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Title: Dual-task training effects on motor and cognitive functional abilities in individuals with stroke: a systematic review

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Abstract

Objective: This systematic review aimed to examine the effects of dual-task balance and mobility training in people with stroke.

Methods: An extensive electronic databases literature search was conducted using MEDLINE, PubMed, EBSCO, The Cochrane Library, Web of Science, SCOPUS and Wiley Online Library. Randomized controlled studies that assessed the effects of dual-task training in stroke patients were included for the review (last search in December 2017). The methodological quality was evaluated using the Cochrane Collaboration recommendation, and level of evidence was determined according to the criteria described by the Oxford Centre for Evidence-Based Medicine.

Results: Thirteen articles involving 457 participants were included in this systematic review. All had substantial risk of bias and thus provided level IIb evidence only. Dual-task mobility training was found to induce more improvement in single-task walking function (standardized effect size=0.14-2.24), when compared with single-task mobility training. Its effect on dual-task walking function was not consistent. Cognitive-motor balance training was effective in improving single-task balance function (standardized effect size=0.27-1.82), but its effect on dual-task balance ability was not studied. The beneficial effect of dual-task training on cognitive function was provided by one study only and thus inconclusive.

Conclusions: There is some evidence that dual-task training can improve single-task walking and balance function in individuals with stroke. However, any firm recommendation cannot be made due to the weak methodology of the studies reviewed.

Word count: 226

Keywords: cerebral vascular accident; dual-task; dual-task training; systematic review

INTRODUCTION

The conventional approach to stroke rehabilitation has mainly focused on balance and gait training in single-task condition. In real-life situations, people not only need to maintain balance and mobility skills, but also the ability to perform other cognitive or motor tasks in conjunction with the balancing or walking task (i.e., dual-tasking).[1] Thus, the traditional training approaches may not adequately prepare the individuals for returning to community living after a stroke event occurs.

Over the past decade, there has been increasing research interest in dual-task balance and mobility training. This dual-task training requires the performance of two tasks simultaneously. Typically, the dual-task protocol consists of a primary motor task (e.g., a walking or balancing task) and secondary attention-demanding task (e.g., a motor or cognitive task). A number of studies have investigated the effectiveness of dual-task training in different populations including older adults[2,3] and individuals with Parkinson's disease[4] or Alzheimer disease.[5]

A systematic review by Wang et al. examined the effectiveness of dual-task training in stroke and concluded that dual-task training can effectively improve gait and balance function in stroke patients in the short term.[6] However, there are methodological concerns that pose threats to validity of their conclusion.

More trials on dual-task training in individuals with stroke have been published in recent years, and an update review on this topic with more vigorous methodology is required. Furthermore, it is known that the pattern and degree of dual-task interference may differ according to the type of cognitive task or motor task that is used.[7,8] Therefore, to thoroughly examine the effectiveness of dual-task training in stroke patients, the different training protocols and outcome measures that are adopted in each study should be carefully considered. Other issues including the recommended training mode (e.g., types of tasks, frequency, and duration) are yet to be addressed. To tackle these knowledge gaps, this systematic review was undertaken to examine the training effects of dual-task balance and mobility exercises on motor and cognitive functional abilities in individuals with stroke.

METHODS

An extensive electronic database search was conducted in the following databases: MEDLINE (1965‐December 2017), PubMed, EBSCO, The Cochrane Library, Web of Science, SCOPUS, and Wiley Online Library. The search period in each database was from its inception to December 2017. To identify other potential literature that was relevant to the topic, the reference list of each eligible article was also screened. Additionally, a forward search for all eligible articles was conducted using Web of Science to ensure that all the relevant articles were included in this review. The last search was done in December 2017. The search strategy for PubMed can be found in Appendix I. A similar strategy was adopted for the other databases.

