MULTISCALE ENTROPY OF EMG DURING WALKING IN YOUNG AND OLDER ADULTS

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INTRODUCTION

Aging is associated with the accumulation of deficits in the function of the neuromuscular system, which may lead to motor deficits, gait instability, and falls. Aging has been hypothesized to manifest in lower complexity of physiological dynamics, evidenced by heart rate, step time, as described using fractal and other multiscale characteristics\(^1\). However, others in the biomechanics field have shown that older adults exhibit higher entropy values, rather than lower values, as a measure of complexity\(^2,3\). This discrepancy seems to arise because different studies have considered different timescales of behaviour. To resolve this inconsistency, we need to compare motor behaviour over a wide range of timescales. To observe the behaviour of the nervous system, we can consider the motor outputs in the form of EMG. Therefore, we tested whether the muscle activation patterns as measured by EMG are more complex in young adults compared to older adults and whether EMG complexity is affected by walking speed.

METHODS AND PROCEDURES

Eighteen healthy older adults (age 72±6) and 17 height- and weight-matched young adults (23±3), with no orthopedic or neurological conditions, participated with informed consent. Each walked for 5 minutes on a Woodway treadmill at 80%, 90% 100%, 110% and 120% of their preferred speed (PWS)\(^4\). EMG from the left gastrocnemius, were sampled at 1080Hz (Bagnoli-8, Delsys). After bandpass filtering (20-300 Hz), sample entropy of the signal was calculated after each successive coarse-graining (averaging then down-sampling) of the EMG signal\(^4,5\). Sample entropy values were integrated over 37 time scales, from timescale 4 to timescale 40, to calculate multiscale entropy, or MSE (Figure 1). These timescales represent dynamics of the EMG signal over ~4 to 40 ms. The effect of the age group and walking speed on MSE and on sample entropy values for timescales 4 to 40 inclusive were assessed using a randomized block design (SAS 9.2).

Figure 1. Schematic of Multiscale Entropy Calculations. The signal is coarse grained to isolate the dynamics at a particular timescale, where successive sets of points are averaged. Sample entropy of each coarse grained signal is calculated and combined to determine the multiscale entropy, or MSE.
RESULTS

The age main effect on MSE was significant (p<0.001). Older adults exhibited an MSE value of 9.86 ± 3.31 compared to 6.42 ± 1.37 in young adults. Walking speed did not influence MSE (p=0.93), and there was no interaction effect between age group and walking speed on MSE (p=0.66).

Results were similar when examining sample entropy values at each individual timescale (Figure 1). Age group differences were significant for all timescales except for scales 33 (p=0.14), 34 (p=0.77), and 35 (p=0.15).

DISCUSSION

Considering the larger MSE values in older adults alone, our results correspond with other studies in biomechanics but not with physiological studies. However, this is not the whole picture: over the timescales studied, older adults exhibit a sample entropy profile more similar to white noise (decaying over timescales) compared to that of young adults who exhibit a more flat profile (Figure 2). It is unclear if at larger timescales, older adults will continue to exhibit overall higher entropy values or lower ones (i.e., more similar to white noise). A possible future study would be to examine sample entropy values at higher timescales. Our results may be evidence of increased neuromuscular noise in older adults, which takes the characteristic of white noise. Future work could also determine whether muscle activation patterns via EMG signals for other muscles exhibit the type of behaviour described here.

REFERENCES


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Figure 2. Mean sample entropy values vs. timescale for both young and older adult age groups. The sample entropy profile of older adults is similar to that of white noise while young adults have a more flat profile. Error bars denote standard deviations within each timescale.