EMG AND KINEMATIC CHANGES WITH GAIT VELOCITIES: THE IMPORTANCE OF VARIABILITY

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SUMMARY
EMG and joint angles are common parameters used to assess abnormal gait. However, little is known about how the variability of these parameters changes with modulations in gait speeds. EMG of the lower limb muscles and 3-D motion capture data were recorded from 6 subjects during walking, running at a fixed speed (4 m/s) and running at their maximal speed (sprinting). Maximum EMG variability decreased with running and sprinting versus walking. Conversely, peak joint angle variability increased with velocity. Increased variability in joint angles with increased velocity has been theorized to be a beneficial mechanism to prevent overuse injuries due to the larger loads carried by running versus walking. Greater EMG deviations at slower speeds may be due to sub-maximal muscle function allowing for altered activation patterns to improve motion efficiency and decrease metabolic cost. Variability should be taken into account when diagnosing biomechanics that may lead to or have caused injury and be included in rehabilitation programs.

INTRODUCTION
Kinematic and EMG data have been used to predict causes of running injuries and to provide feedback in changing running technique to prevent injury [6,7,10]. Kinematic data has also been used in rehabilitation procedures in assisted, therapist or mechanical, retraining [2]. It is important to understand the natural variability in healthy gait before assessing pathological gait. It is not known how increasing gait speed alters the consistency of biomechanics.

When analyzing gait, the function of the triceps surae changes the least, compared to other leg muscle groups, when gait patterns are altered. This allows for comparisons among different gait tasks. While variability of EMG of the lower limb and joint angle has been studied during different gait velocities [3,4,8], the change in consistency with increasing speeds in a single testing session has not. Therefore, the purpose of this study was to evaluate the variation of maximal EMG signals of the lower limb and kinematics, using peak joint angles, during different speeds of gait in a single subject pool.

It has been proposed that the goal of the motor control system is to reduce metabolic load during movement tasks [9]. With several redundant muscles working at sub-maximal levels, alterations in activations can be used to maintain peak efficiency. Faster gait tasks with larger activations allow for fewer combinations of muscle contributions, therefore leading to less variability. Joint angle variability has been shown to prevent overuse injuries in higher contact force tasks [1]. Kinematic alterations during running and sprinting, which produce large contact forces and joint loads, would distribute the impact across a variety of tissue to avoid single point failure. We anticipate an increased variability in kinematics with an increase with gait speed and an increased EMG variability with a decrease in gait speed.

METHODS
Gait analysis was performed on 6 young adults, with an average age of 27 ± 6.7 years, during 5 trials of walking at their self selected speed, running at 4m/s and sprinting at their maximal speed over ground. Each subject signed an informed consent prior to testing. 3-D motion analysis sampling at 200Hz (Qualysis Motion Capture System, Gothenburg, Sweden) was used to collect joint angles and EMG was collected from the medial gastrocnemius (MG), lateral gastrocnemius (LG) and soleus (SL) using a MA-300 EMG System (Motion Lab Systems, Baton Rouge, LA) at 1000Hz. Bipolar silver/silver chloride EMG surface electrodes (Myotronics, inc., Kent, WA) were placed on each of the muscles. Data was processed using Visual 3D (C_Motion...
Inc., Bethesda, MD). EMG data was high pass filtered with a bidirectional Butterworth filter set at 30Hz, the D.C. offset component was removed and the data was rectified. A 4Hz low pass Butterworth filter was used to make a linear envelope of the EMG signals. Interclass correlation coefficients (ICC) were calculated from peak EMG of the liner envelope. ICC and standard error of measurement were calculated from the peak ankle and knee joint angle during the stance phase of gait. ICC values were used to identify variation due to the large magnitude differences between EMG signals across subjects.

It is important to note that peak knee flexion was chosen as a kinematic value for analysis, though no EMG signals of the major knee flexors or extensors were analyzed. This was done because ankle and knee angle are the two major angles that define motion in the sagittal plane. EMG signals from muscles of the lower limb were chosen based on their similar operation as plantar flexors between running and walking tasks.

RESULTS AND DISCUSSION

The ICC values of the EMG signals from the muscles were greater for the high velocity movements (ICC ranged from 0.68-0.93, 0.89-0.97 and 0.90-0.97, for the walk, run and sprint, respectively). Each of the EMG signals varied similarly between the sprint and run tasks (Figure 1). Walking produced less consistent EMG signals, especially those of the LG and SL. The differences in variation between activities may be explained by the amount of muscle activation necessary to produce each motion. While sprinting and running are activities which require close to the muscles’ maximum activation, walking can be accomplished with a combination of muscle activations to supply the same force and motion for each step. Previous studies show that EMG for running in the gastrocnemius has little variation (ICC=0.94[3]), but are more variable in walking (ICC=0.86[4]).

Contrary to the EMG data, variability of joint angles increased as gait velocity increased (Figure 1 and Table 1) by the decreasing ICC values, which were similar to those reported in the literature [4,5]. There is also a consistent increase of the standard error of measurement for the joint angles with increased gait velocity. Inclusion of kinematic variation is needed for gait retraining to prevent patients from being over constrained in their unnatural movements, which could lead to possible injury.

### Table 1. Mean angle and standard error of measurement for the knee and ankle angles during each task. Note that the standard error of measurement increases as velocity increases.

<table>
<thead>
<tr>
<th>Joint (Task)</th>
<th>Mean Angle</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle (Walking)</td>
<td>-55.1</td>
<td>0.7</td>
</tr>
<tr>
<td>Knee (Walking)</td>
<td>20.6</td>
<td>1.1</td>
</tr>
<tr>
<td>Ankle (Running)</td>
<td>-84.1</td>
<td>1.1</td>
</tr>
<tr>
<td>Knee (Running)</td>
<td>44.3</td>
<td>1.8</td>
</tr>
<tr>
<td>Ankle (Sprint)</td>
<td>-85.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Knee (Sprint)</td>
<td>45.0</td>
<td>2.5</td>
</tr>
</tbody>
</table>

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REFERENCES