The inclusion criteria were constructed according to the principle of PICOS (P: participants; I: intervention; C: comparison; O: outcomes; S: study design). The details of the inclusion criteria are explained as follows: (1) P: adults with stroke; (2) I: the experimental group received dual-task balance and/or mobility training (i.e., balance or mobility exercises that were performed in conjunction with a secondary attention-demanding task (i.e., cognitive or upper limb motor task), and a specific description of the training protocol was provided; (3) C: conventional single-task balance and/or mobility training, or no-intervention control; (4) O: the primary outcomes are mobility and balance performance in either the single-task or dual-task condition, while the secondary outcomes are those measurements that reflected the participants' cognitive function, and/or ability to perform, and/or participation level; and (5) S: randomized controlled trial.

The exclusion criteria were: 1) quasi-experimental studies, case series, and case reports; 2) participants with any neurological disease other than stroke; 3) conference abstracts, letters to the editor, theses, and reviews; and 4) the full text of the article was unavailable, despite making effort to contact the original authors.

Two independent researchers (HY, ZJ) screened the titles and abstracts of the searched articles first to determine their potential relevance. The researchers then further decided on the eligibility of the selected articles by reviewing the full text. Agreement made by two researchers on whether or not the article should be included was evaluated by the Kappa test. Disagreement was resolved by discussing the article with a third researcher (YL).

The risk of bias of each article was evaluated by the Cochrane Collaboration recommendation (Cochrane Handbook, version 5.1.0).[9] Two independent reviewers (HY, ZJ) assessed the risk of bias of each study. Disagreement was resolved by another discussion with the third reviewer (YL). The level of evidence of each article was determined according to the criteria described by the Oxford Centre for Evidence-Based Medicine (updated March 2009).[10]

After reading the full text, the researchers extracted data on: demographics, inclusion and exclusion criteria, training protocol, and measured outcomes of the study. Since many outcome measures were used to evaluate gait and balance performance, the gait parameters were classified into five different domains, namely: pace (e.g., speed, and time taken to complete the Timed Up and Go test), rhythm (e.g., cadence, swing percentage, and stride time), postural control (e.g., stride width), asymmetry (e.g., step length asymmetry), and variability (e.g., standard deviation of stride length and standard deviation of stride time),[11] in order to provide a more organized summary of the results and facilitate comparisons across different studies. Although some studies used Timed Up and Go test as an outcome indicator of dynamic balance, we used this test as an outcome measure of walking ability in this review. The balance-related outcomes were also classified into two categories, namely: laboratory measures (e.g., force plate) and clinical measures (e.g., the Berg Balance Scale, Dynamic Gait Index, and Functional Reach Test).[12] The standardized effect size of each outcome was calculated based on the data reported in the selected articles (Cohen's d: 0.2=small, 0.5=medium, 0.8=large).[13] Meta-analysis was not performed, due to the different outcomes and the large degree of heterogeneity of the selected studies.

RESULTS

Thirteen articles (13 studies) were identified as eligible after screening the 1,737 articles that were generated with the above search strategies. The inter-rater agreement for article selection was excellent (Kappa=0.82). The process of article selection is outlined in Figure 1.

The methodological quality of the selected articles is shown in Table 1. All studies had a high risk of bias. The evidence provided in all the reviewed studies was level IIb only (i.e., poor-quality randomized controlled studies).

The characteristics of the study participants are outlined in Table 2. A total of 457 participants were studied. Twelve studies[14-21,23-26] involved individuals with chronic stroke (onset more than 6 months) in their samples, whereas only one study recruited participants at the sub-acute stage (onset less than 6 months).[22] All participants could walk independently at least 10 meters, follow 3-step command, and without apparent aphasia. The differences in training protocol in studies were considerable (Table 2). The training duration, frequency of training, and study period respectively ranged from 15 to 60 min, 3 to 5 times per week, and 4 to 8 weeks.

The type of tasks that were used in the gait/balance dual-task training regimen also varied dramatically. There basically were four different combinations of dual tasks, including primary walking or balance tasks that were performed in conjunction with a secondary cognitive or motor task (walking + motor: four studies;[14-17] walking + cognitive: two studies;[17,18] balance + motor: three studies;[19-21] balance + cognitive: two studies[22,23]). In one of these studies (Liu et al),[17] there were three intervention arms (motor + motor, motor + cognitive, and single-task), the outcomes were compared between each of the dual-task training groups and single-task training group respectively.[17] Another three studies applied more than one of the types of dual-task mentioned above, integrating into their training programs.[24-26] The most commonly used secondary motor task and cognitive task were holding a glass of water or ball, and counting backward respectively. Details of the training protocols are shown in Table 2.

