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Clinical impact of gait training enhanced with visual kinematic biofeedback: Patients with Parkinson's disease and patients stable post stroke ☆

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ABSTRACT

As the world's population ages, falls, physical inactivity, decreased attention and impairments in balance and gait arise as a consequence of decreased sensation, weakness, trauma and degenerative disease. Progressive balance and gait training can facilitate postural righting, safe ambulation and community participation. This small randomized clinical trial evaluated if visual and kinematic feedback provided during supervised gait training would interfere or enhance mobility, endurance, balance, strength and flexibility in older individuals greater than one year post stroke (Gobbi et al., 2009) or Parkinson's disease (PD) (Gobbi et al., 2009). Twenty-four individuals consented to participate. The participants were stratified by diagnosis and randomly assigned to a *control* (usual gait training (Gobbi et al., 2009)) or an *experimental* group (usual gait training plus kinematic feedback (Gobbi et al., 2009)). At baseline and 6 weeks post training (18 h), subjects completed standardized tests (mobility, balance, strength, range of motion). Gains were described across all subjects, by treatment group and by diagnosis. Then they were compared for significance using nonparametric statistics. Twenty-three subjects completed the study with no adverse events. Across all subjects, by diagnosis (stroke and PD) and by training group (control and experimental), there were significant gains in mobility (gait speed, step length, endurance, and quality), balance (Berg Balance), range of motion and strength. There were no significant differences in the gain scores between the control and experimental groups. Subjects chronic post stroke made greater strength gains on the affected side than subjects with PD but otherwise there were no significant differences. In summary, during supervised gait training, dynamic visual kinematic feedback from wireless pressure and motion sensors had similar, positive effects as verbal, therapist feedback. A wireless kinematic feedback system could be used at home, to provide feedback and motivation for self correction of gait while simultaneously providing data to the therapist (at a distance).

1. Introduction

The world's population is aging. By 2030, nearly 20% of the world's population is projected to be over 65 years of age (World Population, 1950–2050). With aging, there are increased numbers of patients who not only become physically inactive, but are challenged with injurious falls, cardiovascular insults or neurodegenerative disease (Hafner 2014; Anon-a; Dorsey et al., 2007; Nussbaum and Ellis 2003; Go et al., 2014). Exercise is critical for healthy aging and maintaining independence, community participation and quality of life for individuals with neurological impairments (Ahlskog et al., 2011; Fletcher et al., 1996). Despite dopaminergic medications, older patients with Parkinson's disease (PD) commonly have difficulty maintaining community ambulation due to rigidity, bradykinesia, tremors, poor postural righting, decreased proprioception and freezing (Suchowersky et al., 2006; Allen et al., 2010; Hirsch and Farley 2009; Gobbi et al., 2009). Further, while an increasing number of people survive a stroke, 6 months post insult, hypertonia, weakness, sensorimotor impairments, pathological synergies and sometimes compromised attention or cognition can lead to difficulties with safe,

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independent transfers and ambulation (15–19%), together with limitations in daily activities and community participation (13–49%) (Jorgensen et al., 1995; Kwakkel et al., 1996; Lang et al., 2011; Veerbeek et al., 2014). Research supports the benefits of task-oriented and progressive gait training to improve mobility, balance, strength and flexibility post neurological impairment, but, unfortunately, the intervention strategies are not 100% effective (Kwakkel et al., 1996; Duncan et al., 2005; Winstein et al., 2014; Goodwin et al., 2008; Keus et al., 2008; King and Horak 2009).

When designing evidence based gait re-training, therapists integrate information from the history (e.g. family, psychosocial, medical, mental and physical), the clinical examination (e.g. posture, balance, biomechanics, sensory, motor, motor planning and ambulatory skills) and previous treatment to identify impairments and dysfunction. Then, together, the physician, the patient, the family and the therapist outline and prioritize short and long term training goals, which are integral to defining a plan of care (Umphred et al., 2013). The next step is to identify the tasks which must be practiced to achieve the desired outcomes (Winstein et al., 2014). This is followed by defining the intensity of supervised therapy needed and establishing a home exercise program to integrate and transfer skills into activities of daily living, recreation, social interactions and work (Lohse et al., 2014; Schaefer and Lang, 2012; Schaefer et al., 2013; Byl et al., 2008). Sometimes therapists also recommend assistive, robotic or computerized devices to improve stability, enhance somatosensory information, move a limb or provide feedback about accuracy, kinematics or efficiency of movement (Chang and Kim, 2013; Byl, 2012; Lo et al., 2010; Byl et al., 2013). These recommendations are matched to patient ability, interests, attention and concentration.

