MUSCLE SYNERGIES DURING VOLUNTARY BODY SWAY: COMBINING ACROSS-TRIALS AND WITHIN-A-TRIAL ANALYSES

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INTRODUCTION

We investigated co-varied changes of muscle activity during voluntary sway tasks that required a quick shift of the center of pressure (COP). We hypothesized that multi-muscle synergies (defined as task-specific covariation of elemental variables) stabilize a COP location in the anterior-posterior direction prior to a voluntary COP shift and that during the shift the synergies would weaken.

The first purpose of the current study has been to develop and test a new method to identify M-modes (leg and trunk muscles organized into groups with parallel scaling of muscle activation level within a group) based on only a handful of trials during voluntary sway. This method combines across-trials and within-a-trial analyses.

The second purpose of the study has been to apply this method to analysis of muscle synergies associated with COP shifts during a quick targeted body sway. This action is common in everyday activities such as reaching for an object, avoiding being hit by an object or a person, leaning to pick up something from the floor, etc.

Our third purpose has been to compare time profiles of an index of a hypothetical multi-muscle postural synergy during voluntary sway performed under the self-paced and reaction-time instructions. We hypothesized that baseline values of a synergy index reflecting the difference between "good variability" and "bad variability" would weaker under the reaction time instruction than under the self-paced manner.

METHODS

Eight healthy subjects participated in the experiment. A force platform recorded the reactive forces and moments. Disposable self-adhesive electrodes (3M) were used to record the surface EMG of the following postural muscles from the right side of the body: lateral head of gastrocnemius, medial head of gastrocnemius, soleus, semi-tendinosus, biceps femoris, gluteus medius, erector spinae, tibialis anterior, vastus lateralis, rectus femoris, tensor fasciae latae, and rectus abdominis. Standing subjects performed two tasks, a cyclic COP shift over a range corresponding to 80% of the maximal amplitude of voluntary COP shift and a unidirectional quick COP shift over the same nominal amplitude. The cyclic sway task was used to define M-modes and the relations between small changes in the gains at M-modes and COP shifts.

A novel approach was used involving principal component analysis applied to indices of muscle integrated activity measured both within a trial and across trials. The unidirectional sway task was performed in a self-paced (SP) manner and under a typical simple reaction time (RT) instruction. M-modes were also defined along trials at those tasks. They are shown to be similar to

M-modes defined in the first task by analysis of angles between pairs of vectors in the muscle space. Integrated indices of muscle activity in the SP-Sway and RT-Sway tasks were transformed into the M-modes.

Variance in the M-mode space was partitioned into two components, one that did not affect the average value of COP shift (V_{UCM}) and the other that did (V_{ORT}). An index (ΔV) corresponding to the normalized difference between V_{UCM} and V_{ORT} was computed.

RESULTS AND DISCUSSION

We hypothesized that multi-muscle synergies stabilize a COP location in the anterior-posterior direction prior to a voluntary COP shift and that during the shift these synergies would weaken. Our experiments provided support for the hypotheses. In particular, we documented multi-muscle (more exactly, multi-M-mode) synergies stabilizing location of the center of pressure (COP) in the anterior-posterior direction in the steady-state phase of the tasks. Voluntary quick sway was shown to be associated with a drop in the magnitude of the synergy index (ΔV) close to zero, which may be interpreted as disappearance of the pre-existent synergy. There were differences between ΔV magnitudes prior to voluntary sway actions performed under the self-paced (SP) and simple reaction time (RT) instruction; these differences were significant prior to sway in the forward direction.

There is also an important methodological aspect to the study, namely the fact that for the first time, we used only a handful of trials to identify muscle modes. This is a potentially important development that may allow using this method for studies of subpopulations who cannot perform numerous trials involved in the earlier used methods.

CONCLUSIONS

We conclude that M-mode synergies stabilize COP location during quiet standing, while these synergies weaken or disappear during fast voluntary COP shifts. Under RT conditions, the COP stabilizing synergies were weaker supposedly to facilitate a quick COP shift without time for preparation. The suggested method of M-mode identification may potentially be applied to analysis of postural synergies in persons with impaired postural control such as elderly persons, persons with atypical development, or in the course of rehabilitation after an injury.

REFERENCES

Wang Y, Zatsiorsky VM, Latash ML (2005) Muscle synergies involved in shifting the center of pressure while making a first step. *Exp Brain Res,* 167: 196-210.

Wang Y**,** Zatsiorsky VM, Latash ML (2006) Muscle synergies involved in preparation to a step made under the self-paced and reaction-time instructions. *Clin Neurophysiol,* 117: 41-56.

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