

How audio-biofeedback of trunk acceleration affects feed-forward and feed-back control of posture

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Introduction – The brain controls posture using feed-forward (FF) (open loop) and feed-back (FB) (closed loop) control. FF control is based on the movements that the brain predicts. FB control is determined by the response of the brain to sensory information. It is unknown how the brain combines FF and FB control to maintain balance. While maintaining balance in different sensory conditions that provide different amounts of available sensory information, the brain uses different degrees of FF and FB control. The effects of additional balance information provided by biofeedback systems have been widely studied, but the relative effect of biofeedback on FF and FB control is unknown. This study investigated how a portable, low-cost, audio-biofeedback (ABF) prototype (Chiari et al., 2004) affects the FF and FB control of posture in quiet stance. Our hypothesis was that ABF improves balance by increasing both FF and FB control.

Methods – Nine healthy subjects, wearing a sensory unit, stood on a force plate. The ABF prototype that we developed provided the subjects, via the earphones, with a sound encoding their trunk accelerations. The force plate was used as a cross-validation device to assess the effect of ABF on balance and on FF and FB control. Each subject wore earphones with ABF and performed 3, 1-minute trial in each of two conditions: with and without foam under the feet. Each subject wore earphones but without ABF and performed the same 1-minute trials in each of the same two conditions. The order of the 12 trials was randomized. During the trials the subjects were instructed to stand and to use the ABF information, when available, to stabilize their posture. Following Prieto et al. (1996), we extracted two parameters from the COP data: (1) the root mean square distance (RMS) and (2) the frequency comprising the 95% of the power (F95%). We also computed the parameters K and ΔTc from a stabilogram diffusion plot following Collins et al. (1993) and Chiari et al. (2000) to determine the amount of FF and FB control applied by the brain in order to maintain balance. ANOVA analysis was computed on RMS, F95%, K , and ΔTc for statistical significance.

Results and Discussion – RMS decreased with ABF ($p < 0.01$). The decrease of RMS indicates greater stability in sway (less sway) and, consequently improvement in balance with ABF. K and ΔTc decreased with ABF ($p < 0.01$), represented by a shortening of the short-term scaling region in the stabilogram diffusion plot. This shortening suggests that sway decreases as a consequence of an increase in FB control. F95% increased with ABF ($p < 0.01$). This result is consistent with our hypothesis that both FF and FB increase with ABF, since increasing F95% likely refers to increasing of postural corrections. Because training augments FF control, larger balance improvements involving more FF control may occur after subjects practice with ABF

References

- L. Chiari, M. Dozza, A. Cappello, F.B. Horak, V. Macellari, D. Giansanti, "An accelerometry-based system for balance improvement using audio-biofeedback", IEEE Trans Biomed Eng. 2004 (submitted)
- T.E. Prieto, J.B. Myklebust, R.G. Hoffmann, E.G. Lovett, B.M. Myklebust. "Measures of postural steadiness: differences between healthy young and elderly adults". IEEE Trans Biomed Eng. 1996 Sep;43(9):956-66.
- J.J. Collins, C. J. De Luca, "Open-loop and closed-loop control of posture: a random-walk analysis of center-of-pressure trajectories". Exp Brain Res. 1993; 95(2):308-18.
- L. Chiari, A. Cappello, D. Lenzi, U Della Croce, "An improved technique for the extraction of stochastic parameters from stabilograms". Gait Posture. 2000 Dec; 12(3):225-34.

