ORIGINAL ARTICLE

Cognitive motor interference for gait and balance in stroke: a systematic review and meta-analysis

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Background and purpose: An increasing interest in the potential benefits of cognitive motor interference (CMI) for stroke has recently been observed, but the efficacy of CMI for gait and balance is controversial. A systematic review and meta-analysis of randomized controlled trials was performed to estimate the effect of CMI on gait and balance in patients with stroke.

Methods: Articles in Medline, EMBASE, the Cochrane Library, Web of Science, CINAHL, PEDro and the China Biology Medicine disc were searched from 1970 to July 2014. Only randomized controlled trials examining the effects of CMI for patients with stroke were included, and no language restrictions were applied. Main outcome measures included gait and balance function.

Results: A total of 15 studies composed of 395 participants met the inclusion criteria, and 13 studies of 363 participants were used as data sources for the meta-analysis. Pooling revealed that CMI was superior to the control group for gait speed [mean difference (MD) 0.19 m/s, 95% confidence interval (CI) (0.06, 0.31), $P = 0.003$], stride length [MD 12.53 cm, 95% CI (4.07, 20.99), $P = 0.004$], cadence [MD 10.44 steps/min, 95% CI (4.17, 16.71), $P = 0.001$], centre of pressure sway area [MD −1.05, 95% CI (−1.85, −0.26), $P = 0.01$] and Berg balance scale [MD 2.87, 95% CI (0.54, 5.21), $P = 0.02$] in the short term.

Conclusion: Cognitive motor interference is effective for improving gait and balance function for stroke in the short term. However, only little evidence supports assumptions regarding CMI's long-term benefits.

Introduction

Recently, cognitive motor interference (CMI) has become more and more popular for improving gait and balance function in the area of sports and rehabilitation medicine [1,2]. CMI occurs when cognitive and motor tasks are performed simultaneously, such as walking whilst performing other cognitive tasks [3]. Most elderly people are more likely to fall when performing cognitive motor tasks in most daily activities [4]. Therefore, exercise for the performance of cognitive motor tasks can simultaneously provide additional benefit on balance function compared with a single-task exercise (cognitive exercise or motor exercise) [5]. Some papers [6,7] have shown that CMI may be more effective for improving balance in stroke than a single-task exercise, but the effect of CMI remains controversial.

There are two systematic reviews [5,8] about CMI. The primary purpose of a systematic review [5] is to assess cognitive interference on gait performance during normal walking as measured by CMI

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methodology. Another systematic review [8] that included 28 papers concluded that the effectiveness of CMI in improving physical functioning in older adults is limited. To date, however, no systematic review and meta-analysis has examined CMI for gait and balance function in patients with stroke.

At present, no data have proved the effectiveness of CMI for improving gait and balance in contrast to cognitive exercise, motor exercise or no intervention in patients with stroke. Therefore a systematic review and meta-analysis was conducted to determine the effect of CMI on gait and balance in stroke.

Methods

Search strategy

Relevant papers were searched in the following data sources (1970 to July 2014): Medline, the Cochrane Library, EMBASE, CINAHL, Web of Science, Physiotherapy Evidence Database scale (PEDro) and China Biology Medicine disc. The search was limited to randomized controlled trials (RCTs) but had no language restrictions. The full electronic search strategies for all databases are provided in Appendix S1. In addition, journals of rehabilitation medicine, neurology and sport science were searched by hand.

Inclusion criteria

1. Types of studies: published papers with completed RCTs were included. No restrictions were made regarding language or the date of the trial.
2. Types of participants: papers with stroke subjects aged over 18 years were included.
3. Types of interventions: only papers that compared an intervention group which performed CMI and a control group which performed a single-task exercise (e.g. walking or strength and balance exercises) or no treatment were considered. CMI was the simultaneous performance of a cognitive task and a motor task, and each task was separate [3]. In the classic CMI, participants performed a motor task (e.g. walking) whilst answering a series of simple addition/subtraction questions (e.g. $100 - 7 = 93$) [9].
4. Types of outcome measures: the primary outcomes were gait variables and balance function. The secondary outcomes were activities of daily living, such as the functional independence measure (FIM) scale.

