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Obstacle avoidance training in individuals with stroke: a systematic review and meta-analysis

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(2376 words)

Abstract

Objective: Obstacle avoidance training in individuals with stroke in combination with other circuit training has been conducted and the effect reported in a systematic review. However, the effect of obstacle avoidance training, when tested alone, remained unknown. The present study conducted a systematic review to seek evidence that obstacle avoidance training alone is effective in helping stroke individuals to improve their locomotor ability.

Design: Systematic review and meta-analysis.

Data sources: MEDLINE, EMBASE, CENTRAL, ICTRP, and PEDro searched up to December 2018.

Review methods: We included only randomized controlled trials examining the effects of obstacle avoidance training on stroke individuals. The main outcome included measures of gait ability and balance ability. Data on outcome measures were subjected to meta-analyses using random-effects models. The certainty of evidence was determined using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach.

Results: Three studies with a total of 81 participants met the inclusion criteria, and 67 participants were used as data sources for the meta-analysis. Obstacle avoidance training was not superior to the control group for gait speed [mean difference (MD) 0.06, 95% confidence interval (CI) (-0.16, 0.04), P = 0.67], and subjective balance ability (Activities-specific Balance Confidence (ABC) scale) also showed no significant difference between the intervention group and the control group [MD 6.65, 95% CI (-7.59, 20.89), P = 0.36]. The certainty of the evidence (GRADE) for all outcomes were low or very low.

Conclusion: The present study suggests that obstacle avoidance training alone may have little or no effect. The reasons for failure to find the effectiveness of obstacle training alone would be the insufficient amount of training in the intervention, as well as the lack

of well-designed studies that measured relevant outcomes.

Keywords: stroke, obstacle avoidance, systematic review, meta-analysis

Strengths and limitations of this study

This is a systematic review and meta-analysis of evidence of the effect of obstacle avoidance training in individuals who have suffered a stroke.

The systematic review was conducted based on the Cochrane Handbook and the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines.

The literature search and study selection, data extraction and risk of bias assessment were conducted by two independent authors.

The limitation on the conclusion of this research include the insufficient amount of training in the intervention, and the lack of well-designed studies that measured relevant outcomes.

Introduction

Individuals with stroke often have impaired walking abilities, primarily due to motor paralysis on one side of their body. Maintaining balance becomes increasingly difficult particularly when adaptive locomotor adjustments in response to environmental properties are necessary (e.g., obstacle avoidance). In fact, the risk of falling is likely to increase when individuals with stroke avoid an obstacle.[1-3] Therefore, it is important for individuals with stroke to improve their walking ability under various environmental constraints through rehabilitation.

Rehabilitation after a stroke involves having the patient correctly recognize both the function that has been lost and the function that remains. Rehabilitation is also designed to make plastic changes in the brain by relearning through repetitive task training.[4] The mixed task-oriented circuit class training, including obstacle avoidance training, may promote relearning of gait.[5] A previous study demonstrated that walking training and task-oriented training related to walking, including obstacle avoidance training, improved both step distance and walking speed,[5] thus shortening the length of stay in the hospital.[6] Obstacle avoidance training has been carried out as part of circuit class training, and the effect was reported in a systematic review.

Several studies that support the effectiveness of obstacle avoidance training were conducted without any combination with other types of training, using a randomized controlled design.[7-10] Additionally, a systematic-review study showed the effectiveness of obstacle avoidance training in combination with other circuit training.[5] To obtain further evidence of the effectiveness of obstacle avoidance training, we conducted a systematic-review and meta-analysis study. We searched for randomized controlled trials in obstacle avoidance training for individuals with stroke and examined the efficacy of

such training compared with the usual approaches. Based on these results, we sought evidence that obstacle avoidance training alone is effective in helping individuals with stroke to improve their locomotor ability.

Methods

The protocol was registered in PROSPERO (CRD42017060691).[11] The systematic review was conducted based on the Cochrane Handbook[12] and the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines.[13] The systematic review and meta-analysis were assessed in accordance with the PRISMA checklist (see supplementary table).[14]

We posed the following research question: "In stroke patients, dose obstacle avoidance training result in an improved, clinically relevant outcome as compared with the usual care without obstacle avoidance training?"

Data sources and searches

Systematic searches were conducted in four academic databases: MEDLINE (searched on December 18, 2018), EMBASE (December 18, 2018), CENTRAL (December 18, 2018), and PEDro (December 18, 2018). A supplemental file shows this process in more detail. We searched for the trials in the ICTRP on December 18, 2018 (the full search strategy is shown in supplementary table). We also searched references in the guidelines of the following organizations: the European Stroke Organization (ESO), the American Heart Association (AHA)/American Stroke Association (ASA), and the National Institute for Health and Care Excellence (NICE).[15-17]

Study selection

The selection and review of the papers were conducted by two independent authors. Two reviewers (D.M. and S.O.) screened the titles and abstracts for the study selection independently to determine whether each citation met the inclusion criteria. They assessed the eligibility based on a full-text review. The reviewers compared their lists, and any differences in opinion between the two authors were resolved through discussion.

To be eligible for inclusion in this systematic review, papers were required to (1) focus on patients with various types of strokes (brain ischemia, or intracranial hemorrhages, or subarachnoid hemorrhage) individuals and (2) conduct obstacle avoidance training in walking practice (interventions of any type, intensity, duration, and frequency). We also searched for references in extracted articles and contacted the authors of each study to obtain necessary data. The search was limited to published and unpublished randomized controlled trials. Crossover trials, cluster randomized trials, non-randomized trials, and observational studies were excluded.

The following primary outcomes were measured: (1) gait speed, measured in a 10 m walking test (10MWT) or obtained during a 6-minute walking test (6MWT); (2) composite gait ability, measured in a Timed Up and Go test (TUG); (3) objective balance ability, measured according to the Berg Balance Scale (BBS). Secondary outcomes were subjective balance ability, measured according to the Activities-specific Balance Confidence scale (ABC); gait endurance, measured in a 6-minute walking test (6MWT); and fall incidence (the incidence of falls six months or one year after intervention).

Data extraction and quality assessment

Data extraction was done using a standardized form that included characteristics of

the participants (number of participants, number of patients excluded from the analysis, and settings), the setup of the intervention environment (obstacle avoidance, other rehabilitation, and using a virtual reality system), types of outcomes (fall incidence, activities of daily living, gait ability, and balance ability), and details of the training programs (types of exercises, duration, and frequency).

