KNEE AND ANKLE JOINT MOTION PATTERN DURING GAIT IN SUBJECTS WITH OVERWEIGHT

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SUMMARY

The purpose of this study was to test the hypothesis that joint kinematic waveforms in overweight subjects during gait are different from those with normal weight. Principal component analysis retained six and four principal components (PC) for the ankle, and for knee and hip, respectively, which explained 84.0%, 80.3%, and 85.5% of the total signal variance. The stepwise selection of logistic regression (LR) variables identified the first PC score for ankle as significant inputs under a χ^2 distribution (Akaike information criterion equal 32.7). The final LR model separated gait from overweight subjects to controls, with 54% accuracy. Overweight subjects presented gait pattern modification in frontal and transverse ankle movement.

INTRODUCTION

Obesity is closely associated with health risks such as diabetes, cardiovascular diseases, stroke and knee osteoarthritis [1,2,3,4]. Walking activities are recommended for the prevention and treatment of obesity, since it expends a significant amount of metabolic energy [5]. However, it has been found that obese people may have increased joint stress due to altered gait pattern [2, 6]. Obese were found to showing alterations in kinematics data during gait analysis, such as: increase in step width, time interval during double support and overall stance of the gait cycle [2]. However, in overweight subjects, such alterations are unknown. Therefore, the purpose of this study was to test the hypothesis that joint kinematics waveforms in overweight subjects during gait are different from those with normal weight. A multivariate analysis approach was used to identify the most important combinations of biomechanics factors that distinguished between overweight and normal weight gait patterns.

METHODS

Twenty four subjects visited the laboratory for gait testing. Patients were then spited according body mass index (BMI) into control group (BMI < 25) (CG) and overweight groups ($25 \leq$ BMI ≤ 30) (OG). The CG consisted of fifteen subjects with age 48.2 ± 6.2 years (mean $\pm$ standard deviation), body mass 60.63 ± 5.85 kg, height 1.64 ± 0.06 m and BMI 22.63 ± 1.23 kg/m². OG was composed by nine subjects with age 49.1 ± 5.7 years, body mass 79.8 ± 11.23 kg, height 1.69 ± 0.1 m and BMI 27.83 ± 1.60 kg/m². All subjects signed a written informed consent approved by a local ethics committee, and were free of neurological illness, degenerative conditions or any general disease that might interfere on gait.

Two force platforms AMTI (Advanced Mechanical Technology Inc, USA) and a three-dimensional motion analysis system OPTOTRAK (Northern Digital Inc, USA) were used in the gait analysis. A total of twelve markers were taped onto the skin of the rear foot, shank, thigh, and pelvis with three markers on each body segment on right lower limb. The force platforms were mounted in series at the middle of the walkway and covered with gray carpet. The subject practiced the walking five times before the trial, walked barefoot at their self-selected speed, and repeated the trial five times. Data acquisition began approximately 1 s before the subject entered the area and ended 1 s after the subject left the area. The data were collected for 10 s at a sampling frequency of 100 Hz. In the present study, kinematics data from right knee and ankle joint were analyzed. The kinematics data were filtered using a bidirectional low-pass Butterworth filter, 2nd order with a cutoff frequency of 7 Hz. Each waveform was interpolated with cubic splines and re-sampled to 51 sample points corresponding to 100% of gait cycle for kinematics data. The average of the second to fourth trials was used in the analysis as a representative sample of the subjects' data of each joint in each motion plan.

Principal Component Analysis (PCA) was performed in the kinematics data of each joint separately, which was represented by a matrix containing data from sagittal, frontal and transverse planes respectively. Thus, the kinematics of each joint was stored in a matrix **E** [24 x 153], where rows corresponded to subjects (fifteen controls and nine overweight patients) and columns corresponded to samples of signals (51 samples for each plan). Due to different magnitudes of the variables, the data were normalized to zero mean and unit variance in matrix **E2** [5]. PCA was applied in each **E2** and the number of principal components (PC) were selected by the scree test [7].

For subject's classification, the logistic regression (LR) was applied, being the independent variables all PC scores retained in the analysis. A stepwise approach was previously

performed to select the input variable by the Akaike information criterion (AIC) of the final model. The model's performance was assessed by the total accuracy obtained by the leave-one-out approach. The data processing and statistical analysis was performed in the software Matlab 6.5 (The Mathworks, USA) and the stepwise was performed in software R (CRAN; http://cran.r-project.org/).

RESULTS AND DISCUSSION
PCA retained six PCs for the ankle, and four for the knee and hip, which explained 84.0%, 80.3%, and 85.5% of the total variance, respectively.

The stepwise selection of LR variables identified the first PC score for ankle as the only significant input under a χ^2 distribution (AIC = 32.7). The final LR model separated gait from overweight subjects with 54% accuracy. Therefore, the ankle joint movement during gait was different in overweight subjects compared to controls. Other kinematic changes were found in the gait of obese subjects (Increased step, prolonged double support), However, no study was found analyzing the gait of subjects with overweight.

To help the interpretation of the attained information by PC retained in the final LR model, the average angular movement of ankle was visually compared between CG and OG (Figure 1A). The loading factors of the first PC indicated that the main differences occur in frontal and transverse planes. This result suggests that during the dynamics of walking a different strategy, rotation of the ankle against lateral shifting of weight is used to maintain the stability anterior-posterior versus mediolateral [2].

Overweight subjects presented gait pattern modification in frontal and transverse ankle movement. If this pattern does not change over time, it can develop a clinical alteration called osteoarthritis.

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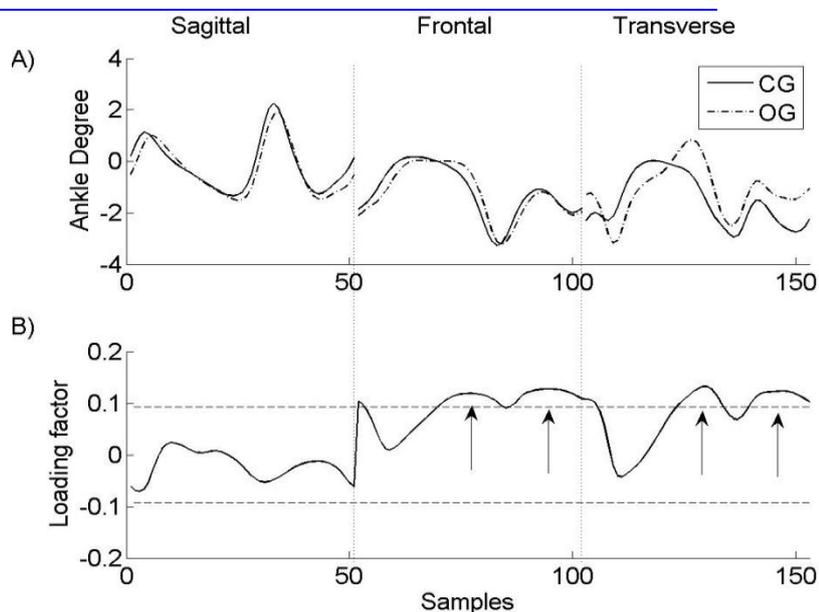
Figure 1: (A) Average of ankle kinematics from CG (continuous line) and OG (dotted line). The vertical lines represent the start of the gait cycle in each plan. (B) The first principal component. The dotted horizontal lines represent the threshold of $\pm$ 70% of the maximum loading factor, and the arrows highlights sections with loading factors greater than threshold.