Selection of studies

Two authors independently used the same selection criteria to screen titles, abstracts and full papers of the relevant articles. A study that did not meet the inclusion criteria was removed. Any disagreement was resolved through discussion. A third author was consulted if disagreement persisted.

Data extraction and quality assessment

The following data were extracted: study characteristics (e.g. author and year), participant characteristics (e.g. age and number of subjects), description of interventions, duration of trial period, types of outcomes assessed and time point. The Cochrane Collaboration recommendations [10,11] were used to evaluate the risk of bias for inclusion in the systematic review. Two review authors independently extracted the data and assessed the methodological quality of each study. Consulting a third author was necessary when a disagreement occurred.

Statistical analysis

Review Manager Software (RevMan5.2, Cochrane Collaboration, Oxford, UK) was used to conduct the meta-analysis. Continuous outcomes was analysed by calculating the mean difference (MD) between groups when the same instrument was used to measure outcomes or the standardized mean difference (SMD) when different instruments were used to measure the outcomes. The chi-squared test and the I^2 statistic were used to assess heterogeneity amongst the studies. The outcome measures from the individual studies were combined through meta-analysis using a random effects model. A P value < 0.05 indicates a significant statistical difference. Sensitivity analysis was performed by removing each study individually to assess the consistency and quality of the results. The Egger's regression test was used to assess publication bias.

Systematic review registration http://www.crd.york.ac.uk/PROSPERO. PROSPERO registration number CRD42012002606.

Results

Study identification

The process of identifying eligible studies is outlined in Fig. 1. Amongst 1005 identified records (including titles and abstracts) from Medline, EMBASE, the Cochrane Library, Web of Science, CINAHL, PEDro, the China Biology Medicine disc and manual search, 44 potentially eligible studies were included. After reviewing the full papers of the 44 potential articles, 15 papers [6,7,12–24] fulfilled the inclusion criteria. The remaining 29 papers were excluded because their

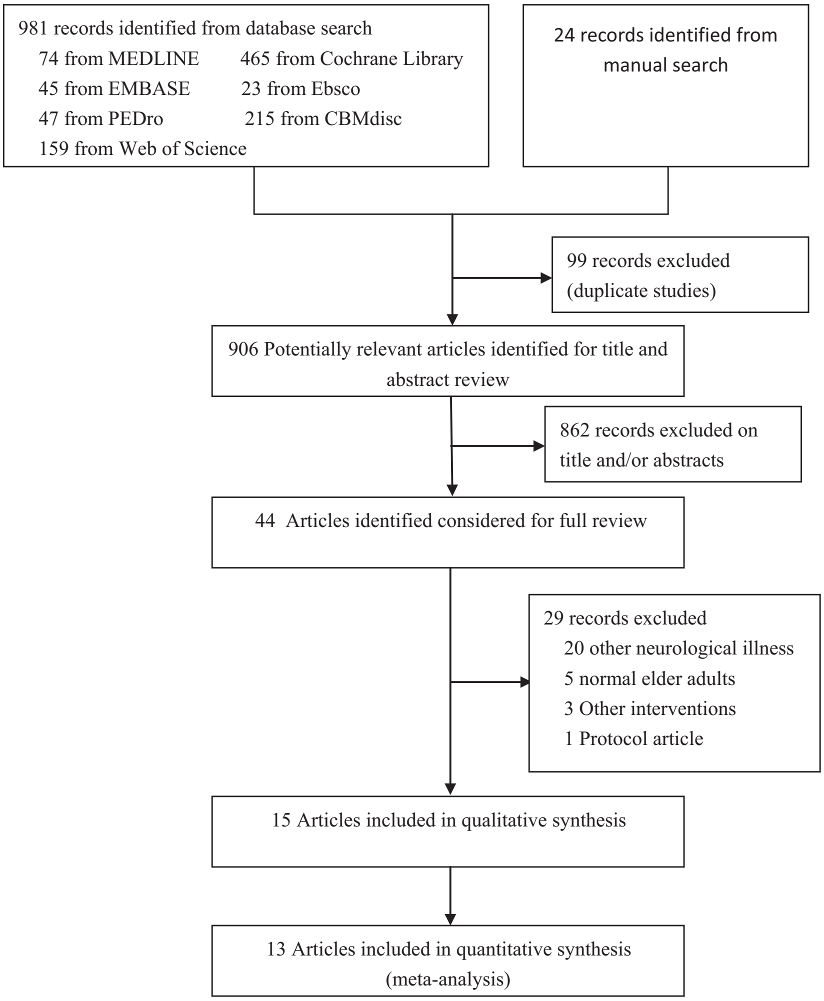

Figure 1 Flow chart of the study selection procedure.

studies included participants with other neurological diseases (e.g. Parkinson's disease and cognitive impairment), normal elder adults and participants who were not stroke patients and did not compare CMI with a control group. Table 1 presents the characteristics of each study included.

