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Contractile dynamics characterization in postural control during demanding postural tasks

Ana L. Albarracín[1], Fernando D. Farfán[1,2], Juan D. Romero-Ante[3], Juan S. Montenegro-Bravo[3] and Eduardo Fernandez-Jover[2,4]

[1]Neuroscience and Applied Technologies Laboratory (LINTEC - CONICET), Universidad Nacional de Tucumán, Tucuman, Argentina.[2]Institute of Bioengineering, Universidad Miguel Hernández of Elche, Spain.[3]Unidad de Investigación en Robótica Médica, Instituto de Bioingeniería, Universidad Miguel Hernández, Avenida de la Universidad, s/n, 03202, Elche, España. [4]Research Networking Center in Bioengineering, Biomaterials and Nanomedicine (CIBER-BBN), Madrid, Spain.

aalbarracin@herrera.unt.edu.ar

INTRODUCTION & AIM

Postural control represents the ability to maintain the body's position in space for stability and orientation. It is essential for everyday activities like standing, sitting, walking, and performing complex movements. Effective postural control relies on the integration of sensory information (from vision, the vestibular system, and proprioception) and the motor system's responses to maintain balance and coordination. With a reduced base of support, postural stability is likely more constrained than with a larger support area, representing the distinct role of individual muscles in maintaining balance under specific conditions. In this preliminary study, we investigated the muscle contraction strategies developed by healthy subjects to maintain stability in challenging postures. Intermuscular coherence are measures commonly used to investigate descending cortical oscillatory drive to a muscle or common oscillatory inputs to different muscles, representing the correlation between each muscle's electromyography (EMG) frequency components. We collected EMG signals bilaterally from lower and upper leg muscles and from one trunk muscle and used intermuscular coherence (IMC) and frequency contents approaches to characterize the muscles synchronization involved in postural control under visual feedback privation.

METHOD

Two healthy participants (one male, one female) were instructed to remain as stable as possible in four postural conditions to assess their stability: 1) standing with feet apart and eyes open, 2) standing with feet apart and eyes closed, 3) tandem stance with eyes open, and 4) tandem stance with eyes closed (Fig. 1).

