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Research article

Motor output oscillations with magnification of visual feedback in older adults

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HIGHLIGHTS

- Magnification of visual feedback increases EMG burst oscillations from 0.5 to 1.0 Hz in older adults.
- The amplified EMG burst oscillations from 0.5 to 1.0 Hz relate to the amplification of force oscillations below 0.5 Hz in older adults.
- Magnification of visual feedback impairs force control in older adults via the amplification of low-frequency oscillations in muscle activity and consequently force output.

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ABSTRACT

Magnification of task visual feedback increases force variability in older adults. Although the increased force variability with magnified visual feedback in older adults relates to the amplification of oscillations in force below 0.5 Hz, the related frequency modulation in muscle activity remains unknown. The purpose of this study, therefore, was to characterize the oscillations in muscle activity that contribute to the amplification of force variability with magnified visual feedback in older adults. Fifteen older adults (76.7 ± 6.4 years, 7 females) performed isometric contractions at 15% of maximal voluntary contraction (MVC) with ankle dorsiflexion with low-gain (0.05°) or high-gain visual feedback (1.2°). The standard deviation (SD) of force increased significantly (55%) from low- to high-gain visual feedback condition ($P < 0.0001$), without changing the mean force ($P > 0.5$). The increase in force variability was related to greater power in force oscillations from 0 to 0.5 Hz ($R^2 = 0.37$). The increase in force oscillations was associated with greater power in EMG burst oscillations from 0.5 to 1.0 Hz ($R^2 = 0.50$). In conclusion, these findings suggest that magnification of visual feedback alters the modulation of the motor neuron pool in older adults and exacerbates force variability by increasing the oscillations in force below 0.5 Hz.

1. Introduction

Magnification of task visual feedback exacerbates the age-related impairments in force control [2,4,11,13,23]. Recently, we have demonstrated that increased force variability with magnified visual feedback in older adults relates to their inability to modulate oscillations in force below 0.5 Hz [11]. Nonetheless, the frequency modulation in muscle activity that induces the amplification of oscillations in force below 0.5 Hz in older adults remains unknown. Here, we attempt to characterize the oscillations in whole muscle activity that contribute to the amplification of force variability with magnified visual feedback in older adults.

A consistent finding in the literature is that magnification of visual feedback increases force variability in older adults and exacerbates the age-associated differences in force control [1,11,13,23]. The first observation likely dates back to Sosnoff and Newell, where they demonstrated exacerbated force variability in older adults during finger abduction, when the gain of visual feedback increased [23]. Similarly, we found that force variability during abduction of the index finger [1,11,13] and ankle dorsiflexion [1] increases with magnification of the visual feedback in older adults, but not in young adults. Tracy et al. have demonstrated similar findings using elbow flexion and knee extension by comparing the force output with and without visual feedback [24]. Despite this con-

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sistent finding, the underlying mechanisms that contribute to the increase in force variability with magnification of visual feedback in older adults remain elusive.

Emerging evidence suggests that force variability during constant contractions largely relates to the rhythmical oscillations in force below 0.5 Hz [11,12,15,16]. One possible mechanism to exacerbate force variability with magnification of visual feedback in older adults, therefore, is the increase in the amplitude of force oscillations below 0.5 Hz. This is supported by current findings in our lab, where magnification of visual feedback resulted in greater force oscillations below 0.5 Hz in older adults with a parallel increase in force variability [11]. In young adults, there is evidence that oscillations in force below 0.5 Hz relate to the rhythmical bursting in the agonist muscle activity [16] or groups of motor units [10,22]. Older adults appear to exhibit an altered modulation of motor units [17,21] and an inability to modulate whole muscle activity with magnification of visual feedback [13]. Despite this evidence, the influence of magnified visual feedback to the neural activation of muscle of older adults remains unclear in the literature. In this study, we test the hypothesis that magnification of visual feedback alters the modulation of the motor neuron pool in older adults and exacerbates force variability by increasing the oscillations in force below 0.5 Hz.

2. Materials and methods

2.1. Participants

Fifteen older adults (76.7 ± 6.4 years, 7 females) volunteered for this study. All participants were healthy, moderately active, right-footed [8], and had normal or corrected vision. The Institutional Review Board at the University of Florida approved the procedures of this project and participants signed an informed consent.