Risk of bias in included studies

Briefly, every study was reported as random allocation. Nine papers of the included trials failed to adopt allocation concealment, whereas eight papers tried to blind the assessors to the allocated treatment. Full details of the methodological quality of these trials are shown in Table 2.

Gait variables

Gait speed

Six studies [12,16,19,20,23,24] were included to estimate the effect of CMI on gait speed. The results showed that CMI for gait speed was better than the control group in a random effects model [MD 0.19 m/s, 95% confidence interval (CI) (0.06, 0.31), $P = 0.003$] (Table 3; Fig. 2a). A sensitivity analysis was performed and it was found that the significance of the results was not changed when studies were removed one by one.

Stride length

Three studies [12,16,17] were included to estimate the effect of CMI on stride length. Results showed that CMI improved stride length better than the control group in a random effects model [MD 12.53 cm, 95% CI (4.07, 20.99), $P = 0.004$] (Table 3; Fig. 2b). It was affected by one study [12] in the sensitivity analysis. Therefore it provided weak evidence of CMI on stride length.

Cadence

Three studies [12,16,17] were included to estimate the effect of CMI on cadence. The results showed that

Table 1 Characteristics of included studies

First author, year	Patient characteristics, sample size	Intervention	Duration of trial period	Outcome	Time point
Her 2011 [6]	Source: hospital rehabilitation department, 38 patients (G1 = 13, G2 = 12, G3 = 13) Mean age (SD): G1 = 63.5 years (6.4), G2 = 64.8 years (5.2), G3 = 64.5 years (4.8)	G1: cognitive motor exercise G2: motor exercise G3: cognitive exercise	Three times a week for 6 weeks	Balance (COP sway area, BBS) and FIM	6 weeks
Zheng 2012 [7]	Source: community groups, 92 patients (G1 = 45, G2 = 47) Mean age (SD): G1 = 69.11 years (5.01), G2 = 68.61 years (4.62) Mean time of post-stroke (SD): G1 = 2.76 years (0.48), G2 = 2.54 years (0.62)	G1: cognitive motor exercise G2: single-task balance exercise	Three times a week for 8 weeks	Balance performance (COP sway area, COP sway distance)	8 weeks
Yang 2007 [12]	Source: community groups, 25 patients (G1 = 13, G2 = 12) Mean age (SD): G1 = 59.46 years (11.83), G2 = 59.17 years (11.98) Mean time of post-stroke (SD): G1 = 4.08 years (3.13), G2 = 4.68 years (7.4)	G1: cognitive motor exercise G2: no intervention	Three times a week for 4 weeks	Gait (walking speed, cadence, stride time and stride length)	4 weeks
Evans 2009 [13]	Source: not specified, 19 patients (G1 = 10, G2 = 9) Mean age (SD): G1 = 44.4 years (8.51), G2 = 45.11 years (9.73) Mean time of post-stroke (SD): G1 = 4.92 years (4.53), G2 = 9.63 years (8.97)	G1: cognitive motor exercise G2: treatment as usual	Five times a week for 5 weeks	Balance (2-min walk)	5 weeks
Seo 2012 [14]	Source: hospital, 40 patients (G1 = 20, G2 = 20) Mean age (SD): G1 = 55.8 years (3.6), G2 = 56.7 years (2.4) Mean time of post-stroke (SD): G1 = 0.6 years (0.2), G2 = 0.56 years (0.2)	G1: cognitive motor exercise G2: single-task balance exercise	Five times a week for 4 weeks	Balance performance (COP sway area and COP sway distance)	4 weeks
Cho 2012 [15]	Source: stroke unit, 22 patients (G1 = 11, G2 = 11) Mean age (SD): G1 = 62.56 years (8.35), G2 = 63.18 years (6.87) Mean time of post-stroke (SD): G1 = 1.05 years (0.22), G2 = 1.05 years (0.02)	G1: cognitive motor exercise + standard rehabilitation programme G2: standard rehabilitation programme	Five times a week for 6 weeks	Balance (BBS, TUGT, COP sway)	6 weeks
Cho 2013 [16]	Source: hospital, 14 patients (G1 = 7, G2 = 7) Mean age (SD): G1 = 64.57 years (4.35), G2 = 65.14 years (4.74) Mean time of post-stroke (SD): G1 = 0.79 years (0.19), G2 = 0.86 years (0.23)	G1: cognitive motor exercise + standard rehabilitation programme G2: standard rehabilitation programme	Three times a week for 6 weeks	Gait (gait speed, stride length, step length, cadence), balance (BBS, TUGT)	6 weeks
Kim 2009 [17]	Source: not specified, 22 patients (G1 = 11, G2 = 11) Mean age (SD): G1 = 52.42 years (10.09), G2 = 51.75 years (7.09) Mean time of post-stroke (SD): G1 = 2.16 years (0.83), G2 = 2.02 years (0.74)	G1: cognitive motor exercise + conventional physical therapy G2: conventional physical therapy	Four times a week for 4 weeks	Gait (stride length, step length, cadence, step time), balance (BBS, 10-m walking, COP sway area, COP sway distance)	6 weeks