All studies compared the outcomes of the dual-task training group with those of the single-task training group (Table 3, 4, and 5),[14,15,17-26] with the exception of Yang et al., which compared the training group with a no-intervention control group (Table 3).[16]

Three studies compared the effects of walking-motor dual-task training with single-task walking training (Table 3).[14,15,17] The training effect on single-task pace (gait speed) and postural control (stride length and step length on both affected and unaffected sides) in the dual-task group were significantly better than that in the single-task group, with small to large effect sizes.[14,15] However, the training effect on rhythm (cadence, step time, cycle time, and single limb support period) under the single-task condition was not consistent.[14,15,17]. Yang et al. found that dual-task training resulted in significant improvements in pace (gait speed), rhythm (cadence, stride time), and postural control (stride length) in both the single-task and dual-task conditions, compared with no intervention controls, with large effect sizes.[16]

Two studies evaluated the effect of walking-cognitive dual-task training (Table 3).[17,18] Dual-task training resulted in greater improvements in Dynamic Gait Index[18] and cadence[17] in single-task condition than single-task walking training, with medium effect sizes. Other outcomes, such as the figure-of-8 walk test (single-task condition)[18], walking speed (single-task and dual-task conditions)[17,18] and the Timed Up and Go test[18] (single-task and dual-task conditions) showed no significant between-group difference.

Balance-motor dual-task training was evaluated in three studies (Table 4).[19-21] All balance performances were assessed in single-task condition. Overall, both the laboratory-based and clinical balance outcomes showed significantly better improvement after dual-task training compared with single-task balance training, with small to large effect sizes. The only exception was the sway path score[19], which showed no significant difference between groups.

Balance-cognitive dual-task training was assessed in two studies (Table 4).[22,23] The superiority of dual-task training in improving the anteroposterior and mediolateral sway distance with eyes open[23], mediolateral sway distance with eyes closed[23], and the weight distribution index-pressure with eyes open[22] under the single-task condition was demonstrated, with medium to large effect sizes. The degree of improvement in other balance measures did not show any significant between-group differences.[22,23]

The training effects on cognitive function (Stroop Test, Attention Test, Trail Making Test-A, Mini-Mental State Examination)[18,22], motor impairment (Trunk Impairment Scale, Fugl-Meyer lower extremity score),[20,22] and disability level (Modified Barthel Index)[22] (all measured in the single-task condition) were investigated in three studies (Table 5),[18,20,22] and only the Stroop test (medium effect size) and the Trunk Impairment Scale (large effect size) showed significant results.[18,20]

Three studies incorporated more complex dual-task conditions (including both balancing and walking as primary tasks, or both cognitive and motor tasks as secondary tasks) into their training protocols.[24-26] For the single-task gait measures, the improvement in gait speed[24,26], Timed Up and Go test[25], step length,[25] cadence,[26] Functional Gait Assessment scores [25] were all significantly greater than that in the single-task training group (Table 3). The dual-task training group also improved more in single-task balance function (Table 4), including the Five Times Sit to Stand Test,[25] Berg Balance Scale,[25,26] Functional Reach Test [24], anteroposterior and mediolateral sway velocity with eyes closed,[24] and mediolateral sway velocity with eyes open.[24] However, the degree of improvement in the anterposterior sway velocity with eyes open protocol[24] was similar between the two groups (Table 4).

Discussion

Almost all the trials identified were of low quality with a high risk of bias, which limits any firm conclusions that can be drawn. Despite the different training protocols adopted, dual-task training program could significantly improve most gait parameters [14-18,24-26] and balance function under single-task conditions.[19-26] There was no evidence, however, to suggest that dual-task training was superior to single-task training in improving gait parameters under dual-task condition.[17,18] The beneficial effects of dual-task training on single-task cognitive function[18] and other outcomes[20,22] were evaluated by one study only and thus inconclusive.