Standard data extraction forms were used by the two authors independently. Disagreement in data extraction was resolved through discussion. When the information was inadequate, we contacted the study authors to gather sufficient information.

Risk of bias assessment was conducted using RevMan 5.3 (RevMan 2014). The following items were independently assessed by two reviewers (D.M. and O.S.) using the Cochrane Risk of Bias Tool.[12] Each domain was assessed as high risk, low risk or unclear. The assessments were compared by two authors, and any differences in opinion between the two reviewers were resolved through discussion and, where this failed, through arbitration by a third reviewer (Y.K.). In the evaluation of publication bias (PB), since the number of studies was less than 10, we did not test for funnel plot asymmetry; rather, we evaluated PB by searching the clinical trial registry.

Data synthesis and analysis

For continuous outcomes (gait speed, TUG, BBS, ABC, and 6MWT), the mean difference (MD) with 95% CI was calculated. The MD was used when data, including meta-analyses, were derived from the same indicators. Adverse events were narratively summarized, since the definition of these outcomes varied among studies.

The heterogeneity was assessed by visual inspection of the forest plots and calculated I-squared statistic (I-squared values of 0% to 40%: might not be important; 30% to 60%:

may represent moderate heterogeneity; 50% to 90%: may represent substantial heterogeneity; 75% to 100%: considerable heterogeneity). Where heterogeneity was identified (I-squared statistic> 50%), we investigated the reason.

Date syntheses were conducted with RevMan 5.3 (RevMan 2014). We conducted a meta-analysis using the random-effects model. We calculated MD with 95% CI in the continuous variables. All adverse events were excluded from the meta-analysis. An analysis of exercise versus any other controls was carried out.

We conducted a sensitivity analysis to determine the robustness of the findings. The sensitivity analysis of the primary outcome was planned in the following three ways: (1) restricting the analysis studies to those that had a low risk of selection bias, (2) excluding trials with missing data, and (3) converting the random-effects model to a fixed-effects model.

Patient and public involvement

No patients will be involved in this study.

Summary of findings table

The “Summary of findings table" was created using outcomes that included gait speed, composite gait ability, objective balance scale, subjective balance scale, and gait endurance (**Table 1**). The five GRADE considerations (study limitations, consistency of effect, imprecision, indirectness and publication bias) were used to assess the certainty of evidence as it relates to the studies contributing data to the review for the outcomes.[12 18 19] Two review authors independently assessed the quality of the evidence. The two authors compared their lists and any differences in opinion between the two authors were

resolved through discussion.

Table 1. Summary of findings.

Outcome (time frame)	No. of patients (studies)	Certainty of the evidence (GRADE)	Comparator	Intervention vs. comparator mean difference (95% CI)
Gait speed (m/s) (1 day to 4 weeks)	67 (3 RCT)	⊕⊖⊖⊖ Very low [abc]	The mean gait speed across control groups ranged from 0.71 to 0.95 m/s	-0.06 (95% CI: -0.16, 0.04) faster in intervention group.
Composite gait ability TUG (sec) (4 weeks)	29 (1 RCT)	⊕⊕⊖⊖ Low [ab]	15.37 sec	-0.1 (95% CI: -1.0, 0.7) faster in intervention group.
Objective balance ability BBS score (4 weeks) Scale:0 to 56	29 (1 RCT)	⊕⊕⊖⊖ Low [ab]	46.14	0.0 (95% CI: -0.6, 0.7)
Subjective balance ability ABC score (3 to 4 weeks) Scale: 0 to 100	49 (2 RCT)	⊕⊖⊖⊖ Very low [abc]	The mean ABC score across control groups ranged from 62.58 to 72.23	6.65 (95% CI: -7.59, 20.89) higher in intervention group.
Gait endurance 6MWT (m) (4 weeks)	29 (1 RCT)	⊕⊕⊖⊖ Low [ab]	277.43 m	5.4 (95% CI: 2.9, 7.9) longer distance in intervention group.

GRADE Working Group grades of evidence

High quality: Further research is very unlikely to change our confidence in the estimate of effect.

Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.

Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

Very low quality: We are very uncertain about the estimate.

[a] Participants and personnel were not blinded

[b] Number of participants was small.

[c] The outcome data were incomplete for 10% of participants.

Results

The process of identifying eligible studies is outlined in **Fig. 1**. Amongst 2,319 identified records (including titles and abstracts) from MEDLINE, EMBASE, CENTRAL, ICTRP, PEDro, and a manual search, 23 potentially eligible studies were included. After a review of the full text of 23 potential articles, three papers[8-10] fulfilled the inclusion criteria. Nineteen of the remaining 20 papers were excluded because their studies included intervention with several other forms of walking training (e.g., circuit class training and task-oriented training). One study[7] was excluded because both groups participated in obstacle avoidance training (in the water vs. on the ground). There was no ongoing study.

Insert Figure 1 (PRISMA flow)

Three studies[8-10] with a total 81 participants met the inclusion criteria, and three studies with a total of 67 participants were used as data sources for the meta-analysis (**Fig. 1**). The characteristics of each study included are presented in **Table 2**. The risk of bias assessment is outlined in **Table 3**. In both studies, participants were not blinded to the intervention. Also, the studies had incomplete outcomes. One study[8] reported an unknown risk of bias from published data, and so we contacted the authors. According to the authors, they had planned to measure the three-axis accelerometer and QOL. However, considering several circumstances and the patients' condition, they did not measure above outcomes.

Table 2. Characteristics of included studies.