(continued)

Table 1 *(Continued)*

First author, year	Patient characteristics, sample size	Intervention	Duration of trial period	Outcome	Time point
Yang 2011 [18]	Source: hospital, 14 patients (G1 = 7, G2 = 7) Mean age (SD): G1 = 56.3 years (10.2), G2 = 65.7 years (5.9) Mean time of post-stroke (SD): G1 = 1.41 years (0.72), G2 = 1.36 years (0.87)	G1: cognitive motor exercise (virtual reality treadmill training) G2: traditional treadmill training	Three times a week for 3 weeks	Balance (COP sway area, COP sway distance)	3 weeks
Yang 2008 [19]	Source: community groups, 20 patients (G1 = 11, G2 = 9) Mean age (SD): G1 = 55.45 years (11.25), G2 = 60.89 years (9.25) Mean time of post-stroke (SD): G1 = 5.93 years (4.17), G2 = 6.10 years (10.32)	G1: cognitive motor exercise (virtual reality treadmill training) G2: traditional treadmill training	Three times a week for 3 weeks	Gait (gait speed), balance (ABC)	3 weeks 4 weeks
Mirelman 2009 [20]	Source: not specified, 18 patients (G1 = 9, G2 = 9) Mean age (SD): G1 = 61.8 years (9.94), G2 = 61 years (8.32) Mean time of post-stroke (SD): G1 = 3.14 years (2.08), G2 = 4.85 years (2.19)	G1: cognitive motor exercise (virtual reality training) G2: traditional training	Three times a week for 4 weeks	Gait (gait speed, step length), balance (6-min walk)	4 weeks
Jung 2012 [21]	Source: not specified, 21 patients (G1 = 11, G2 = 10) Mean age (SD): G1 = 60.5 years (8.6), G2 = 63.6 years (5.1) Mean time of post-stroke (SD): G1 = 1.05 years (0.275), G2 = 1.28 years (0.39)	G1: cognitive motor exercise (virtual reality training) G2: traditional training	Five times a week for 3 weeks	Balance (TUGT, ABC)	3 weeks
Mirelman 2010 [22]	Source: not specified, 18 patients (G1 = 9, G2 = 9) Mean age (range): 62 years (41–75) Time of post-stroke: greater than 2 years	G1: cognitive motor exercise (virtual reality training) G2: traditional training	Five times a week for 4 weeks	Gait (kinetic gait parameters)	4 weeks
Xiao 2012 [23]	Source: hospital, 12 patients (G1 = 6, G2 = 6) Mean age (SD): G1 = 55.83 years (10.78), G2 = 57.17 years (11.16) Mean time of post-stroke (SD): G1 = 0.12 years (0.06), G2 = 0.12 years (0.05)	G1: cognitive motor exercise (virtual reality treadmill training) G2: conventional physiotherapy	Five times a week for 3 weeks	Gait (gait speed)	3 weeks
Jaffe 2004 [24]	Source: community groups, 20 patients (G1 = 10, G2 = 10) Mean age (SD): G1 = 58.2 years (11.2), G2 = 63.2 years (8.3) Time of post-stroke: an average of 3.7 years duration post-stroke	G1: cognitive motor exercise (virtual reality treadmill training) G2: traditional treadmill training	Six sessions for 2 weeks	Gait (gait speed, step length, stride length), balance (6-min walk)	2 weeks 4 weeks

