GAIT VARIABILITY TO PREDICT MOTOR LEARNING OF A NOVEL MOTOR TASK

[1] Sophia Ulman, [2] Robin M. Queen, and [1] Divya Srinivasan

[1] Industrial and Systems Engineering, Virginia Tech, Blacksburg, VA, USA
[2] Kevin P. Granata Biomechanics Lab, Biomedical Engineering and Mechanics, Blacksburg, VA, USA
email: smu4@vt.edu

INTRODUCTION

Motor variability (MV) is a fundamental feature of movement that refers to the variation observed in the spatiotemporal dispersion of joint movements, inter-joint coordination patterns, and muscle activities, when an individual completes the same task numerous times. While variability is natural and inherent in any human movement, it was traditionally assumed to be undesirable, as it was thought to contribute to less accurate performance. However, basic motor control research has progressed in recent years, and now suggests that movement variability has important functional implications for the preservation of motor performance, both with respect to short-term adaptations of movement strategies and longer-term motor learning. Existing evidence of motor variability being predictive of motor learning has been reported during simple reaching tasks [1]. Whether this concept is generalizable to other kinds of movements such as gait is currently unknown.

The goal of this study was to assess whether motor variability in normal gait at a self-selected speed (baseline condition) was associated with motor learning in a young healthy population performing a novel motor task. The novel motor task involved clearing an obstacle course within a designated time while performing a dual task. We hypothesized that inter-individual differences in motor learning ability in the novel task would be explained by differences in baseline gait variability. As a secondary objective, we also aimed to determine which variability measures (stride characteristics. lower limb joint kinematics and inter-joint coordination as quantified by vector coding) were most discriminative of inter-individual differences in learning ability in our cohort of young healthy adults.

METHODS

Thirty-two participants (16 F, 16 M), aged 21.28 (SD 1.76) years, with no known history of musculoskeletal disorders or injuries were recruited. Each participant was asked to walk barefoot continuously at a comfortable, self-selected pace for six minutes in order to reliably capture baseline motor variability [2]. Gait kinematics were collected using a 10-camera motion capture system (Qualysis INC, Gothenburg, Sweden), and passive reflective markers placed at select anatomical landmarks on the pelvis and lower limbs. After baseline over-ground walking, each participant was asked to walk through an obstacle course barefoot while holding a bowl of colored water. In order to complete the course successfully, they needed to finish the course within a specified time constraint while not spilling the bowl of water. The course consisted of directional cones, an agility ladder, a low balance beam, and stepping stools to step over. "Performance" in the novel task was quantified by the number of trials taken by each participant to achieve success, i.e. obstacle course completion within the pre-set time.

Marker data were exported into Visual 3D (C-motion Inc., USA) for data processing. Spatiotemporal stride characteristics and hip, knee, and ankle joint angles in the sagittal and frontal planes, during the stance and swing phases of gait, were extracted for further analysis. Standard deviation of each joint angle trajectory was calculated as the root mean square of standard deviation obtained at each normalized time point across all trials, during the stance and swing phases (~35-40 strides). Inter-joint coordination was quantified through vector coding [3]: hip-knee and knee-ankle couples in the sagittal and frontal planes during stance and swing were computed, and the stride-to-stride SD of joint coupling angles were used to quantify coordination variability. Two stepwise linear regression models were estimated to assess the association between performance (response variable) and the following predictor variables:

1. Stride characteristics (mean and stride-to-stride SD);
2. Joint trajectory variability of hip, knee and ankle joints, and stride-to-stride SD of hip-knee and knee-ankle joint couples in the frontal and sagittal planes during stance and swing phases.

JMP (SAS Inst. Inc., USA) was used for all statistical analyses, and a type I error rate of 5% was considered to be acceptable for statistical significance in tests of each variable in the regression models.

RESULTS AND DISCUSSION

On average, the participants took 10.97 (range 2-21) trials to learn to clear the obstacle course. A model using only stride characteristics of baseline gait (top panel in table 1) to predict performance was not statistically significant. However, when joint kinematic variability measures were used as predictor variables (bottom panel of table 1), 95.6% of the variance in performance could be explained by the model. Thus, our results support the functional significance of joint kinematic variability in over-ground walking even for a homogenous group of young and healthy adults: inter-individual differences in the rate of learning a novel motor task was predicted by differences in kinematic variability between individuals. Specifically, individuals with the fastest learning rate exhibited increased variability in knee frontal and ankle sagittal joint angle trajectories during the stance phase, and increased knee-ankle coordination variability during the swing phase. Our results are also novel from the perspective of showing that swing phase joint kinematic variability is also meaningful to study in gait, as hip and knee joint variabilities as well as inter-joint coordination variabilities are predictive of performance.

CONCLUSIONS

Although the functional significance of motor variability has been demonstrated in various clinical populations and among older adults, ours is one of the first studies showing strong association between gait variability and short-term motor learning in a cohort of young and healthy individuals.