Author, Year, Country	Setting	Number of participants	Study type	Intervention (contents, frequency)	Control (standard care)	Outcomes
Lord SE et al., 2006, New Zealand	Subjects were assessed in 1 of 3 setting: 2 in the community and 1 clinic environment .	27 (control (no task): 9, intervention (motor task): 9) Other intervention (cognitive task): 9	2×3 randomized factorial design	2 main factors: task (no task, motor task, cognitive task) and environment (clinic, suburban street, shopping mall) For the single task condition, the participants were asked to walk at a comfortable speed for 6 minutes without taking in 1 of 3 environment: (1) the clinic environment, (2) the suburban street, (3) the shopping mall. For the dual task condition, in addition to the above task, the participants were asked to step over a wooded block as motor task, or the participants were asked to respond whether the numbers spoken by the researchers were even or odd as cognitive task. Intervention duration was not reported.		Gait speed (obtained during 6MWT), cadence, and step length
Yang YR et al., 2008, Taiwan	Exercise laboratory	24 (intervention: 12, control:12)	Pilot RCT	Virtual reality based treadmill training: the scenarios consisted of lane walking, street crossing, obstacles striding across, and park stroll. Intervention for 20 minutes/session, 3 sessions a week for 3 weeks.	Treadmill training	Gait speed (10MWT), community walking time, walking ability questionnaire (WAQ), and ABC
Jeong YG et al., 2016, Korea	Exercise laboratory	30 (intervention: 15, control: 15)	Pilot RCT	Treadmill walking with obstacle-crossing. Intervention for 30 min/day, 5 times/week, for 4 weeks.	Treadmill walking	10MWT, 6MWT, BBS, TUG, and ABC

Table 3. Assessment of risk of bias in included trials

Trial	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selective reporting
Lord et al. 2006 [9]	Unclear	Unclear	High	Unclear	Low	Unclear
Yang et al. 2008 [10]	Unclear	Low	High	Low	High	Unclear
Jeong et al. 2016 [8]	Low	Low	High	Low	High	Low

Primary outcomes

Pooling revealed that the group that underwent obstacle avoidance training was not superior to the control group in terms of gait speed [MD -0.06, 95% CI (-0.16, 0.04), P = 0.67] (**Fig. 2**). For gait speed, no heterogeneity was observed ($Tau^2 = 0.00$, $I^2 = 0\%$). The results of the sensitivity analysis were also the same as the original results. Data on composite gait ability and objective balance ability were available in one of the three

studies. The MDs (95% CI) of the TUG and BBS scores were -0.15 (-1.0, 0.7) and 0.03 (-0.6, 0.7), respectively.

Secondary outcomes

Subjective balance ability (ABC scale) also showed no significant difference between the intervention group and the control group [MD 6.65, 95% CI (-7.59, 20.89), P = 0.36] (**Fig. 3**). Substantial heterogeneity was observed ($Tau^2 = 89.28$, $I^2 = 83\%$). Data on gait endurance were available in one of the three studies, while data on fall incidence were not available in any of the studies. The MD (95% CI) of 6MWT was 5.4 (2.9, 7.9).

There were no reports of adverse events during intervention in any of the three studies.

Insert Figure 2

Insert Figure 3

Discussion

We found three RCT studies based on our criteria. The certainty of the evidence was low or very low because of serious study limitations and imprecision. The meta-analysis showed that there was no improvement in gait speed or subjective balance ability in the intervention group with obstacle avoidance training.

There are at least two reasons we failed to find the effectiveness of obstacle avoidance training alone. First, for all three of the selected studies, the amount of training was small. According to the systematic review of the circuit class training, the duration

of intervention was approximately 60 minutes in a single session, and various walking-related training tasks were continuously performed.[5] In contrast, the duration of the obstacle avoidance training was only 20–30 minutes (see **Table 2**). The frequency of intervention (3–5 times per week) did not change. A previous RCT showed that training of lower limbs, such as walking in addition to normal training, significantly improved walking ability as compared to the group that added 30 minutes of upper limb training or did not do any additional training.[20] In the meta-analysis, increasing the momentum of the lower limbs has been reported to improve gait speed and endurance. [6 21] Therefore, an insufficient trial period could lead to a failure to show the effectiveness of obstacle avoidance training alone.

A second reason would be an insufficient amount of training in the intervention, as well as the lack of well-designed studies that measured relevant outcomes such as fall incidence or composite gait ability. Indeed, no research has examined the occurrence rate of falling, and only one study has examined the composite gait ability. In addition, the obstacle avoidance ability (e.g., success rates, avoidance reaction time, and foot clearance) was not measured in the selected RCT studies for individuals with stroke. A previous systematic review for the elderly showed that the effect of physical training was evaluated by obstacle avoidance ability.[22] A previous observational studies of individuals with stroke reported that obstacle crossing training led to improvement in obstacle avoidance ability as one aspect of the gait adaptability training of individuals with stroke.[23] However, in this systematic review and meta-analysis, no outcome from the obstacle avoidance performance was reported. For these reasons, the present study suggests that obstacle avoidance training alone may have little or no effect.

Study Limitations

The limitation on the conclusion of this research is that most studies had a high or unclear risk of bias. Another limitation was the small number of RCT studies. Although a well-designed study[8] showed an improvement in gait endurance and objective balance ability, the obstacle avoidance training group was not superior to the control group in this systematic review and meta-analysis. From these results, it is difficult to determine whether there is an influence on the improvement of walking ability and balance ability. In the future, trials with a low risk of bias need to be accumulated to verify our findings. Since the purpose of rehabilitation is to improve walking ability under various environmental constraints, it is necessary to confirm the effect of obstacle avoidance training other than step over training. Recently, an observational study reported that the participants walked through narrow apertures.[24] In the future, it is desirable to conduct RCT studies of the obstacle avoidance training of walking through apertures, including the occurrence rate of falling, and obstacle avoidance ability in the outcomes.

As a clinical limitation, obstacle avoidance training as a single task is not useful from best available evidence, and it is better to consider other interventions, such as using combinations or increasing the amount of walking training.

Conclusions

This review shows that obstacle avoidance training, when tested alone, in individuals with stroke may have little or no effect. The reasons for failure to find the effectiveness of obstacle training alone would be the insufficient amount of training in the intervention and the lack of well-designed studies that measured relevant outcomes such as fall incidence, composite gait abilities, and obstacle avoidance abilities. Further

research is required to identify the effect of obstacle avoidance training alone.

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Contributors: DM, YK, MB, YT, and YH conceived the study. The protocol manuscript was drafted by DM, and revised by all authors. DM and YK designed the search strategies, and DM and SO will perform the search. DM and SO will screen studies for inclusion, extract data and assess the risk of bias of included studies. YK will arbitrate disagreements between reviewers. DM, SO and YK will analyze and interpret the data. All authors have provided conceptual and/or methodological expertise. All authors have contributed to the critical revision of this manuscript for important intellectual content. All authors agree to be accountable for all aspects of the work and have read and approved the final manuscript.