ABC, Activities-specific Balance Confidence; BBS, Berg balance scale; COP, centre of pressure; FIM, functional independence measure; TUGT, timed up and go test.

Table 2 Risk of bias assessment of included studies

First author, year	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selective reporting	Other bias	Risk of bias
Her 2011 [6]	Low	High	High	High	Low	Low	Unclear	High
Zheng 2012 [7]	Low	Low	High	Low	Low	Low	Unclear	High
Yang 2007 [12]	Low	Low	High	Low	Low	Low	Unclear	High
Evans 2009 [13]	Low	Low	High	High	Low	Low	Unclear	High
Seo 2012 [14]	Low	High	High	High	Low	Low	Unclear	High
Cho 2012 [15]	Low	High	High	High	High	Low	Unclear	High
Cho 2013 [16]	Low	Low	High	Low	High	Low	Unclear	High
Kim 2009 [17]	Low	High	High	Low	Low	Low	Unclear	High
Yang 2011 [18]	Low	High	High	Low	Low	Low	Unclear	High
Yang 2008 [19]	Low	Low	High	Low	Low	Low	Unclear	High
Mirelman 2009 [20]	Low	High	High	Low	Unclear	Low	Unclear	High
Jung 2012 [21]	Low	Low	High	Low	Low	Low	Unclear	High
Mirelman 2010 [22]	Low	High	High	High	Unclear	Low	Unclear	High
Xiao 2012 [23]	Low	High	High	High	Low	Low	Unclear	High
Jaffe 2004 [24]	Low	High	High	High	Low	Low	Unclear	High

Table 3 Summary of results

Outcome	Trials	Participants	Statistical method	Effect estimate	Heterogeneity I^2, P value	Effect P value
Gait						
Gait speed	6 [12,16,19,20,23,24]	112	Mean difference (IV, random, 95% CI)	0.19 [0.06, 0.31]	36%, 0.17	0.003
Stride length	3 [12,16,17]	61	Mean difference (IV, random, 95% CI)	12.53 [4.07, 20.99]	9%, 0.33	0.004
Cadence	3 [12,16,17]	61	Mean difference (IV, random, 95% CI)	10.44 [4.17, 16.71]	0%, 0.86	0.001
Step length	3 [16,17,20]	54	Mean difference (IV, random, 95% CI)	2.61 [−1.90, 7.12]	1%, 0.36	0.26
Balance						
COP sway area	4 [6,7,14,17]	270	Standardized mean difference (IV, random, 95% CI)	−1.05 [−1.85, −0.26]	88%, $<$0.001	0.01
COP sway distance	4 [7,14,15,17]	276	Standardized mean difference (IV, random, 95% CI)	−0.49 [−1.10, 0.12]	81%, $<$0.001	0.11
BBS	4 [6,15–17]	96	Mean difference (IV, random, 95% CI)	2.87 [0.54, 5.21]	50%, 0.11	0.02
TUGT	3 [15,16,21]	57	Mean difference (IV, random, 95% CI)	−0.98 [−3.83, 1.87]	32%, 0.23	0.50
ABC	2 [19,21]	41	Mean difference (IV, random, 95% CI)	7.27 [−5.95, 20.48]	77%, 0.04	0.28

ABC, Activities-specific Balance Confidence scale; BBS, Berg balance scale; CI, confidence interval; COP, centre of pressure; IV, inverse variance; TUGT, timed up and go test.

CMI was better than the control group for improving cadence in a random effects model [MD 10.44 steps/min, 95% CI (4.17, 16.71), $P = 0.001$] (Table 3; Fig. 2c). Sensitivity analysis revealed that the pooled result was stable when studies were removed one by one.