Experimental design

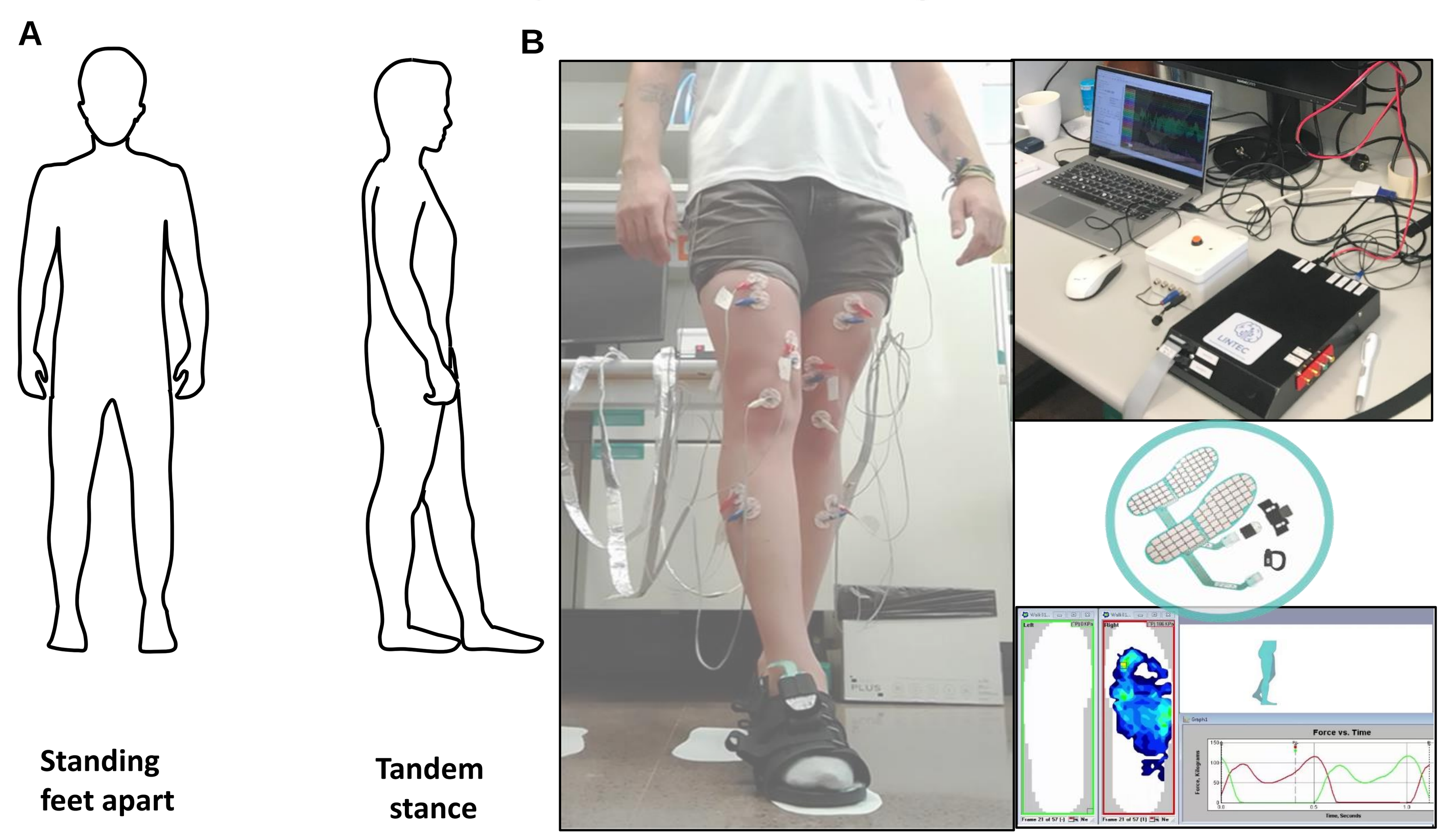
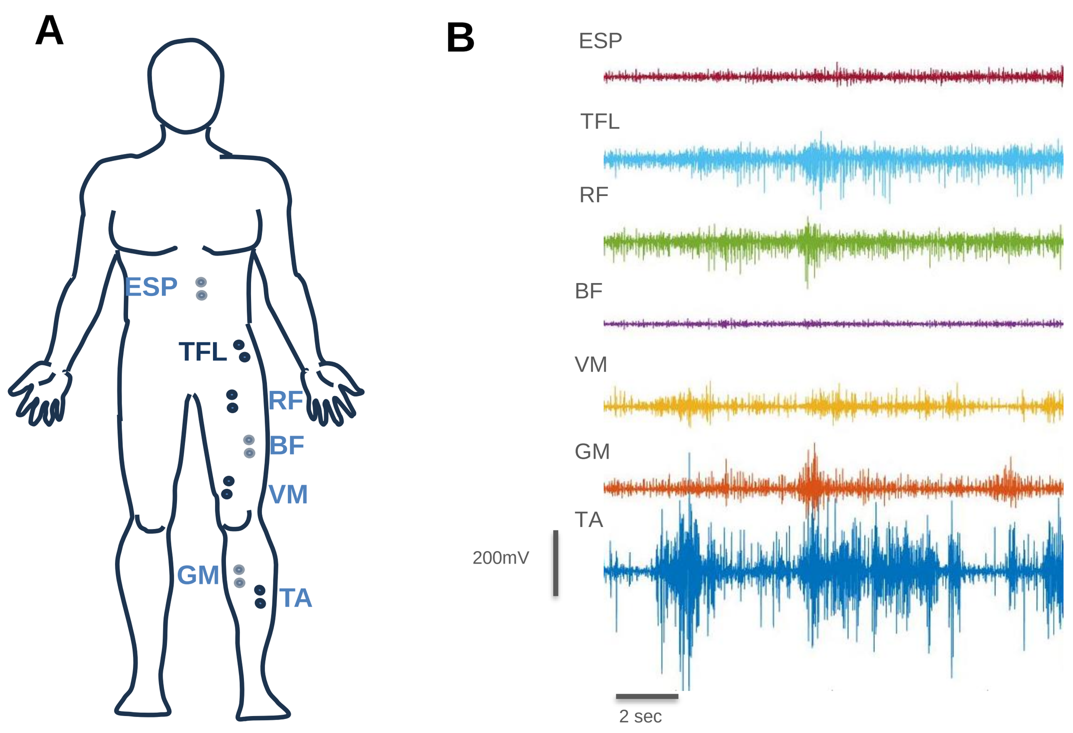