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Data sharing statement: Additional data from this study are available upon request to corresponding authors via e-mails.

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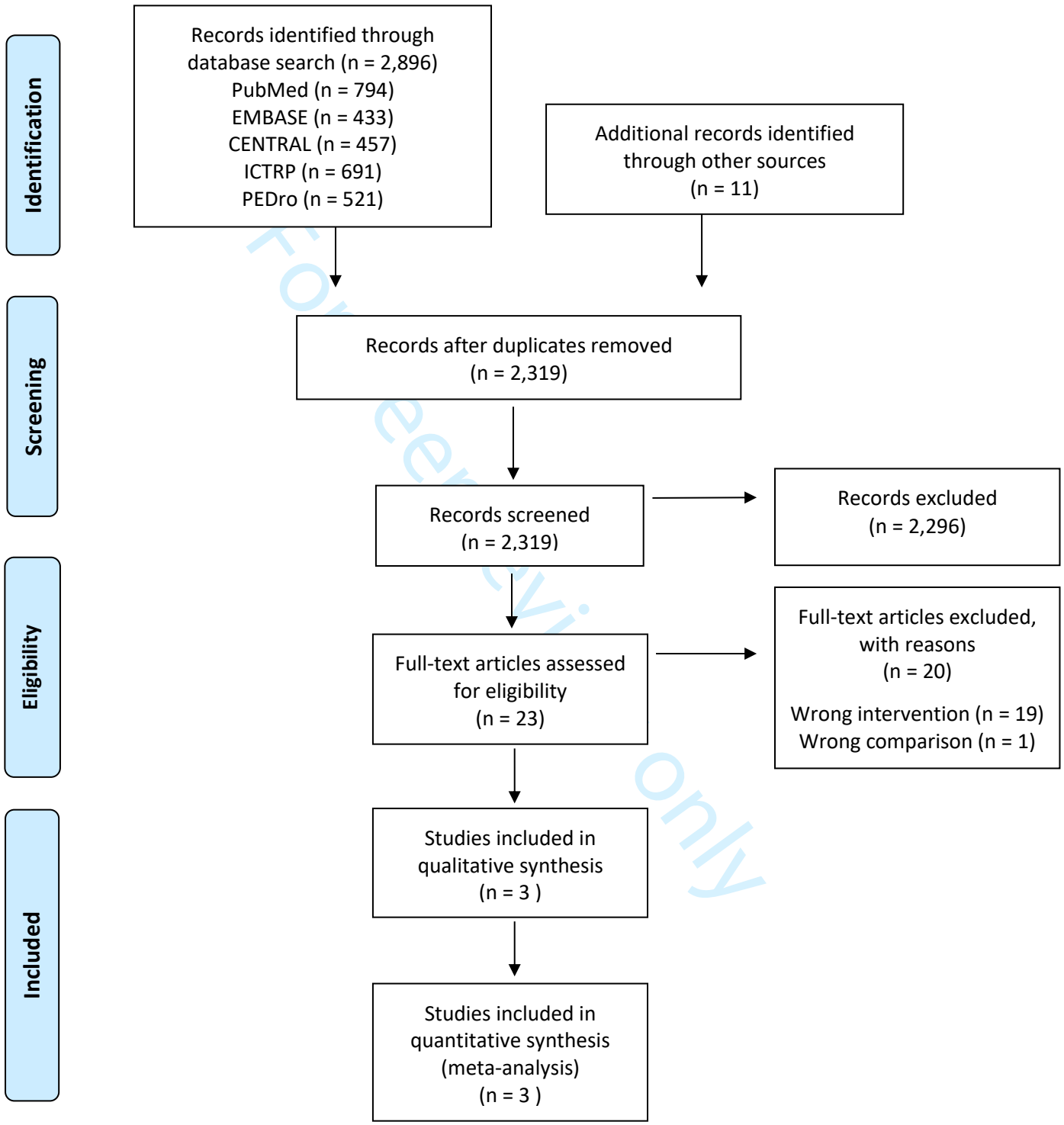
Figure Legends

Fig. 1. Preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow diagram

Fig. 2. Effect of training with obstacle avoidance on gait speed

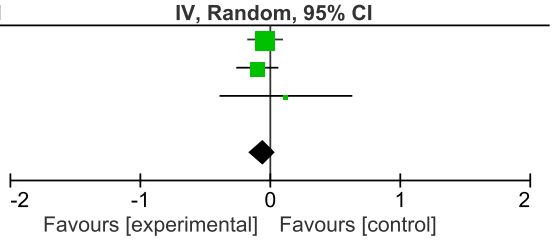
Fig. 3. Effect of training with obstacle avoidance on subjective balance ability (ABC scale)

Fig 1.



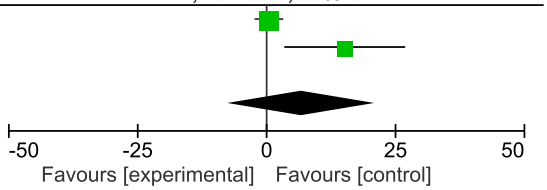
Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Jeong 2016	0.91	0.23	15	0.95	0.14	14	55.7%	-0.04 [-0.18, 0.10]
Load 2006	0.61	0.17	9	0.71	0.18	9	40.3%	-0.10 [-0.26, 0.06]
Yang 2008	0.85	0.31	11	0.73	0.73	9	4.0%	0.12 [-0.39, 0.63]
Total (95% CI)			**35**			**32**	**100.0%**	**-0.06 [-0.16, 0.04]**

Heterogeneity: Tau² = 0.00; Chi² = 0.79, df = 2 (P = 0.67); I² = 0%
Test for overall effect: Z = 1.10 (P = 0.27)



Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Jeong 2016	63.02	3.01	15	62.58	4.45	14	57.8%	0.44 [-2.34, 3.22]
Yang 2008	87.38	6.81	11	72.23	16.86	9	42.2%	15.15 [3.42, 26.88]
Total (95% CI)			**26**			**23**	**100.0%**	**6.65 [-7.59, 20.89]**

Heterogeneity: Tau² = 89.28; Chi² = 5.72, df = 1 (P = 0.02); I² = 83%
Test for overall effect: Z = 0.91 (P = 0.36)



PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	#1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	#2-4
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	#5-6
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	#5-6
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	#6
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	#7
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	#6-7
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	supplementary material
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	#7
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	#7-8
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	#7-8
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	#8
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	#8
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	#8-9

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	#9
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	#9
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	#10-11
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	#11
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	#11-12
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	#12-13
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	#12-13
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	#12
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	#12
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	#13-14
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	#14-15
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	#15
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	#16

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: www.prisma-statement.org.

