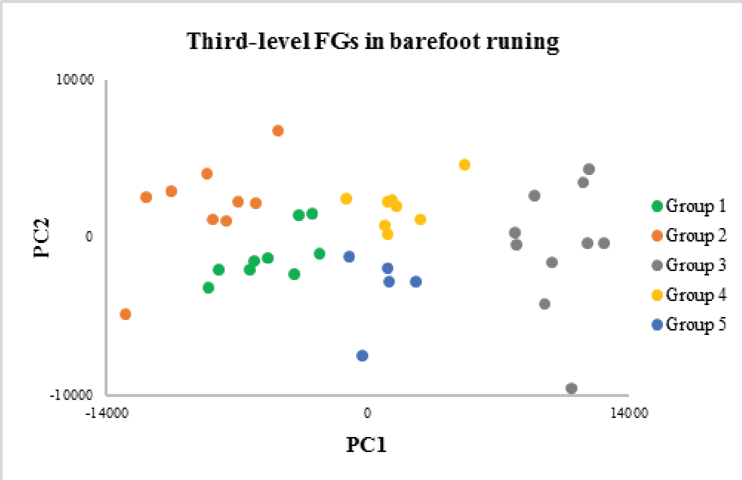

Figure 1: Third-level FGs in barefoot running condition.

DISCUSSION: According to our results, FGs in different levels can be determined using unsupervised clustering methods. Identification of FGs is a rather difficult task that require a large sample of subjects and complex computational methods. Almost a decade ago, Nigg (2010) proposed the concept of FG however; there is just one study that practically found FGs (Hoerzer, von Tscharner, Jacob, & Nigg, 2015). Hoerzer et al, (2015) defined eight first-level FGs with distinctive movement patterns, but current study defined FGs in different level. Higher level FGs are more desirable but when subjects are seek in higher order level FGs number of groups increase. Thus, to proper determination of higher level FGs, high sample size of subjects must be recruited. Only 41 subjects in this study found in third-level FGs, but the rest of the subjects belong to the third-level FGs, if the sample size was large enough.

CONCLUSIONS: The FGs were well recognized with the use of dimension reduction and unsupervised clustering methods. The results showed that there are third-level FGs that have similar response to at least three interventions. Identifying FGs in higher level and their features is very important for predicting the effect of interventions and prescribe appropriate treatment.

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