VIBRATION IMPAIRS PROPRIOCEPTION DURING ACTIVE CYCLICAL ANKLE MOVEMENTS

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INTRODUCTION

Accurate information about the mechanical state of the body is a vital element of functional motor control. The role of proprioception in human motor control has commonly been investigated using vibration. Essentially, tendon vibration causes many small stretches of the musculotendon complex, evoking a sense of larger length changes than are actually occurring [1]. However, recent findings in the upper extremity have demonstrated that vibration does not influence position sense when muscles are actively supporting or moving a load, as the body’s mechanical state may instead be derived from sense of effort [2].

In the lower extremity, functional tasks such as locomotion require active, cyclical movements. However, the effects of vibration at the ankle have primarily been investigated either when the joint is moved passively [3], or undergoes a simple, ballistic-like motion [4]. It is unclear whether vibration would influence motor control during more functional tasks, when sense of effort may also play a role.

The purpose of this study was to test whether altering proprioception with vibration would influence active, cyclical ankle movements. We hypothesized that vibration would cause subjects to overestimate the amplitude of ankle movements. We also hypothesized that vibration would be more effective during slower movements in which subjects had more time to respond to feedback. Finally, we hypothesized that the frequency of vibration would influence its effectiveness.

METHODS

Twelve young (24±1 yrs), healthy subjects performed a series of 30s ankle oscillation trials while lying prone. Ankle angle (plantar/dorsiflexion) was quantified using LED markers placed on the medial and lateral sides of the knee, ankle, and foot of each leg. Custom-built vibrators were strapped over the distal tendons of the right plantarflexors and dorsiflexors.

For all trials, subjects were instructed to match the motion of their left and right ankles, and given real-time visual feedback of their left ankle angle on a computer screen. Movement amplitude (5, 7.5, or 10°) was prescribed with a visual target, while movement period (1 or 3 s) was prescribed using a metronome. Each subject performed trials with no vibration and with 80-Hz vibration, the optimal frequency to activate muscle spindles [1]. Additionally, subgroups of subjects (n=4 per subgroup) performed trials with 40-Hz, 120-Hz, and 160-Hz vibration. Each trial condition was repeated 3 times in randomized order, for a total of 54 trials.

To quantify the ability of subjects to match bilateral ankle motion, we calculated the Amplitude Ratio for each movement condition. Amplitude Ratio was defined as the average amplitude of right ankle motion divided by the average amplitude of left ankle motion (Fig. 1). An Amplitude Ratio of 1.0 would indicate that both ankles moved through the same range of motion. We performed repeated measures ANOVAs to determine if movement condition significantly influenced Amplitude Ratio.

Figure 1. Typical ankle movement patterns (and measured amplitudes) are shown for a single subject for trials with no vibration (A) and 80-Hz vibration applied to the right ankle (B).
RESULTS AND DISCUSSION

Application of 80-Hz vibration clearly influenced motion of the vibrated ankle (Fig. 1). 80-Hz vibration had a significant main effect ($p<0.0001$) on the Amplitude Ratio (Fig. 2), as the right ankle moved through a smaller range of motion when vibration was applied. The Amplitude Ratio for each vibrated movement condition was significantly smaller than the Amplitude Ratio for all non-vibrated movement conditions. These results demonstrate that humans use proprioceptive feedback to scale their movements, even during active rhythmic tasks.

Characteristics of the movement pattern (prescribed amplitude and period) modulated the effect of 80-Hz vibration (Fig. 2). Across all non-vibrated movement conditions, the Amplitude Ratios were not significantly different, indicating that subjects were equally able to match their bilateral movements independent of amplitude and period. However, 80-Hz vibration had a larger effect during small amplitude movements (interaction $p=0.0003$). 80-Hz vibration also had a larger effect during long period movements (interaction $p<0.0001$). In both cases, disturbing proprioception had a larger effect for movement conditions in which velocities were lower, potentially allowing more time for feedback to play a role in controlling movement.

Vibration frequency influenced its effectiveness. In all subgroups, 80-Hz vibration significantly decreased the Amplitude Ratio ($p<0.0001$). 40-Hz vibration did not significantly affect Amplitude Ratio (Fig. 3A). In contrast, higher frequency vibration (120- and 160-Hz) decreased Amplitude Ratio significantly more than 80-Hz vibration (Fig. 3B-C). These results contradict our expectation that 80-Hz vibration would most effectively disturb proprioception, possibly because vibration amplitude scaled with vibration frequency.

CONCLUSIONS

Vibration influenced Amplitude Ratio, indicating that peripheral feedback contributes to motor control during active, cyclical ankle movements. However, this effect was weakened during faster motions, in which feed-forward commands may play a larger role. Additionally, controlling the vibration frequency influenced the magnitude of its effect. These results suggest that we may be able to use vibration to investigate the proposed role of proprioceptive feedback in the optimization of cyclical movements [5] or to improve lower extremity function in clinical populations [6].

REFERENCES