Appendix. Search Strategy

MEDLINE via PubMed	Search Date: Dec/18/2018	No. trials
#1	cerebrovascular disorders[mh]	340098
#2	stroke [tiab]	214501
#3	poststroke[tiab]	4481
#4	post-stroke[tiab]	7607
#5	cva[tiab]	2562
#6	apoplex* [tiab]	3051
#7	apoplexy* [tiab]	2951
#8	SAH	11418
#9	#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8	447589
#10	obstacle*[tiab]	42292
#11	avoidance*[tiab]	63634
#12	task*[tiab]	326509
#13	circuit*[tiab]	111076
#14	#10 OR #11 OR #12 OR #13	526921
#15	Exercise[mh]	172629
#16	Exercise therapy[mh]	44691
#17	rehabilitation[mh]	280813
#18	Physical Fitness[mh]	26565
#19	physical therapy modalities[mh]	140062
#20	#15 OR #16 OR #17 OR #18 OR #19	450023
#21	rehabilitation[tiab]	148672
#22	physical fitness[tiab]	8980
#23	training[tiab]	358168
#24	mobilization[tiab]	48140
#25	mobilisation[tiab]	5339
#26	physical therapy[tiab]	18559
#27	physiotherapy[tiab]	17248
#28	treadmill[tiab]	29617
#29	#21 OR #22 OR #23 OR #24 OR #25 OR #26 OR #27 OR #28	593233
#30	#20 OR #29	916879
#31	#14 AND #30	58502
#32	#9 AND #31	3671
#33	randomized controlled trial[pt]	473479
#34	controlled clinical trial[pt]	561431
#35	randomized[tiab]	463598

#36	placebo[tiab]	199269
#37	clinical trials as topic[mesh: noexp]	185546
#38	randomly[tiab]	302662
#39	trial[ti]	191297
#40	#33 OR #34 OR #35 OR #36 OR #37 OR #38 OR #39	1195880
#41	animals[mh] NOT humans[mh]	4525626
#42	#40 NOT #41	1100461
#43	#32 AND #42	794

Embase via Elsevier	Dec/18/2018	No. trials
S1	(EMB.EXACT.EXPLODE("cerebrovascular disease"))	610770
S2	(ab(stroke) OR ti(stroke))	338926
S3	(ab(poststroke) OR ti(poststroke))	5825
S4	(ab(post-stroke) OR ti(post-stroke))	14810
S5	(ab(cva) OR ti(cva))	5705
S6	(ab(apoplex*) OR ti(apoplex*))	4311
S7	(ab(SAH) OR ti(SAH))	14060
S8	S7 OR S6 OR S5 OR S4 OR S3 OR S2 OR S1	733656
S9	(ab(obstacle*) OR ti(obstacle*))	53177
S10	(ab(avoidance*) OR ti(avoidance*))	84655
S11	(ab(task*) OR ti(task*))	401172
S12	(ab(circuit*) OR ti(circuit*))	133632
S13	S12 OR S11 OR S10 OR S9	651421
S14	EMB.EXACT("physiotherapy")	91246
S15	EMB.EXACT.EXPLODE("exercise")	367581
S16	EMB.EXACT.EXPLODE("kinesiotherapy")	79363
S17	EMB.EXACT("rehabilitation")	273604
S18	(EMB.EXACT("occupational therapy"))	23582
S19	(EMB.EXACT.EXPLODE("feedback system"))	131460
S20	(EMB.EXACT("joint mobilization"))	1212
S21	S20 OR S19 OR S18 OR S17 OR S16 OR S15 OR S14	830974
S22	(ab(rehabilitation) OR ti(rehabilitation))	213069
S23	(ab("physical fitness") OR ti("physical fitness"))	11052
S24	(ab(training) OR ti(training))	483139
S25	(ab(mobili*ation) OR ti(mobili*ation))	73822
S26	(ab("physical therapy") OR ti("physical therapy"))	25118
S27	(ab(physiotherapy) OR ti(physiotherapy))	31310
S28	(ab(treadmill) OR ti(treadmill))	38903
S29	S28 OR S27 OR S26 OR S25 OR S24 OR S23 OR S22	812943
S30	S29 OR S21	1348815
S31	S30 AND S13 AND S8	5748
S32	(EMB.EXACT("double blind procedure"))	162431
S33	(ab(double NEAR/1 blind*) OR ti(double NEAR/1 blind*))	198715
S34	(ab(placebo*) OR ti(placebo*))	287000
S35	(ab(blind*) OR ti(blind*))	394051

S36	S35 OR S34 OR S33 OR S32	566534
S37	S36 AND S31	433

CENTRAL	Nov/27/2017	No. trials
#1	cerebrovascular disease	7564
#2	stroke	54497
#3	poststroke	3367
#4	post-stroke	3131
#5	cva	509
#6	apoplex*	505
#7	SAH	906
#8	#1 or #2 or #3 or #4 or #5 or #6 or #7	57849
#9	obstacle*	1374
#10	avoidance*	4997
#11	task*	29218
#12	circuit*	3773
#13	#9 or #10 or #11 or #12	38053
#14	physiotherapy	10877
#15	exercise	70707
#16	kinesiotherapy	2422
#17	rehabilitation	46793
#18	occupational therapy	5089
#19	feedback system	5032
#20	joint mobilization	919
#21	#14 or #15 or #16 or #17 or #18 or #19 or #20	114870
#22	rehabilitation	46793
#23	"physical fitness'	6746
#24	training	62855
#25	mobili$ation	10
#26	"physical therapy'	42478
#27	physiotherapy	10877
#28	treadmill	6453
#29	#22 or #23 or #24 or #25 or #26 or #27 or #28	131896
#30	#21 or #29	167041
#31	#8 and #13 and #30	2017
#32	(double next/1 blind*) or placebo*:ab,ti or blind*:ab,ti	371794
#33	#31 and #32	790
	Trials	457

ICTRP	Dec/18/2018	No. trials
#1	obstacle* OR avoidance*	538
#2	task oriented OR circuit training	153
Total		691

PEDro		Dec/18/2018	No. trials
#1	tiab	obstacle*	80
#2	tiab	avoidance*	220
#3	tiab	circuit*	221
Total			521

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Obstacle avoidance training in individuals with stroke: a systematic review and meta-analysis

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Keywords:	Stroke < NEUROLOGY, REHABILITATION MEDICINE, MEDICAL EDUCATION & TRAINING

Obstacle avoidance training in individuals with stroke: a systematic review and meta-analysis

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(2867 words)

Abstract

Objectives: To determine evidence that obstacle avoidance training alone is effective in helping improve the locomotor ability of individuals with stroke.

