PAD CAUSES ALTERATIONS IN THE VARIABILITY OF GAIT PATTERNS

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INTRODUCTION

Peripheral arterial disease (PAD) affects 8 to 12 million people in USA and is a leading cause of morbidity due to the ambulatory limitations associated with claudication. In PAD, the arteries supplying the legs are blocked by atherosclerosis, significantly reducing blood flow to the muscles. The reduced blood flow leads to inadequate levels of oxygen during physical activity and PAD patients have muscle ischemic pain and inability to walk normal distances (claudication; Nehler et al., 2003). PAD patients walk initially without pain but as the oxygen demands in the muscle increase with ongoing exercise the leg becomes progressively more ischemic and painful. Eventually, this pain causes patients to stop walking.

There are a variety of treatment options for claudicants including lifestyle modification, pharmacologic therapy and surgery. However, the degree of effectiveness of these methods is under debate. This is partially due to the inadequacy of the methods used to assess after treatment improvements in gait performance (Scherer et al., 2006). Thus, there is a need for a more sensitive quantitative tool to determine the severity of functional limitations, effectiveness of treatments, and other risks (i.e. falling) that could result from PAD. Recent literature has shown that the examination of gait variability in elderly using nonlinear analysis can describe subtle functional changes that usually go undetected using traditional approaches (Stergiou et al., 2003). Gait variability can actually be a predictor of falling in the elderly and can differentiate between pathological populations and healthy controls (Maki, 1997). Research for PAD may also benefit from a similar approach. Therefore, our purpose was to use nonlinear methods to determine gait variability in PAD patients compared to healthy controls and to determine how gait variability in PAD patients is affected by claudication.

METHODS

Fifteen PAD patients (PAD) and 15 controls (CON) walked on a treadmill while kinematics (60 Hz) were recorded using a Motion Analysis system. Walking trials of up to three minutes were captured during pain free (PF) and subsequently pain (claudication, P) conditions. Claudication was induced using a common clinical protocol where the patient walked on a treadmill, set at 10% grade and 0.67 m/s, until the onset of pain at which point the pain condition was collected. Relative lower extremity joint angles were calculated for all trials that lasted at least 30 footfalls.

The time series from the unfiltered joint angles were analyzed using the Chaos Data Analyzer Professional software (Sprott & Rowlands, 1995) to calculate the largest Lyapunov Exponent (LyE) for each trial-condition. The LyE describes variability by quantifying the exponential separation in the trajectories of the joint angles with time in state space. As nearby points separate, they diverge and produce instability. To correctly calculate the LyE, it is necessary to first reconstruct the state space by estimating the embedding dimensions and the time lag. The embedded dimension is a measure of the number of dimensions needed to unfold a given attractor, while the time lag determines how many data points will be used in the analysis. These two parameters were calculated using custom software in MATLAB. The embedded dimension used for the study was 10 and the average time lag was 16.7. CON and PAD-PF means of LyE values were compared using independent t-tests. Paired t-tests were used to determine differences between PAD-PF and PAD-P conditions.

RESULTS AND DISCUSSION

PAD–PF patients had significantly larger LyE values as compared to CON (Table 1). Typical LyE values are around 0 for periodic data, 0.1 for chaotic data and close to 0.5 for random data (Stergiou et al., 2003). However, no differences were found between PAD-PF and PAD-P conditions. These findings collectively show that the gait pattern of PAD patients has altered variability that occurs even before the onset of pain. These changes could be one reason PAD patients have impaired balance and increased risk of falls (Gardner et al., 2001). Lack of differences between PAD-PF and PAD-P conditions may be explained by adaptation to the claudication which is now present at baseline pain free ambulation.

SUMMARY/CONCLUSIONS

PAD patients experience increased gait variability prior to the onset of claudication. The larger LyE values observed in the PAD patients indicate increased randomness in their gait patterns. These findings are similar to those found for the elderly population (Kurz and Stergiou, 2003). This increased variability observed at the ankle and the knee may result in greater uncertainty during walking and could be contributing factors to the higher prevalence of falls in PAD patients.

This study will be the basis for future work to investigate how variability in gait patterns of PAD patients is related with the increased rate of falling, evaluate more effectively different treatment methodologies, and design targeted interventions to improve walking in PAD patients.

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Table 1: Group means for the largest Lyapunov Exponent (mean ±SD). Significant differences (P < .05) between groups are marked with an asterisk (*).

LyE	Control	PAD pain	PAD pain free
Ankle	.091 ± .015	.096 ± .014	.105 ± .016*
Knee	.092 ± .014	.099 ± .019	.102 ± .011*
Hip	.101 ± .009	.100 ± .012	.100 ± .008