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Motor adaption during repeated motor control testing: Attenuated muscle activation without changes in response latencies

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ABSTRACT

With repeated exposure to postural perturbations the human postural control system can adapt and create efficient strategies to counteract these perturbations. The Motor Control Test (MCT) is commonly used to elicit reactionary postural movements. Though this device has been assessed for possible learning effects and reliability of composite scores, yet no study has evaluated possible neuromuscular alterations repeated bouts might elicit. Twenty participants (age: 25 ± 4.73 years; height: 183.8 ± 8.5 cm; mass: 85.2 ± 15.6 kg) volunteered and, following familiarization, performed five full-randomized MCTs over six testing sessions. The first five sessions occurred on consecutive days, with the sixth occurring two days later. Electromyography (EMG) was recorded on right lower extremity knee flexors and extensors, and ankle plantarflexors and dorsiflexors. Response latencies and Mean and RMS muscle activity were calculated and analyzed using 1 × 5 (within days) and 1 × 6 (across days) RM ANOVA. Decreases in muscle activation of proximal musculature were noted between days and trials within days, however these changes were not maintained after the two-day retention period. No differences were detected for MCT scores. These results suggest repeated MCT exposure modifies neuromuscular responses to maintain similar reaction time through a postural control strategy shift.

1. Introduction

The primary goal of upright postural control is to ensure that the center of mass (COM) stays within the base of support (BOS) through coordination of multiple muscle groups around the ankle, knee, and hip joints (Winter, 1995). If a disruption to postural equilibrium is met with an improper motor response, it can result in the translation of the COM outside of the BOS, increasing the risk for a fall (Winter, 1995). However, rapid adaptation of the neuromuscular system's reactive and anticipatory mechanisms to novel environmental perturbations decreases the possibility of this type of error (Horak and Nashner, 1986; Sousa et al., 2012a). The postural control system modifies neuromuscular responses and habituates with repeated exposure to surface perturbations (Welch and Ting, 2014; Pai and Bhatt, 2007). An early study by Horak and Nashner (1986) found that spatial and temporal characteristics of lower extremity and trunk musculature activation changed with repeated postural disruptions in backward and forward directions (Horak and Nashner, 1986). More recently, alterations to lower extremity kinematics and muscle activity have been shown with repeated horizontal translation exposure (Welch and Ting 2014; Schmid and Sozzi, 2016). Supraspinal mechanisms also change with repeated perturbation exposure. The fronto-central cortex has demonstrated decreased activation suggesting that over time, attentional demands decrease in response to perturbations (Hülsdünker et al., 2015; Sousa et al., 2012b).

One method of taxing the postural control loop is through sudden alterations of the supporting surface, and using deviations in reactive responses to identify pathological states and risks for future falls (Lockhart et al., 2005). A common test to examine these reactive mechanisms is computerized dynamic posturography's Motor Control Test (MCT) which attempts to access the latency and response strength of automatic neuromuscular responses to both forward and backward horizontal platform translations at three different magnitudes (Nashner, 1997), both expected and unexpected. This device derives a composite latency score of the time between perturbation onset and mechanical response of each leg.

The reliability of the MCT has been evaluated in healthy adults and in those with certain pathological states (Hale et al., 2009; Leitner et al., 2009). Hale and colleagues (2009) compared the MCT response latencies of young adults with intellectual disabilities to an age matched

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control. Over three non-consecutive testing sessions, the control group demonstrated no changes in their mean latency across testing sessions and across trials on the same day. Similar results were found in those with intellectual disabilities. The authors concluded that no learning effect was present on the results from the MCT and that a singular test was suitable for evaluation (Hale et al., 2009). Additionally, lower extremity muscle activation scales with an increase in the magnitude of the perturbations of the MCT (Chander et al., 2015). Previous studies have yet to evaluate neuromuscular factors, which demonstrate adaptations due to postural loop taxation, while performing repeated MCTs. The purpose of this study was to determine whether repeated MCTs elicit changes to neuromuscular responses in healthy young adults, and to identify the impact of these repeated bouts on sensory organization test (SOT) performance. We hypothesized that neuromuscular factors and response latencies would decrease with exposure to balance perturbations, and SOT performance after repeated bouts of MCTs would improve.

2. Methods

2.1. Participants

Twenty healthy adults (male = 10, female = 10 age: 25 ± 4.73 years; height: 183.8 ± 8.5 cm; mass: 85.2 ± 15.6 kg) participated. These participants had no history of cardiovascular, neurological, vestibular, or musculoskeletal disorders and were recreationally trained with 150 min of aerobic training 3–4 days/week and resistance exercises at least 2 days/week, for three months prior. This study was approved by the university's ethics board and all participants gave written informed consent. *A priori* sample size estimation based on previous work in our laboratory was calculated using G-power software (Dusseldorf, Germany) with a desired power of 0.8 with $\alpha = 0.05$.