REFERENCES

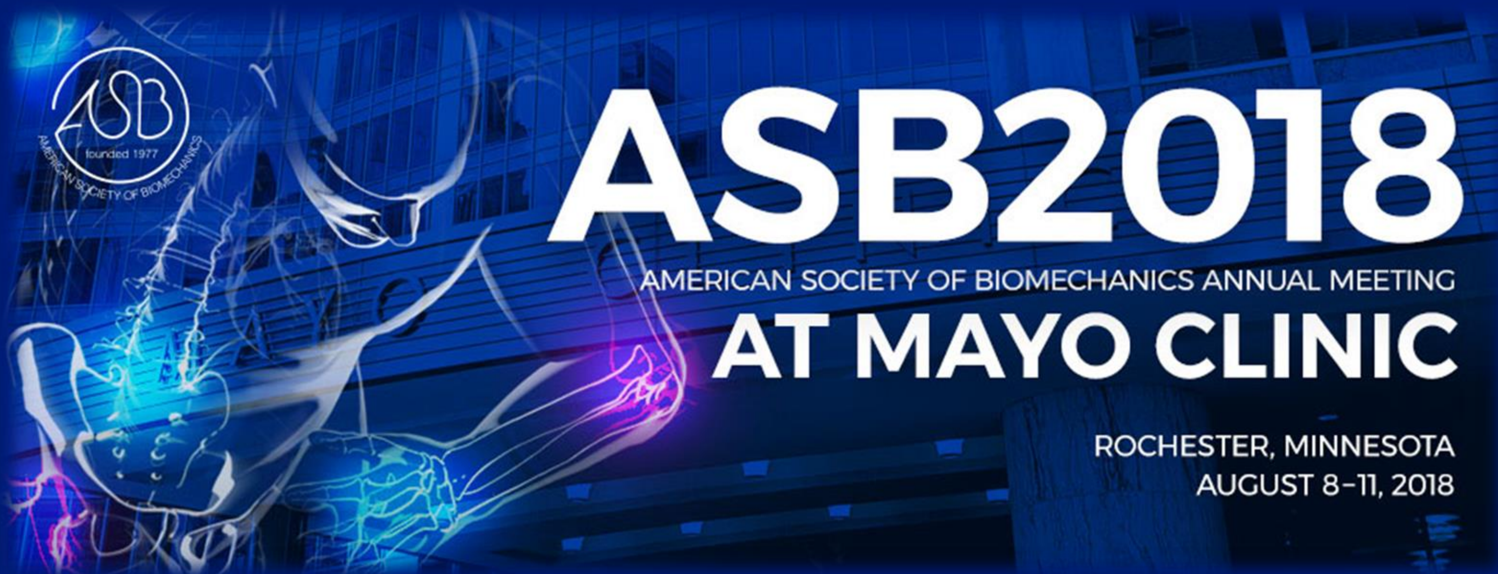
1. Wu et al. *Nature neuro.* **17**, 312, 2014.
2. Konig et al. *Gait & Posture.* **39**, 615-617, 2014.
3. Heiderscheit et al. *J. Appl. Biomech.* **18**, 2002.

ACKNOWLEDGEMENTS

We would like to acknowledge the contributions of Melanie Kangelaris and Willow Ruud for their assistance with data collection and processing.

Table 1: Association between variability measures and performance.

	Input Variables to models		**Model prediction**
Spatiotemporal gait characteristics model	Speed Swing time: mean and SD Stance time: mean and SD Step time: mean and SD Cycle Time: mean and SD	Step length: mean and SD Stride length: mean and SD Stride width: mean and SD	Model not significant
Joint kinematics variability model	Sagittal Hip Angle SD stance Frontal Hip Angle SD stance Sagittal Knee Angle SD stance **Frontal Knee Angle SD stance * (r = - 0.18)** **Sagittal Ankle Angle SD stance * (r = - 0.35)** Frontal Ankle Angle SD stance Sagittal Hip-Knee SD stance Frontal Hip-Knee SD stance Sagittal Knee-Ankle SD stance **Frontal Knee-Ankle SD stance * (r = 0.03)**	Sagittal Hip Angle SD swing **Frontal Hip Angle SD swing * (r = 0.28)** **Sagittal Knee Angle SD swing* (r = 0.22)** Frontal Knee Angle SD swing Sagittal Ankle Angle SD swing Frontal Ankle Angle SD swing **Sagittal Hip-Knee SD swing* (r = 0.02)** **Frontal Hip-Knee SD swing * (r = 0.1)** **Sagittal Knee-Ankle SD swing * (r = - 0.1)** **Frontal Knee-Ankle SD swing * (r = - 0.1)**	Model R^2 = 95.6%, $p < 0.001$


ASB
founded 1977
AMERICAN SOCIETY OF BIOMECHANICS
ASB2018
AMERICAN SOCIETY OF BIOMECHANICS ANNUAL MEETING
AT MAYO CLINIC
ROCHESTER, MINNESOTA
AUGUST 8–11, 2018

ABSTRACTS