2.2. Experimental protocol

We examined the ability of individuals to maintain force with left ankle dorsiflexion. Each experimental session lasted ~2 h. Each participant performed the following: 1) task familiarization; 2) MVC with ankle dorsiflexion; 3) ten dorsiflexion isometric contractions at low-gain visual feedback (0.05°) or high-gain visual feedback (1.2°) respectively (counterbalanced); 4) repetition of the MVC task.

2.3. Experimental arrangement

2.3.1. Experimental setup and apparatus

The participants were seated comfortably in an upright position and faced a 32-inch monitor (Samsung Sync Master™ 275t+) located 1.25 m away at eye level. The monitor displayed lines representing the target force and the force produced by the ankle dorsiflexion using a custom-written program in Matlab® (Math Works™ Inc., Natick, MA, USA). All participants affirmed that they could see the display clearly. The left hip joint of the participant was flexed to ~90° with 10° abduction, the knee was flexed to ~90°, and the ankle was in neutral position (0° of dorsiflexion). The left foot rested on a custom foot device with an adjustable footplate and was secured by straps over the metatarsals to ensure a secure position (Fig. 1B). This arrangement allowed only dorsiflexion of the ankle, which was produced primarily by the contraction of the tibialis anterior (TA) muscle.

2.3.2. Control of visual feedback

We altered the gain of visual feedback by manipulating the visual angle as we and others have done in the past [11,13,16,25]. We increased the visual angle from 0.05° to 1.2° to challenge visuomotor processing in older adults [11,13].

2.3.3. Force measurement

The dorsiflexion force of the left ankle joint was recorded with an one-dimensional force transducer (100 lb Miniature Beam Load Cell, Interface Inc., AZ, USA), which was installed on the front of the foot device. The force signal was low-pass filtered at 20 Hz, and sampled at 1 kHz with a Power 1401 A/D board (Cambridge Electronic Design, Cambridge, UK) and a NI-DAQ card (Model USB6251, National Instruments, Austin, TX, USA).

2.3.4. EMG measurement

The TA muscle activity was recorded with a surface EMG electrode (Bagnoli TM, Single Differential, Delsys, Boston, MA, USA) that was taped on the skin distally to the innervation zone and in line with the muscle fibers. The reference electrode was placed over the patella. The EMG signal was sampled at 1 kHz with a Power 1401 A/D board (Cambridge Electronic Design, UK). The EMG signal was amplified (×1000) and band-pass filtered at 20–450 Hz (Bagnoli-16 Main Amplifier Unit, Delsys, Boston, MA, USA).

2.3.5. MVC task

During the MVC task (Fig. 1B), participants increased their ankle force from baseline to the maximum and then maintained the maximal force for ~3 s. Participants completed MVC trials until two trials were within 5% of each other with one minute rest between trials.

2.3.6. Isometric force task

The goal of the task was to trace a target (Fig. 1A) with the force output of ankle dorsiflexion. The visual feedback displayed on the monitor was the participant's force (blue line) relative to the target (red line). We instructed participants to gradually increase their force to match the target force within 1.5 s and maintain their force on the target (15% MVC) as accurately and as consistently as possible for 20 s. The target force for both low-gain and high-gain visual feedback condition was identical. A custom-written program in Matlab® manipulated the targeted force level and gain of visual feedback. Participants performed 10 trials at each visual feedback gain (0.05° and 1.2°) respectively. The rest time between each trial was 1 min. The order was randomized (block randomization).

2.4. Data analysis

Data were analyzed off-line using a custom-written program in Matlab®. Both force and EMG data were analyzed over a segment of 18 s in the middle of 20 s.

2.4.1. Target force

The target force for each participant was normalized to 15% of his or her respective MVC value.

2.4.2. Force control

We quantified force variability with the SD of the detrended force signal. We performed a Fourier analysis on the force signal [5]. For statistical comparisons, the frequency data of the force signal were divided into four frequency bins (0–0.5, 0.5–1.0, 1.0–1.5, and 1.5–2.0 Hz). These frequency bins were based on the highest resolution (0.056 Hz) of the Fourier analysis that could be accomplished with 18 s of force data. The dependent variable for the spectral analysis of the force signal was the sum of power in each frequency bin.

2.4.3. Neural activation of the agonist muscle

We examined the Tibialis Anterior (TA) activation with the interference EMG and the EMG burst activity. The interference EMG