Step length

Three studies [16,17,20] were included to estimate the effect of CMI on step length. No significant difference was observed between CMI and the control group for step length in a random effects model [MD 2.61 cm, 95% CI (−1.93, 7.14), $P = 0.26$] (Table 3, Fig. S1a). Sensitivity analysis found that the pooled result was not influenced by individual trials.

Balance

Centre of pressure sway area

Four studies [6,7,14,17] were included to estimate the effect of CMI on centre of pressure (COP) sway area. The results showed that CMI was better than the control group on COP sway area in a random effects model [SMD −1.05, 95% CI (−1.85, −0.26), $P = 0.01$] (Table 3; Fig. 3a). Sensitivity analysis found that the significance of the result was changed when one study [7] was removed, which offered inferior evidence for the effect of CMI on COP sway.

Centre of pressure sway distance

Six studies [7,14,15,17] were included to estimate the effect of CMI on COP sway distance. No significant

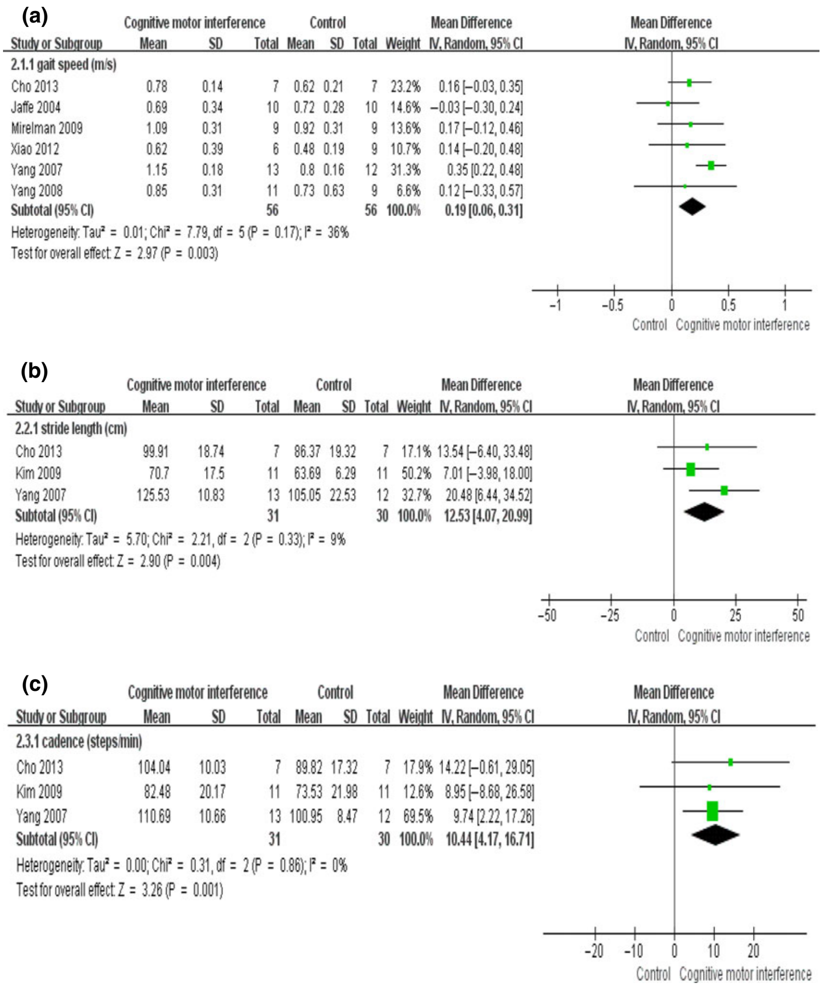

Figure 2 Meta-analyses of cognitive motor interference on gait function: (a) gait speed (m/s); (b) stride length (cm); (c) cadence (steps/min). CI, confidence interval; IV, inverse variance.

difference was observed between CMI and the control group on COP sway distance in a random effects model [SMD −0.49, 95% CI (−1.10, 0.12), $P = 0.11$] (Table 3; Fig. S1b). It was affected by one study [15] in the sensitivity analysis. Hence, it is necessary to provide more evidence to make judgements about the effect of CMI on COP sway distance.