Fig.1. Experimental protocol. **A.** Postural conditions. In standing feet apart the base of support (BOS) is larger compared to tandem stance. The distance between the feet increases the BOS, making it easier to maintain balance. In a tandem stance, the feet are aligned in a straight line, reducing the width of the base of support causing loss of balance. **B.** Photographs and images of the equipment used for the experimental protocol

Signal processing



EMG recordings

Filtering of EMG data
10-100Hz bandstop
50 Hz notch filter

Data segmentation
10 repetitions for each postural condition

IMC analysis
(Networks)

Power Spectral Density
(PSD) estimation

Fig.2. EMG signals and electrode locations. **A.** Electrodes in bipolar configuration were situated over 7 muscles (both sides): tibialis anterior (TA), gastrocnemius medialis (GM), vastus medialis (VM), rectus femoris (RF), biceps femoris (BF), tensor fasciae latae (TFL) and Erector spinae muscle (ESP). Note that GM,BF and ESP are located on the back of the subjects. **B.** EMG signals obtained during tandem stance and eyes open (1,5 sec segments).

RESULTS & DISCUSSION

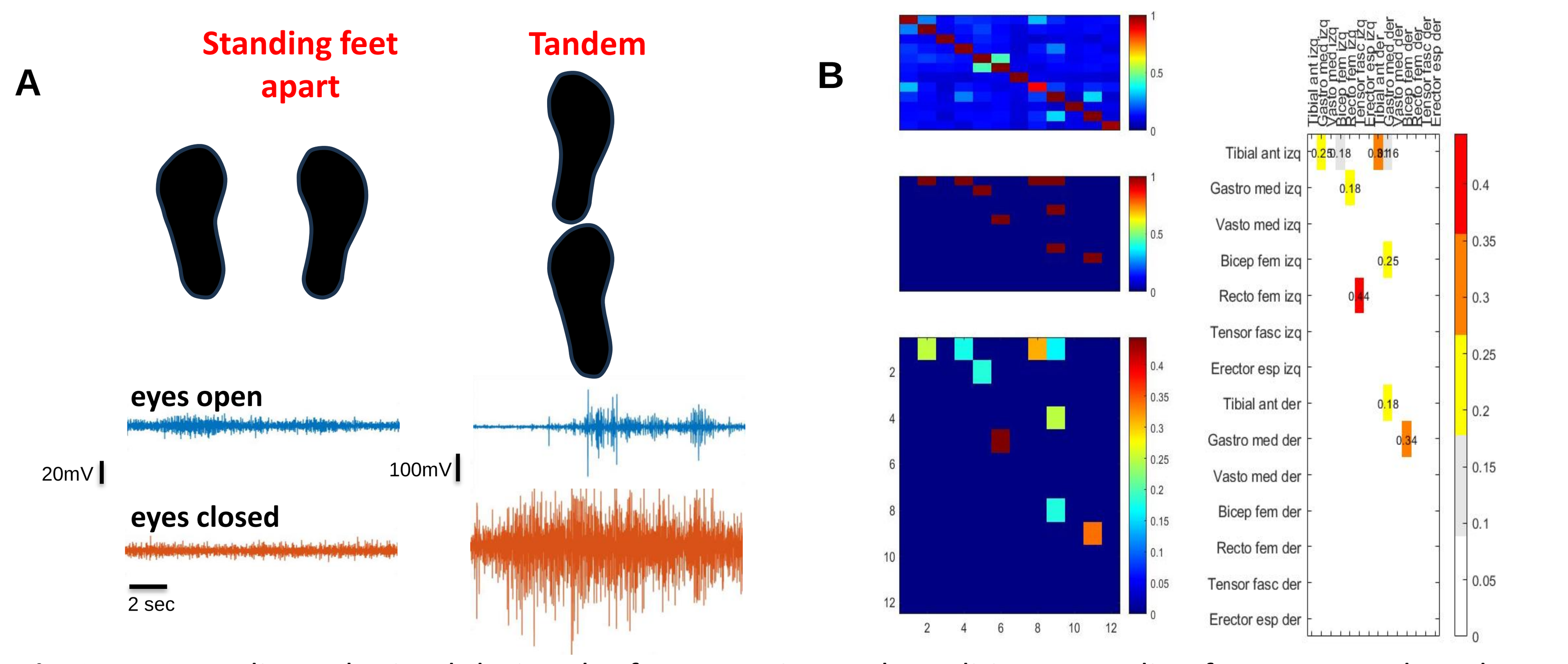


Fig. 3. A. Recordings obtained during the four experimental conditions: standing feet apart and tandem, with or without vision feedback. EMG amplitud is notably increased in tandem condition and still more with eyes closed. **B.** Connectivity matrix in beta band