Design: Systematic review and meta-analysis.

Setting: MEDLINE, EMBASE, CENTRAL, ICTRP, and PEDro were searched until December 2018. Two independent reviewers extracted data. Outcome measurement data were subjected to meta-analyses using random-effects models. Data syntheses were

conducted using RevMan 5.3. The certainty of evidence was determined using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach.

Participants: Papers that focused on participants with stroke and performed the usual gait training and those that included the adaptive locomotor training.

Primary and secondary outcome measures: Primary outcomes were gait speed, composite gait ability, and objective balance ability. Secondary outcomes were subjective balance ability, gait endurance, and fall incidence.

Results: Two studies with a total of 49 participants were used as data sources for the meta-analysis. The gait speed in the obstacle avoidance training was not higher than that in the control group (mean difference [MD] 0.03, 95% confidence interval [CI] [−0.11, 0.16], P = 0.51). The certainty of evidence was very low. Moreover, the subjective balance ability (activities-specific balance confidence scale) showed no significant difference between the intervention and control groups (MD 6.65, 95% CI [−7.59, 20.89], P = 0.36), but with extreme certainty of evidence.

Conclusions: This study suggests that obstacle avoidance training may have little or no effect on individuals with stroke. The failure to find the effectiveness of obstacle avoidance training alone would be caused by the insufficient amount of training in the

intervention, as well as the lack of well-designed studies that measured relevant outcomes.

PROSPERO registration number: CRD42017060691

Keywords: stroke, obstacle avoidance, systematic review, meta-analysis

Strengths and limitations of this study

This is a systematic review and meta-analysis of evidence on the effects of obstacle avoidance training in individuals who have suffered stroke.

This systematic review was conducted based on the Cochrane Handbook and the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines.

The literature search and study selection, data extraction, and risk of bias assessment were conducted by two independent reviewers.

This study is limited due to the insufficient amount of training in the intervention, and the lack of well-designed studies that measured relevant outcomes.

Introduction

Individuals with stroke often have impaired walking abilities, primarily due to motor paralysis on one side of the body.[1-3] They also have difficulty maintaining balance, particularly when adaptive locomotor adjustments in response to environmental properties are necessary (e.g., obstacle avoidance).[4] In fact, the risk of falling is likely increased when individuals with stroke avoid an obstacle.[5-7] Therefore, their walking ability should be improved under various environmental constraints through rehabilitation.

Rehabilitation after a stroke involves correct recognition of both lost and retained functions. It is also designed to reprogram the brain by relearning through repetitive task training.[8] The mixed task-oriented circuit class training, including obstacle avoidance training, may promote relearning of gait.[9] A previous study demonstrated that walking and task-oriented training related to walking, such as obstacle avoidance training, improved both the step distance and walking speed,[9] thus reducing the length of hospital stay.[10] Obstacle avoidance training has been performed as part of the circuit class training, and its effect was reported in this systematic review.[9]

Gait training with adaptive locomotion training, such as obstacle avoidance, is usually selected in a clinical setting. Several studies supporting the effectiveness of obstacle avoidance training were conducted for participants with chronic stroke without combining with any other types of training, using a randomized controlled design.[11-14] Furthermore, a systematic review study also showed the effectiveness of obstacle avoidance training combined with other circuit training.[9] However, the effects produced in the absence of adaptive locomotion training (i.e., the intervention effect produced from the usual gait training) are controversial. To eliminate this issue, whether the sole adaptive

locomotion training would lead to improved gait ability is investigated in this study. The search for randomized controlled trials (RCTs) on obstacle avoidance training for individuals with stroke was conducted to examine its efficacy by comparison with the usual approaches. Based on these results, obstacle avoidance training was found effective in helping individuals with stroke improve their locomotor ability.

Methods

The protocol in this study was registered in PROSPERO (CRD42017060691).[15] The systematic review was conducted based on the Cochrane Handbook[16 17] and the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines.[18] The systematic review and meta-analysis were assessed in accordance with the PRISMA checklist (see supplementary table).[19]

The following research question was used: "In participants with stroke, does obstacle avoidance training result in an improved, clinically relevant outcome compared with the usual care without obstacle avoidance training?"

Data sources and searches

Systematic searches were conducted in four academic databases: MEDLINE, EMBASE, CENTRAL, and PEDro (all searched on December 18, 2018). Trials in the ICTRP were searched on December 18, 2018. These processes are presented in more detail in online supplementary file 1. References were also searched in accordance with the guidelines of the following organizations: the European Stroke Organization, the American Heart Association/American Stroke Association, and the National Institute for Health and Care Excellence.[20-22]

Study selection

Two independent reviewers (D.M. and S.O.) selected and reviewed the papers, and independently screened the titles and abstracts for the study selection, to determine whether each citation met the inclusion criteria. They assessed eligibility based on a full-text review. The reviewers compared their lists, and any differences in opinion between them were resolved through discussion.

To be eligible for inclusion in this systematic review, papers should (1) focus on participants with various types of strokes (brain ischemia, intracranial hemorrhages, or subarachnoid hemorrhage) and all phases of stroke (acute, subacute, or chronic) individuals and (2) performed the usual gait training and those that included adaptive locomotor training in addition to usual gait training (interventions of any type, intensity, duration, and frequency). Studies with subjects with a disease other than stroke, or who underwent five types of training related to walking, such as circuit class training, were excluded from the study. The control condition was a physical therapy intervention, such as normal walking training for participants with stroke. The exclusion criteria of control conditions were as follows: the control group underwent interventions other than physical therapy if the intervention group did not undergo the intervention. References of extracted articles were also searched, and the authors of each study were conducted to obtain necessary data. The search was limited to published and unpublished RCTs. Crossover trials, cluster randomized trials, non-randomized trials, and observational studies were excluded.