The results of our systematic review are in agreement in those of a previous review by Wang et al.[6] in showing that dual-task exercise training was more effective in improving pace (gait speed), rhythm (cadence), and postural control (stride length) in individuals with stroke. In terms of balance function, both reviews showed superiority of dual-task exercise training in improving the centre of pressure sway area and Berg balance score, but not in improving the centre of pressure sway distance. However, there are also some differences in findings. Our results demonstrated the superiority of dual-task exercise in improving step length under single-task condition,[15,26] while Wang et al. reported no significant results on this outcome. The discrepancies of findings may be due to several reasons. First, whether the step length was measured on the affected side or unaffected side was not specified in Wang et al.[6] Besides, the three studies that were included in their meta-analysis did not fulfill our selection criteria. In their metaanalyses, Wang et al. did not delineate the studies that compared between dual-task training and single-task training from those that compared between dual-task training and no intervention controls.[6] In contrast, we did not perform any meta-analysis due to the heterogeneity of the studies reviewed. We also made separate comparisons on our analysis, depending on the nature of the comparison group (Table 3).

Although studies that used motor + motor training protocol were included in both reviews, the number of these studies was more in ours (total of seven; walking + motor: four,[14-17] balance + motor: three[19-21]) than Wang et al.[6] (one study; walking + motor[16]). These seven studies included in our review actually provided quite consistent evidence that motor-motor dual-task training can improve single-task gait and balance function better than single-task training (Table 3 and 4). If only the motor-cognitive training studies were considered, the overall evidence on these effects would be substantially weaker.

The training effect of dual-task exercise program has also been examined in other patient populations. It was demonstrated by a systematic review that people with Parkinson's disease could improve their gait speed, stride time, Berg balance scale scores after receiving dual-task training. However, whether the gait parameters were measured under single- or dual-task condition was not specified in their review.[27] The strength of evidence was also limited by the quality of studies included. Another systematic review also examined the training effect of dual-task exercise program in various neurological disorders, including brain injury, Parkinson disease, and

Alzheimer disease.[28] In their review that included 14 studies, it was found that dual-task exercise training can improve gait speed and stride length in both single-task and dual-task conditions for people with Parkinson disease and Alzheimer disease, and gait speed and stride length in dual-task condition for people with brain injury. There was also evidence of a modest impact of dual-task exercise training on balance and cognitive function in people with Parkinson disease and Alzheimer disease.[28] However, the majority of the studies reviewed used a no-intervention control group. Taken together, available research on individuals with neurological conditions seems to provide evidence only for the benefit of dual-task training in improving single-task and dual-task mobility and balance when compared with no-intervention controls. This is mostly in line with the study by Yang et al.[16] in our review, which showed benefits of dual-task training on single-task and dual-task mobility function. Also similar to our findings in stroke, whether dual-task training is superior to other forms of intervention remains understudied.

The methodological quality of the studies included in this review was not good. Three of the 13 studies were blinded to the participants[17,22,23] Concealed allocation was only implemented in three studies.[16,23,24] The sample size of most of the studies was small. Particularly, four studies[17,18,22,25] involved less than 20 participants, which lowered the representativeness of the study and reduced the reliability of detecting significant differences between groups in treatment outcomes. Only three studies[16-18] assessed dual-task performance. The long-term follow-up assessment results were reported in only one study[18]

Our systematic review has some limitations. Some potentially relevant studies may have been missed because articles not published in English. In addition, due to the different training protocols and outcome measures used, meta-analysis could not be performed.

More well designed, randomized trials with larger sample sizes are needed to compare the efficacy of dual-task programs in individuals with stroke. Standardized measurements of single-task and dual-task balance, mobility, and cognitive function should be incorporated as outcomes[29-31], in addition to daily living skills. More effort should also be made to compare the effects of different protocols. How long the therapeutic effects (if any) can be sustained should also be investigated. Further research should also explore the determinants of successful treatment outcomes (e.g., age or disability level).

Conclusion

Although there is some evidence from individual studies that use of dual-task exercise training can improve single-task balance and walking function better than single-task training, the poor quality of the studies should hamper any conclusions drawn from the research.

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