PARAMETERIZING JOINT-LEVEL VARIABILITY DURING WALKING FOR STROKE VICTIMS

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INTRODUCTION

Predicting how likely an individual is to fall could improve rehabilitation outcomes, thereby improving the quality of life for millions of individuals. Variability in gait temporal parameters is correlated with fall risk [1] and with clinical measures of gait impairment [2]. Since changes in temporal parameters occur due to changes in joint movements, leg joint variability may provide valuable information about fall risk. Joint variability has been parameterized for young, healthy adults walking at their self-selected speed [3] but not for other populations. Since stroke is a common cause of impaired gait, this abstract presents initial work in parameterizing joint variability for stroke victims. Specifically, it shows that joint variability can be parameterized mathematically using low-order Fourier series for both stroke victims and healthy adults.

METHODS

Joint angle data from 7 stroke patients (average speed 0.5 m/s), 6 slow, healthy adults (average speed 0.5 m/s), and 7 young, healthy adults (average speed 1.2 m/s) walking overground at their self-selected speed were used. The data from the stroke and slow, healthy subjects were collected using a Coda CX1 (Charnwood Dynamics, Leicestershire, England) active marker motion analysis system system. The data from the young, healthy subjects were collected using a Vicon (camera model: T20S, Oxford, UK) motion capture system. For comparison, artificial joint angle data were created with known variability (filtered zero-mean random noise). A total of 34 strides from each population were used, except for the slow, healthy subject data which had 29 strides. (The young subject data were a subset of the data from [3]). Each stride was divided into stance and swing periods, and the periods were analyzed separately. The affected and contralateral sides were analyzed separately for the stroke subject data, while only the right leg was analyzed for the healthy data.

The per-subject mean motion for each joint was determined and subtracted from the total joint motion for each step (Fig. 1). This gave a time history of the joint variability. To parameterize the variability mathematically, a second-order Fourier series was fit to the stance period variability and a first-order Fourier series was fit to the swing period variability (Fig. 1). The quality of each fit was calculated using the R^2-value and the normalized root mean square error (RMSE). The normalized RMSE is the RMSE divided by the range of the variability. Pairwise t-

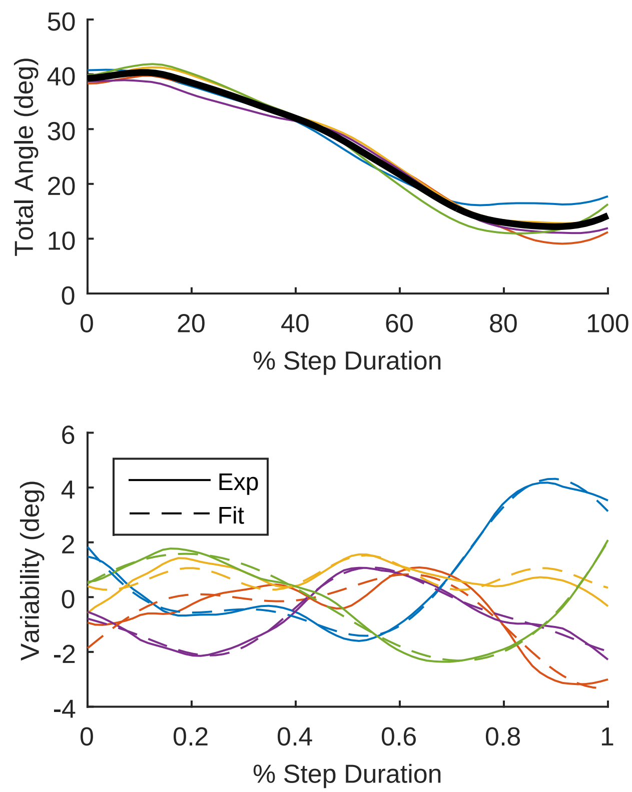

Figure 1: Top: The total (thin lines) and mean (thick line) joint angles. The pointwise difference between the mean and total angle is the variability. Bottom: The experimental variability and the best fit second-order Fourier series. The Fourier series fits the data very well. Both plots show the affected-side stance hip angles for a stroke subject.