The following primary outcomes were measured: (1) gait speed, measured in a 10-m walking test (10MWT) or during a 6-minute walking test (6MWT); (2) composite gait

ability, measured in a Timed Up and Go test (TUG);[23] and (3) objective balance ability, evaluated by researchers and measured according to the Berg Balance Scale (BBS). Secondary outcomes were subjective balance ability evaluated by participants and measured according to the Activities-specific Balance Confidence scale (ABC); gait endurance, measured in a 6-minute walking test (6MWT); and fall incidence (at six months or one year post-intervention).

Data extraction and quality assessment

Data extraction was performed using a standardized form that included participant characteristics (number of participants, number of patients excluded from the analysis, and settings), the intervention environment setup (obstacle avoidance, other rehabilitation training, and using a virtual reality system), types of outcomes (fall incidence, activities of daily living, gait ability, and balance ability), and training program details (types of exercises, duration, and frequency).

Standard data extraction forms were used by the two reviewers independently. Disagreement over data extraction was resolved through discussion. When the information was inadequate, the study authors were conducted to gather sufficient information.

The risk of bias of the included studies were also evaluated using the Cochrane Risk of Bias Tool.[16 17] Each domain was assessed as high risk, low risk or unclear. Assessments were compared by two reviewers, and any differences in opinion between them were resolved through discussion and arbitration by a third reviewer (Y.K.) if consensus is not met. During the publication bias evaluation, funnel plot asymmetry was not evaluated because the number of studies was <10; rather, publication bias was evaluated by

searching the clinical trial registry.

Data synthesis and analysis

For continuous outcomes (gait speed, TUG, BBS, ABC, and 6MWT), the mean difference (MD) with 95% confidence interval (CI) was calculated. The MD was used when data, including meta-analyses, were derived from the same indicators. We originally planned to use SMD in PROSPERO because the outcomes could be on a different scale; however, MD was adopted because the outcomes were on the same scale. Adverse events were summarized narratively, since the definition of these outcomes varied among studies.

Heterogeneity was assessed by visual inspection of forest plots and calculated I-squared statistic (I-squared values of 0%–40%: might not be important; 30%–60%: may represent moderate heterogeneity; 50%–90%: may represent substantial heterogeneity; 75%–100%: considerable heterogeneity).[16 17] The heterogeneity reason was investigated whenever identified (I-squared statistic> 50%).

Data syntheses were conducted using RevMan 5.3 (RevMan 2014). A meta-analysis was conducted using the random-effects model. MD with 95% CI was calculated in continuous variables. All adverse events were excluded from the meta-analysis. An analysis of exercise versus any other controls was carried out.

A sensitivity analysis was conducted to determine the robustness of the findings. The sensitivity analysis of the primary outcome was planned in the following three ways: (1) restricting the analysis studies to those with a low risk of selection bias, (2) excluding trials with missing data, and (3) converting the random-effects model to a fixed-effects model. Selection bias that may have the largest effect on our research question was

eliminated through the sensitivity analysis, as predefined. Finally, only two RCTs were identified; therefore, other risk of bias did not need to be assessed.

Participant and public involvement

No participants will be involved in this study.

Summary of findings table

The "Summary of findings table" was created using outcomes including gait speed, composite gait ability, objective balance scale, subjective balance scale, and gait endurance (**Table 1**). The five GRADE considerations (study limitations, consistency of effect, imprecision, indirectness, and publication bias) were used to assess the certainty of evidence as it related to studies contributing data to the review of outcomes.[16 17 24 25]

Table 1. Summary of findings.

Outcome (time frame)	No. of patients (studies)	Certainty of evidence (GRADE)	Comparator	Intervention vs. comparator mean difference (95% CI)
Gait speed (m/s) (3 to 4 weeks)	49 (2 RCT)	⊕⊖⊖⊖ Very low [abc]	The mean gait speed after treadmill walking training without obstacle-crossing in real-life situations ranged from 0.71 to 0.95 m/s.	0.03 m/s (95% CI: −0.11, 0.16) faster in intervention group.
Composite gait ability TUG (sec) (4 weeks)	29 (1 RCT)	⊕⊕⊖⊖ Low [ab]	The mean time of TUG after treadmill walking training without obstacle-crossing in real-life situations was 15.37 s.	0.15 s (95% CI: −3.95, 4.25) faster in intervention group.
Objective balance ability BBS score (4 weeks) Scale:0 to 56	29 (1 RCT)	⊕⊕⊖⊖ Low [ab]	The mean score of BBS after treadmill walking training without obstacle-crossing was 46.14.	−0.03 score (95% CI: −2.01, 1.95) higher in intervention group.

Subjective balance ability ABC score (3 to 4 weeks) Scale: 0 to 100	49 (2 RCT)	⊕⊖⊖⊖ Very low [abc]	The mean score of ABC after treadmill walking training without obstacle-crossing in real-life situations ranged from 62.58 to 72.23.	−6.67 score (95% CI: −20.97, 7.58) higher in intervention group.
Gait endurance 6MWT (m) (4 weeks)	29 (1 RCT)	⊕⊕⊖⊖ Low [ab]	The mean walking distance after treadmill walking training without obstacle-crossing was 277.43 m.	−5.40 m (95% CI: −36.59, 25.79) longer distance in intervention group.

GRADE Working Group grades of evidence

High quality: Further research is very unlikely to change our confidence in the estimate of effect.

Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.

Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

Very low quality: The estimate is very uncertain.

[a] Participants and personnel were not blinded.

[b] The number of participants was small.

[c] The outcome data were incomplete for 10% of participants.

