Wireless Vibrotactile Trainer for Balance Rehabilitation

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During balance rehabilitation, physical therapists typically provide verbal instruction and/or physically reposition a patient to demonstrate proper postural position and movements. We have developed a wireless device that enables an expert (such as a physical therapist) to map his/her movements to a trainee in a hands-free fashion. The trainee is subsequently able to mimic the motion of the expert by interpreting positional cues presented via vibrotactile feedback to the relevant body segments. This device will potentially enable a therapist to aid multiple patients simultaneously and/or remotely, or enable a trainee (such as an athlete or student) to replicate expert movements. The device comprises an Expert Module (EM) and Trainee Module (TM). Both the EM and TM are composed of six degree-of-freedom inertial measurement units, microcontrollers, and batteries. The TM also has an array of vibrating actuators that provides the user with vibrotactile biofeedback. The expert dons the EM, and his/her relevant body position is computed by an algorithm based on an extended Kalman filter that provides asymptotic state estimation. The captured body position information is transmitted wirelessly to the trainee, and directional instructions regarding the desired motion/position are displayed via vibrotactile feedback. The trainee is instructed to move in the direction of the vibration sensation until the vibration is eliminated. While prior work has demonstrated the use of vibrotactile stimulation for improved motor learning, this portable and wireless device is suitable for use outside of a laboratory environment. Five healthy young blindfolded subjects were instructed to mimic recorded expert anterior-posterior trunk tilt motion using the aforementioned device in a series of proof-of-concept studies designed to investigate the effects of changing the feedback activation threshold and varying the nature of the feedback. To characterize the efficacy of the system, we performed a cross correlation of expert and trainee trunk tilt angle while varying the threshold angle difference at which vibrotactile feedback was applied. Preliminary results showed that subjects performed best at 0.5 and 0.75 degree thresholds among those tested (0.5, 0.75, 1.0, 1.25, 1.5). The normalized mean cross correlations for the 0.5 and 0.75 threshold conditions were 0.96 and 0.97 respectively, while the mean differences between expert and trainee trunk tilt angles were 1.1 and 1.2 degrees respectively. Further studies at 0.5 and 0.75 threshold conditions confirmed that proportional plus derivative feedback of the angle difference resulted in superior performance compared to proportional or derivative feedback alone. Repetition of the task was not significant suggesting that trainees could immediately use the device to accurately replicate expert anterior-posterior trunk tilt movements.

Automated Noninvasive Clinical Dehydration Detection Device

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Dehydration is a common problem in healthy individuals as well as the elderly and chronically ill. People are often poorly attuned to hydration, and despite widespread awareness of the problem, fatal and near-fatal episodes occur frequently. Typical indicators of hydration status include changes in body weight, urine specific gravity, blood plasma levels, and bioelectrical impedance. Challenges to estimating hydration status from these indicators include the invasive nature of some methods as well as the cost and time required. We have developed a noninvasive device for monitoring hydration status. Our design is inspired by the traditional clinical protocol that approximates fluid loss on the order of 1-2% dehydration by assessing radial pulse before and after a supine to standing transition. The prototype comprises an inertial measurement unit (Xsens MTi) and a wearable heart rate monitor (Polar S810i). In order to compare heart rate behavior under normal and low hydration levels, fluid loss equivalent to 1-4% of the baseline body weight was induced by exercise in three healthy subjects during two data collection sessions. In the first (control) session, subjects replaced fluids every 15 minutes during exercise to maintain their body weight within 0.2% of their baseline value. Fluids were not replaced during the second (test) session, and subjects lost an average of 1.2% of their body weight. Heart rate and body position measurements were recorded before and after exercise while subjects performed repeated supine-to-standing movements and knee-to-chest stretching exercises (supine position only). All post-processing was performed using MATLAB (The MathWorks). Average heart rate was calculated over a 10 second period. Pilot data demonstrates the device's ability to detect hydration changes on the order of 1% in one-third the time required by the traditional clinical protocol (30 seconds compared to 90 seconds). The average rise time from baseline to maximum heart rate and the maximum heart rate following supine-to-standing transitions were significantly longer and greater, respectively, in the dehydrated subjects. Although not statistically significant, the average heart rate during knee-to-chest stretching exercises was elevated in the dehydrated state.

