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Bilateral movement training and stroke motor recovery progress: A structured review and meta-analysis

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ABSTRACT

The purpose was to conduct a structured review and meta-analysis to determine the cumulative effect of bilateral arm training on motor capabilities post stroke. Forty-eight stroke studies were selected from three databases with 25 comparisons qualifying for inclusion in our meta-analysis. We identified and coded four types of bilateral arm interventions with 366 stroke patients. A random effects model using the standardized mean difference technique determined a large and significant effect size (0.734; $SE = 0.125$), high fail-safe N (532), and medium variability in the studies ($I^2 = 63\%$). Moderator variable analysis on the type of bilateral training revealed two large and significant effects: (a) BATRAC (0.842; $SE = 0.155$) and (b) coupled bilateral and EMG-triggered neuromuscular stimulation (1.142; $SE = 0.176$). These novel findings provide strong evidence supporting bilateral arm training with the caveat that two coupled protocols, rhythmic alternating movements and active stimulation, are most effective.

1. Introduction

In a 1977 *Psychological Bulletin* article, Glencross advocated that researchers consider integrating central and peripheral processes in the control of skilled movements (Glencross, 1977). Through the years, the central versus peripheral debate subsided; however, integrating input from both sources continues. Moreover, the exact nature of control in skilled movements still drives many research agendas. In fact, many stroke motor recovery interventions integrate input from central and peripheral

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sources. Re-acquiring upper extremity movements necessary for activities of daily living such as buttoning a shirt or blouse, zipping a jacket, pouring a drink, and buttering bread or toast are essential for making progress toward motor recovery.

To perform any of these four everyday tasks requires coordinating movements on two arms and hands. Thus, a leading question for stroke patients concerns bilateral arm practice: Would bilateral arm training help alleviate some motor dysfunctions and improve motor capabilities? We know that bilateral movements takes advantage of the inherent dependencies between arms; spatial and temporal dependencies (Carson, 2005; Cincotta & Ziemann, 2008; Hallett, 2001a; Hummel et al., 2005; Lacroix et al., 2004; Rossini, Calautti, Pauri, & Baron, 2003). Further, symmetrical bilateral movements are known to activate similar neural distributed networks in both hemispheres. Specific activated areas include the supplementary motor area, sensorimotor cortex, cingulate motor cortex, lateral premotor cortex, superior parietal cortex, and cerebellum (Debaere, Wenderoth, Sunaert, Van Hecke, & Swinnen, 2004; Goldberg, 1985; Jancke et al., 2000; Nachev, Kennard, & Husain, 2008; Swinnen & Wenderoth, 2004).

In spite of the inherent neural interaction patterns in the two hemispheres when both arms simultaneously move in homologous actions, consistent effective bilateral movement training findings are lacking. A comprehensive review on stroke and bilateral arm training identified contradictory findings (Carson & Swinnen, 2002; Cauraugh & Summers, 2005). Moreover, recent individual stroke rehabilitation and bilateral arm treatment studies found support (Cauraugh, Coombes, Lodha, Naik, & Summers, 2009; Cauraugh, Kim, & Summers, 2008) and failed to find support on the efficacy of bilateral training (Tijs & Matyas, 2006). Further complicating the issue is an initial meta-analysis on stroke rehabilitation and bilateral movements that reported a relatively large effect size (Stewart, Cauraugh, & Summers, 2006). However, perhaps spurious findings were found given the minimal number of studies analyzed (11), and the failure to report (a) a forest plot of the effects, (b) a funnel plot involved in publication bias, or (c) the heterogeneity of individual effect sizes (I^2). These conflicting findings warrant a structured review and meta-analysis that includes new statistical techniques to determine the comprehensive effect of motor capabilities as a function of bilateral movement training. Thus, we will attempt to answer an enduring stroke rehabilitation question concerning progress toward recovery: Do bilateral movement training protocols improve motor capabilities in the upper extremities of stroke survivors?

This structured review and meta-analysis focused on studies that investigated contributions of bilateral arm training toward improving upper extremity movements post intervention. Granted, a few studies reported direct comparisons between bilateral and unilateral training, although a majority of the experiments were interested in establishing the efficacy of specific bilateral arm movement protocols versus control groups (i.e., with or without standard care). Thus, our intention was to determine the cumulative effect of bilateral arm movement training regardless of the comparison groups. Even though a considerable amount of evidence comes from unilateral training studies that followed constraint-induced movement therapy (CIMT) guidelines (e.g., EXCITE trial; (Wolf et al., 2006, 2008)), we were not concerned with directly comparing forced-use and bilateral arm training.

2. Methods

2.1. Study selection and inclusion/exclusion criteria

An exhaustive search of the literature was conducted using three databases: (a) ISI web of Knowledge, (b) PubMed Central, and (c) Cochrane Collaboration of systematic reviews. Ten primary key words/phrases guided our search: stroke, bilateral arm training, hemiplegia, hemiparesis, motor recovery/control/function, upper extremity/limb, neurorehabilitation, bimanual coordination, coupling, and recovery protocols. References from selected studies were carefully inspected to identify studies that were not retrieved in one of our database searches. The systematic searches of the databases were conducted by two authors (NL & SN), and they identified 48 potential research studies (Cauraugh & Kim, 2002, 2003a, 2003b, 2003c; Cauraugh, Kim, & Duley, 2005; Cauraugh et al., 2008, 2009; Chan, Tong, & Chung, 2009; Chang, Tung, Wu, Huang, & Su, 2007; Chang, Tung, Wu, & Su, 2006; Coupar, Van Wijck, Morris, Pollock, & Langhorne, 2007; Cunningham, Stoykov, & Walter, 2002; Desrosiers, Bourbonnais,