Berg balance scale (BBS)

Four studies [6,15–17] were included to estimate the effect of CMI on the BBS. The results showed that CMI was better than the control group on the BBS in a random effects model [MD 2.87, 95% CI (0.54, 5.21), $P = 0.02$] (Table 3; Fig. 3b). Sensitivity analysis revealed that the pooled result was influenced by individual trials. Thus more evidence is needed to ensure the influence of CMI on the BBS.

Timed up and go test (TUGT)

Three studies [15,16,21] were included to estimate the effect of CMI on the TUGT. No significant difference was observed between CMI and the control group for the TUGT in a random effects model [MD = −0.98 s, 95% CI (−3.83, 1.87), $P = 0.50$] (Table 3; Fig. S1c). Sensitivity analysis revealed that the pooled result was not influenced by individual trials.

Activities-specific Balance Confidence (ABC) scale

Two studies [19,21] were included to estimate the effect of CMI on the Activities-specific Balance Confidence (ABC) scale. No significant difference was observed between CMI and the control group for ABC in a random effects model [MD 7.27, 95% CI (−5.95, 20.48), $P = 0.28$] (Table 3; Fig. S1d).

Other walk test

One study [17] evaluated the effect of CMI on a 10-m walking test, which showed that CMI could improve in the 10-m walking test compared with the control group. Another study [20] assessed the effect of CMI on a 6-min walking test, which showed that CMI

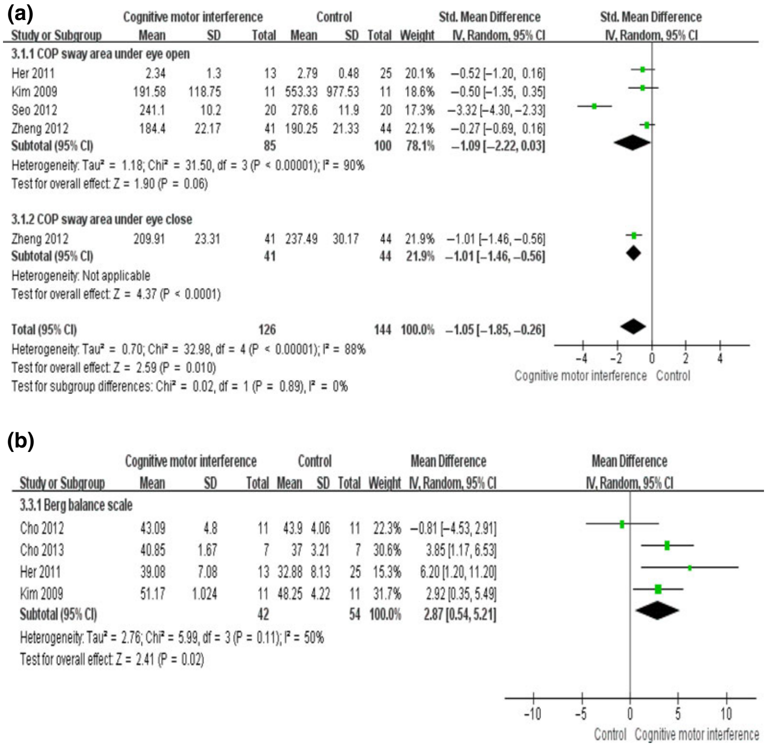

Figure 3 Meta-analyses of cognitive motor interference on balance function: (a) centre of pressure sway area (mm^2); (b) Berg balance scale. CI, confidence interval; IV, inverse variance.

could improve in the 6-min walking test compared with the control group. Another study [19] assessed the effect of CMI on a 400-m walking test, which showed that CMI could improve in the 400-m walking test compared with the control group.

Activities of daily living

One study [10] evaluated the effect of CMI on FIM, which showed that CMI could improve on FIM compared with the control group.

Publication bias

Egger's regression test did not show any publication bias for gait speed (asymmetry test $P = 0.337$), stride length (asymmetry test $P = 0.874$), cadence (asymmetry test $P = 0.748$), step length (asymmetry test $P = 0.869$), COP sway area (asymmetry test $P = 0.301$), COP sway distance (asymmetry test $P = 0.088$), BBS test (asymmetry test $P = 0.598$) and TUGT (asymmetry test $P = 0.92$).