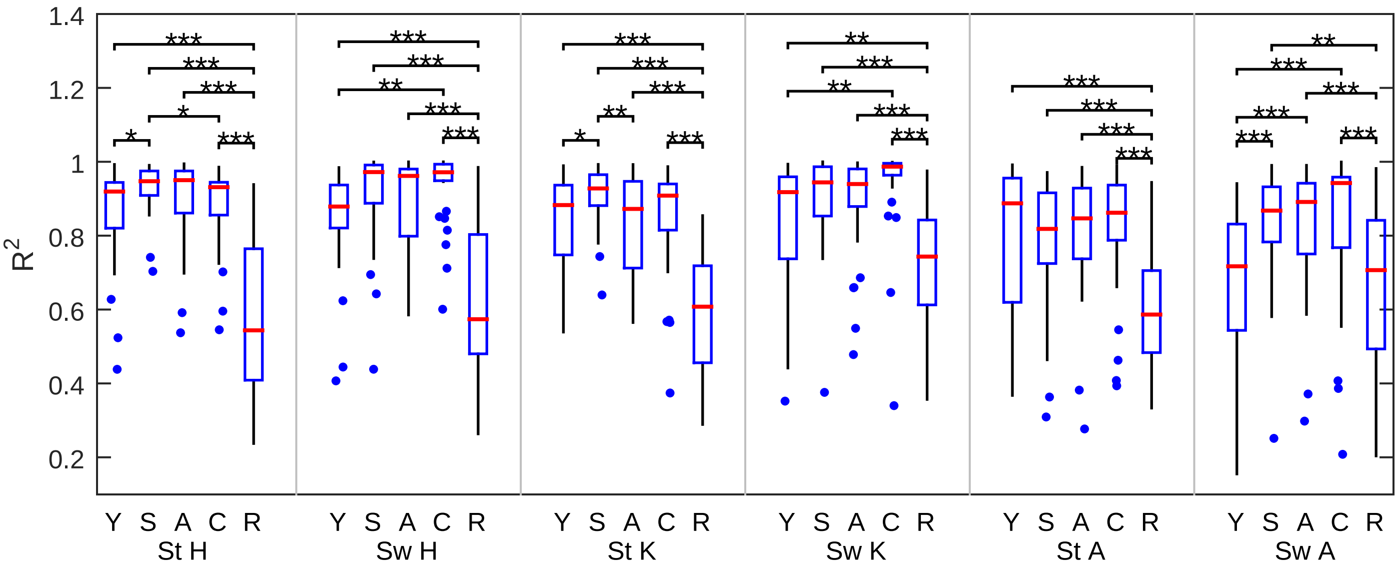

Figure 2: The R^2 values for all groups (**Y**oung healthy, **S**low healthy, stroke **A**ffected side, stroke **C**ontralateral side, a**R**tificial), joints (**H**ip, **K**nee, **A**nkle), and periods (**St**ance, **Sw**ing). Larger values indicate better fit. Statistically significant differences are indicated: * = p-value < 0.05, ** = p-value < 0.01, *** = p-value < 0.001. Statistical significance was similar for the RMSE values. Blue dots indicate outliers.

tests using the R^2-value and the normalized RMSE were conducted between each of the five groups for each joint and period.

RESULTS AND DISCUSSION

With the exception of the young swing ankle, low-order Fourier series fit the true experimental data significantly better than the artificial data as expected using both goodness of fit measures (Fig. 2). This provides confidence that the variability is not simply measurement noise and that similarities or differences between populations are true. The fits for the true experimental data were quite good, with R^2-values consistently above 0.8 and normalized RMSE consistently below 8% of the variability range. For all joints and periods of the stroke subjects, the goodness of fit between the affected and contralateral sides were similar. For the stance joints, the goodness of fit was similar between the young, slow, and stroke subjects. For the swing joints, the goodness of fit was slightly better for the stroke and slow subjects than for the young subjects. This indicates that a second (or first)-order Fourier series well captures the joint variability as a function of step progression in stance (or swing) joints for both healthy adults and stroke victims. This is true despite considerable differences in mean walking speed. Further, the systems used to collect the experimental data were different, indicating that joint variability and this parameterization is robust to different data collection methods, at least some gait impairments, and walking speed.

CONCLUSIONS

The joint variability during walking for both healthy adults and stroke victims has a remarkably similar structure and can be parameterized mathematically using the same method for both populations. Further, the accuracy of the parameterization is similar. The values that define the Fourier series may be different for each population, although this work remains to be done. The full characterization of joint variability will be included in physics-based models of human gait [4] and used to investigate fall risk.

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