2.2. Instrumentation

The NeuroCom® EquitestTM (NeuroCom International, Inc. Clackamas, Oregon) was used to assessed static balance measurements using the Sensory Organization Test (SOT) [(1) eye open (EO) on a stable platform, (2) eye closed (EC) on stable platform, (3) EO with visual manipulation on a stable platform (EOSRV), (4) EO on a moving platform (EOSRP), (5) EC on a moving platform (ECSRP), and (6) EO on a moving platform with visual manipulation (EOSRVP)] and response times were assessed using Motor Control Test (MCT) (backwards small [BWS], medium [BWM] and large [BWL], and forward small [FWS], medium [FWM], and large [FWL]). Muscle activity was measured using the Noraxon TelemyoTM T2400 G2 wireless EMG system (Scottsdale, Arizona) at 1500 Hz. The wireless sync between the NeuroComEquitest and the NoraxonTelemyo system was triggered using the Noraxon Compact Wireless Sync System (Scottsdale, Arizona).

2.3. Experimental procedures

The first visit included assessment of height, body mass, administrative paperwork, and a single practice Motor Control Test on the NeuroCom® Equitest at least 48 h ahead of the first testing session. For each session thereafter participants performed five fully randomized MCTs, totaling 30 perturbations per session and 180 overall (Welch and Ting, 2014). Six testing sessions occurred within the span of seven days. Five sessions occurred on consecutive days followed by a two-day retention period in which the participants were not tested. The sixth and final testing session occurred after this two-day period.

Bipolar electrodes with an inter-electrode distance of 2 cm were placed over the muscle bellies of the vastus medialis (Q), medial hamstring (H), tibialis anterior (TA) and medial gastrocnemius (G) with the ground placed over the tibial tuberosity. Participants were instructed to stand as still as possible and told of the specific visual sensory condition (EO, EC) throughout each of the SOT assessments. On completion of the SOT, participants were instructed to exit the NeuroCom® Equitest for a five-minute washout period. Participants again entered the NeuroCom® Equitest for the remaining MCT assessments. Participants were blinded to the magnitude and direction of perturbations. After completing the MCT, participants were instructed to exit the NeuroCom® Equitest for another five minutes. Four subsequent MCTs occurred with the same washout periods. On the following four testing days, participants performed the same protocol. After five consecutive days of testing, a two-day retention period with no MCT exposure occurred. Afterward, a sixth and final testing day occurred following the same experimental procedures.

2.4. Data processing

The motor control latencies derived from the NeuroCom® Equitest has an inverse relationship with balance performance with higher latencies implying slower reaction times to the platform perturbation. Latencies are quantified as the time between the platform translation and the participant's response. Sensory organization equilibrium scores with a greater value represent greater balance performance. Latency scores and equilibrium scores were exported from the NeuroCom® Equitest for analysis. Raw EMG data was band-pass filtered (20–250 Hz) and full-wave rectified prior to analysis. Mean and root-means squared muscle activity for each muscle group was calculated by averaging the three sub-trials within each balance perturbation.

2.5. Statistical analysis

Mean latencies, individual trial latencies, and mean muscle activity during MCTs were analyzed using a 1 × 6 [Condition × Day] repeated measures analysis of variance (ANOVA) and within session trial latencies were analyzed using 1 × 5 [Condition × Trial] repeated measures ANOVA. Equilibrium scores derived from the SOT were analyzed using a one-way repeated measures ANVOA. Initially, sex was included as a between subjects factor to examine sex differences in each analysis. If no sex differences were found the sample was collapsed across sex (n = 20). The assumption of sphericity was accessed in each analysis and, if violated, the Greenhouse-Geiser correction factor was utilized. If interactions were observed, simple effects were calculated using a Tukey LSD post hoc correction with SPSS version 23 (IBM® SPSS® Statistics V23.0, Armonk, New York 10504-172). Statistical significance was set a priori at an alpha level of 0.05.

3. Results

3.1. Sex differences

Initial analyzes for repeated measures ANOVAs for all variables revealed no significant differences between sexes ($p > 0.05$). Subsequent analyzes were performed on the entire sample collapsed across sex (n = 20).

3.2. Mean muscle activity

3.2.1. Between days

A significant main effect was detected for BWL Day-Trial 1 H ($F(1.864,14) = 4.150$, $p = 0.026$ $\eta^2 = 0.241$) and Day-Trial 1 Q ($F(1.576,14) = 4.692$, $p = 0.046$ $\eta^2 = 0.163$). Pairwise comparisons for BWL Day-Trial 1 H revealed Day 1 exhibiting significantly higher mean muscle activity than Day 2 ($p = 0.041$), Day 3 ($p = 0.025$), Day 4 ($p = 0.015$), and Day 5 ($p = 0.018$) but not Day 6 ($p = 0.179$). BWL Day-Trial 1 Q Day 1 exhibited significantly higher mean muscle activity than Day 2 ($p = 0.033$), Day 4 ($p = 0.033$), and Day 5 ($p = 0.04$) but not Day 3 ($p = 0.256$) or Day 6 ($p = 0.179$) These values are depicted