Discussion

A variety of exercise programmes were used to improve gait and balance function in patients with stroke. Previous systematic reviews had focused on single-task exercise programmes (e.g. strength and balance exercises). However, most people were more likely to fall when performing cognitive motor tasks in most daily activities. At present, an increasing interest in the potential benefits of CMI for stroke has been observed, and some papers [6,7] have suggested that CMI could improve gait and balance function for patients with stroke compared with a single-task exercise. But the efficacy of CMI for gait and balance is controversial. Therefore, this systematic review and meta-analysis provides evidence from relevant papers assessing CMI versus a single-task exercise or no intervention.

Our systematic review of papers from 15 RCTs, which covered 395 participants, provided evidence supporting the effect of CMI for improving gait and balance in stroke. Statistically significant differences were found on comparing CMI to a control group for 10 outcomes, including gait speed, stride length, cadence, performance in BBS, COP sway area, 2-min walk, 6-min walk, 10-m walk, 400-m walk and FIM. The improvements seen for gait speed, BBS, COP sway area, walk test and FIM were at levels that may signify clinical importance for stroke. In addition, no serious complications were observed in the 15 papers which investigated adverse events. By contrast, several other balance outcome measures (e.g. the ABC scale and TUGT) showed no significant benefit on comparing CMI with a control group. However, the number of included studies and participants were insufficient to decide the overall effect of CMI.

Strengths and limitations

To our knowledge, this study is the first systematic review and meta-analysis to estimate the effects of CMI for gait and balance function in stroke by comparing with other treatments or no intervention. The past [5,8] systematic reviews either did not compare CMI to a control group or focused on qualitative synthesis rather than meta-analysis. In contrast to previous reviews [5,8], all the papers of this review only considered patients with stroke, and most papers included in this review are new. A meta-analysis of the effects of CMI compared with other treatments or no intervention was performed. And this review was conducted in accordance with PRISMA guidelines (Data S1).

Our systematic review has some limitations, however. First, the systematic review is limited by the quality of the included trials. A single study tried to blind the subjects, and no study blinded the therapists; six of the 15 studies conducted concealed allocation, and two of the 15 studies conducted intention-to-treat analyses. In addition, most of the papers included were within the last 3 years, but high quality studies were still insufficient. Secondly, the total number of patients was not large; thus, identifying small disparities between the effects of CMI and the control group was difficult. Because there were insufficient studies, subgroup analyses comparing CMI versus a single-task exercise or comparing CMI versus no intervention were not conducted. Thirdly, longer-term outcomes on gait and balance function could not be assessed as most studies had short intervention durations and short follow-up periods; in fact, the duration of follow-up was from 2 weeks to 8 weeks for all the studies.

Implications for research

Overall, high quality papers were still insufficient in our systematic review. Future studies should improve methodological standards which reduce possible biases. The following standards should be included: blind assessors; concealed allocation; adequate follow-up; measures to reduce withdrawals; intention-to-treat analysis; and between-group comparisons. In addition, papers should adhere to generally accepted standards of reporting clinical trials.

As previously mentioned, the sample size of most studies in this meta-analysis was small, and many studies had a short follow-up period. Therefore some large-scale RCTs are needed. To assess how long any improvement intervention may last based on CMI, follow-up sessions with longer durations should be performed for patients with stroke. Additionally, several different training programmes are currently in use for CMI, which may lead to different results. Thus, a systematic review and meta-analysis of different CMIs is necessary to determine the optimal intervention approach in stroke.

Conclusions and implications for practice

In our systematic review, statistically significant differences between CMI and the control group were found with regard to the following outcomes: gait speed, stride length, cadence, performance in BBS, COP sway area, 2-min walk, 6-min walk, 10-m walk, 400-m walk and FIM. Thus, our meta-analysis results should be useful for stroke patients and for medical staff and healthcare decision makers in coming up with effective exercise regimes for this age group.

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Disclosure of conflicts of interest

The authors declare no financial or other conflicts of interest.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Search strategies for all databases.
Figure S1. Meta-analyses of cognitive motor interference on gait and balance function.
Data S1. PRISMA 2009 checklist.

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