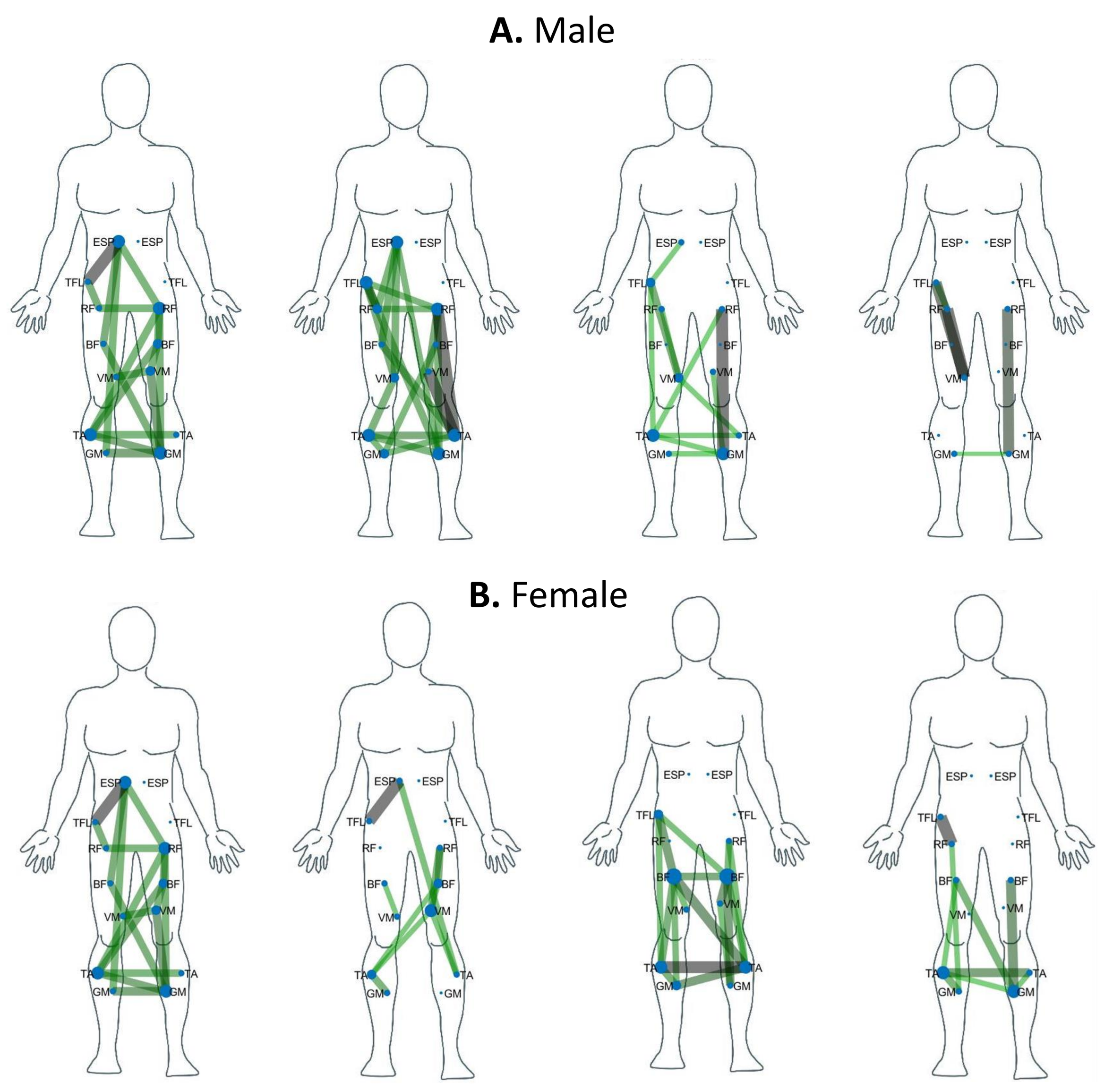


Fig. 4. IMC analysis in beta band. **A.** Networks generated during different conditions to stabilize the posture. From left to right: condition 1 (standing with feet apart and eyes open), condition 2 (standing with feet apart and eyes closed), condition 3 (tandem eyes closed), condition 4 (tandem with eyes closed. The connection between RF and GM muscles increases its strength when the eyes are closed in the standing posture and strengthens even more in the tandem posture. TFL and VM connectivity turns higher when the eyes are closed in tandem stance. **B.** Networks generated in female subject for the same postural protocol. The connection between BF and GM muscles notably increases during tandem stance and for eyes closed the connection between TFL and RF strengthens.

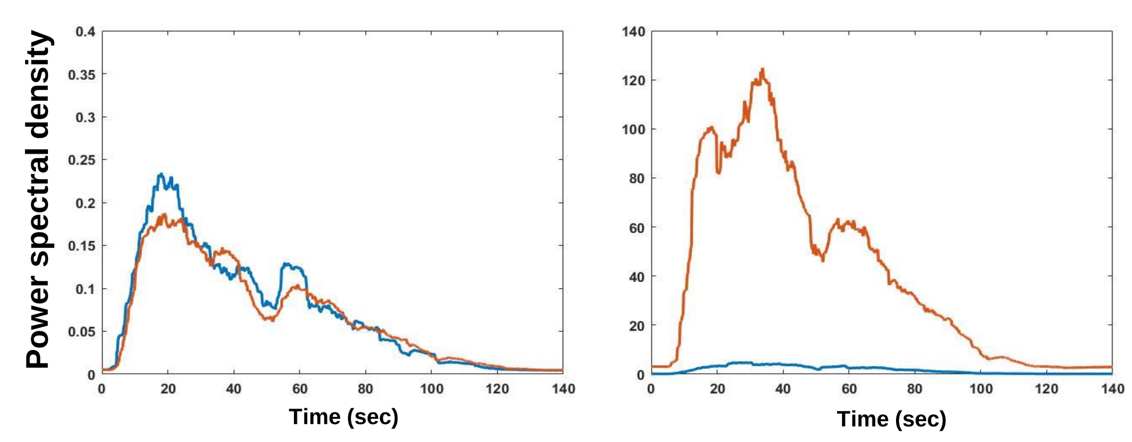


Fig.5. **Frequency analysis.** PSDs were estimated by using periodogram. *Left*: PSD corresponding to TFL for the standing condition with eyes open (blue) and with eyes closed (orange). *Right*: tandem condition with eyes open (blue) and with eyes closed (orange). The power of the signals were distributed between beta and gamma bands. However, there is a notably increase in power for tandem conditions.

CONCLUSION

This experimental approach allowed to characterize muscle dynamic contraction under different postural conditions with and without visual information. We have found that different strategies and specific muscles synchronization were required for controlling balance in high demanding postures. Amplification of muscle activity and coactivation of the lower leg muscles were observed during the most challenging posture and without visual information. In this study we describe characteristic oscillatory modulations and synergistic activations as motor strategies for maintaining the balance after a demanding postural condition. These results are discussed in relation to the possibility of accurately assess the efficiency of postural motor strategies.

FUTURE WORK / REFERENCES

This preliminary study provides results about the postural control strategies of two healthy subjects. In the future, a larger number of participants will be evaluated in order to confirm the trends observed in this work. Finally, inertial (IMU) and plantar sensors data will be included in the upcoming analysis in order to establish biomechanical metrics related to the temporal and frequential patterns determined using EMG recordings.