The precise biomechanical abnormalities in walking may not be accurately nor comprehensively assessed with visual analysis supplemented with standard measurements of endurance, gait speed, performance time, range of motion (ROM) and strength. Kinematic gait data on sequencing, velocity, symmetry, and ground reaction forces could facilitate improved mobility training through the enrichment of knowledge of both the therapist and the patient (Liu et al., 2012; Kong and Tomizuka 2009; Bae et al., 2013; Zhang et al., 2012; Zhang et al., 2014). The challenge is to determine if heightened, dynamic sensory feedback is disruptive or reinforcing for individuals with neurological impairments who are trying to improve gait efficiency (e.g. speed, quality, symmetry, stability, movement initiation). If visual kinematic feedback enriches verbal instructions from the therapist and the patient can integrate both verbal and visual information to correct gait impairments, then a wireless kinematic biofeedback system could be useful in the clinic with "one on one" supervision or possibly at home with remote data analysis and feedback.

The purpose of this study was to evaluate the effectiveness of "one on one" supervised gait training with and without visual, kinematic biofeedback to improve mobility, balance, strength and flexibility for patients with gait impairments post diagnosis of PD or chronic stroke. We hypothesized "one on one" progressive gait training with a therapist (18 h) would be associated with improved mobility, balance, strength and flexibility. We also hypothesized that the improvements would be similar for "one on one" progressive gait training and "one on one" gait training supplemented with kinematic biofeedback. We also proposed that patients one year post stroke would make similar gains in mobility, balance, strength, flexibility and endurance following gait training (with or without kinematic feedback) compared to adults one year post diagnosis of PD.

2. Material and methods

2.1. Subjects

Adults, males or females, 30–75 years of age, who had gait impairments one year or more post stroke or diagnosis of PD (without other significant health problems) were eligible for study participation. The subjects were independent in self-care, able to communicate in English (or come with an interpreter), able to follow instructions, interested in being more mobile and could rise from a chair and walk without personal assistance for a minimum of 100 feet. All of the subjects had participated in previous research at the University of California, San Francisco (UCSF) or had received physical therapy in the UCSF Faculty Practice or the UCSF PT Heath and Wellness Center. Twenty six subjects were contacted by phone, met the eligibility screen and were scheduled for consent, testing to confirm eligibility (independence, depression, cognition, severity of PD and stroke) and baseline testing. Mental alertness was assessed with the VA mental Status Test ($\geq 24/30$) (Tariq et al., 2006) and the Beck Depression Scale (Beck, 1996) was administered to rule out individuals with severe depression (< 12). To confirm independence at home, the Café 40- Functional Independence Scale (Fung et al., 1997) was administered ($\geq 50\%$). The severity of impairment post PD had to fall between I and III on the Hoehn and Yahr Scale (Goetz et al., 2004) and subjects post stroke had to obtain a minimum score of 10 on the lower extremity (Fugl-Meyer et al., 1975). One subject did not meet the eligibility criteria. A second subject met the eligibility requirements but could not commit the time to gait training therapy twice a week. Thus, 24 subjects proceeded to the baseline evaluation. The subjects were then coded by diagnosis and randomly assigned to a *control* (usual gait training) or an *experimental* group (usual gait training reinforced with kinematic visual feedback). This study was approved by the Committee on Human Research at UCSF.

2.2. Baseline and follow up evaluations

At baseline and following 12 training sessions, the subjects were administered standardized tests for mobility, balance, strength and ROM. The subjects were also asked to report the number of falls experienced the month before admitted and the month during training. Mobility (gait speed) was measured with the Timed 10-Meter Walk at fastest speed (Bohannon, 1997; Bohannon and Andrews, 2011; Anon-b), the Six Minute Walk (American Thoracic Society, 2002), the Dynamic Gait Index (Whitney et al., 2000), and the Tinetti Gait Assessment (Tinetti 1986). In order to comprehensively measure balance (Foreman et al., 2011) three different tests were administered: Timed Up and Go Test (TUG) (Podsiadlo and Richardson, 1991; Thrane et al., 2007), Five Times Sit to Stand (FTSTS) Test (Meretta et al., 2006; Bohannon, 2006) and the Berg Balance Scale (Steffen et al., 2002; Berg and Maki 1992; Berg et al., 1995; Berg et al., 1992). Strength was tested following the guidelines for manual muscle testing (Kendall et al., 2005) using the Microfet Dynamometer microFET2. The force generated for each muscle group (pounds) was summed to a total score of strength for each leg. Range of motion was measured with a goniometer following standard guidelines (Norkin and White, 1995), with the degrees of motion measured at each joint in the lower extremity summed to create a total flexibility score for each leg. The subjects with PD also completed a self-report questionnaire on freezing (Giladi et al., 2009). Both the subjects post stroke and those with PD completed self-report questionnaires on sleep (Chaudhuri et al., 2002), fatigue (Neuberger, 2003), resilience (Wagnild and Young, 1993), and pain (Visual Analog Scale-VAS) (Price et al. 1983).