Results

The process of identifying eligible studies is outlined in **Fig. 1**. Among 2,319 identified papers (including titles and abstracts) from MEDLINE, EMBASE, CENTRAL, ICTRP, PEDro, and manual search using the following search terms: stroke, obstacle, avoidance, task, exercise, rehabilitation, and training. Twenty-three potentially eligible studies were included. After reviewing the full text of 23 potential articles, two papers[13] [14] met the inclusion criteria. Nineteen of the remaining 21 papers were excluded because their studies included several other forms of walking training (e.g., circuit class training

and task-oriented training). One study[11] was excluded because obstacle avoidance training was not compared with regular training; however, both groups participated in obstacle avoidance training (in the water vs. on the ground). Another study[12] was excluded because of the wrong design (a cross-sectional study that assessed participants' characteristics in various environments including obstacle avoidance). There was no ongoing study.

Insert Figure 1 (PRISMA flow)

Two studies[13 14] with a total of 54 participants met the inclusion criteria, and two studies with a total of 49 participants were used as data sources for the meta-analysis (**Fig. 1**). The discrepancy between the number of participants included in the meta-analysis and the total participants is due to some dropouts for the meta-analysis; four dropouts in Yang[14] and one in the Jeong study.[13] The characteristics of each study included are presented in **Table 2**. The risk of bias assessment is outlined in **Table 3**. In both studies, participants were not blinded to the intervention. Moreover, the studies had incomplete outcomes. One study[13] reported an unknown risk of bias from published data; therefore, the authors were contacted. According to the authors, they had planned to measure the three-axis accelerometer and quality of life. However, considering several circumstances and patients' condition, they did not measure the above outcomes.

Table 2. Characteristics of included studies.

Author, Year, Country	Setting	Number of participants (Phases of stroke)	Study type	Intervention (contents, frequency)	Control (standard care)	Outcomes
Yang YR et al., 2008, Taiwan	Exercise laboratory	24 (Chronic) intervention: 12, control:12	Pilot RCT	Virtual reality-based treadmill training: the scenarios consisted of lane walking, street crossing, obstacles striding across, and park stroll. Intervention for 20 minutes/session, 3 sessions a week for 3 weeks.	Treadmill training without virtual reality.	Gait speed (10MWT), community walking time, walking ability questionnaire, and ABC
Jeong YG et al., 2016, Korea	Exercise laboratory	30 (Chronic) intervention: 15, control: 15	Pilot RCT	Treadmill walking with obstacle-crossing in real-life situations. Intervention for 30 min/day, 5 times/week, for 4 weeks.	Treadmill walking without obstacle crossing.	10MWT, 6MWT, BBS, TUG, and ABC

Table 3. Risk of bias assessment in included trials

Trial	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selective reporting
Yang et al. 2008 [14]	Unclear	Low	High	Low	High	Unclear
Jeong et al. 2016 [13]	Low	Low	High	Low	High	Low

Primary outcomes

Pooling revealed that the group who underwent obstacle avoidance training was not superior to the control group in terms of gait speed [MD 0.03, 95% CI (−0.11, 0.16), P = 0.51] (**Fig. 2a**). For gait speed, no heterogeneity was observed ($Tau^2 = 0.00$, $I^2 = 0\%$). Data on composite gait and objective balance abilities were available in one of the three studies. MD (95% CI) of the TUG was 0.15 (−3.95, 4.25) (**Fig. 2b**), and that (95% CI) of the BBS scores was −0.03 (−2.01, 1.95) (**Fig. 2c**). Sensitivity analysis results were approximately the same as the original results (Table 4).

Insert Figure 2

Table 4. Results of the sensitivity analysis for each primary outcome

	Analysis 1: restricting the analyses on studies with low risk of selection bias		Analysis 2: excluding trials imputed with missing data		Analysis 3: converting random-effects model to fixed-effects model	
Primary outcomes	N of trials	Result	N of trials	Result	N of trials	Result
Gait speed	1 RCT (Jeong 2016)	0.04 [−0.10, 0.18]	2 RCTs (Yang 2008, Jeong 2016)	0.03 [−0.11, 0.16]	2 RCTs (Yang 2008, Jeong 2016)	0.03 [−0.11, 0.16]
TUG	1 RCT (Jeong 2016)	0.15 [−3.95, 4.25]	1 RCT (Jeong 2016)	0.15 [−3.95, 4.25]	1 RCT (Jeong 2016)	0.15 [−3.95, 4.25]
BBS	1 RCT (Jeong 2016)	−0.03 [−2.01, 1.95]	1 RCT (Jeong 2016)	−0.03 [−2.01, 1.95]	1 RCT (Jeong 2016)	−0.03 [−2.01, 1.95]

Secondary outcomes

The subjective balance ability (ABC scale) also showed no significant difference between the intervention and control groups (MD −6.67, 95% CI [−20.92, 7.58], P = 0.36) (**Fig. 3a**). Substantial heterogeneity was observed ($Tau^2 = 89.62$, $I^2 = 83\%$). Data on gait endurance were available from one of the two studies,[13] whereas data on fall incidence were not available from any study. The MD (95% CI) of 6MWT was −5.40 (−36.59, 25.79) (**Fig. 3b**).

There were no reports of adverse events during the intervention in any of the three studies.

Insert Figure 3

Discussion

Summary of findings

Two RCT studies that met our criteria were found. The certainty of evidence was low or very low due to serious study limitations and imprecision. The meta-analysis showed that the obstacle avoidance training cannot improve the walking speed or subjective balance ability compared to the normal walking training.

Comparison with literature

There are at least two reasons for the failure to find the effectiveness of obstacle avoidance training alone. First, the amount of training is insufficient for both selected studies. According to a systematic review on circuit class training, the duration of intervention was approximately 60 minutes in a single session, and various walking-related training tasks were continuously performed.[9] In contrast, the duration of obstacle avoidance training was only 20–30 minutes (see **Table 2**). No difference in training frequency (3–5 times per week) was observed between the intervention and training groups. A previous RCT showed that the lower limb training group (walking training in addition to normal training; upper and lower limb training on the functional recovery of activities of daily living or walking training), significantly differed from that of the control group (upper limb training or did not undergo any additional training in addition to normal training) in walking ability.[26] In the meta-analysis, the momentum of the lower limbs has been increased to improve gait speed and endurance.[10 27] Therefore, an insufficient trial period may not show the effectiveness of obstacle avoidance training alone.

The second reason would be the lack of well-designed studies that measured relevant outcomes, such as fall incidence or composite gait ability. Indeed, no research has examined the occurrence rate of falling, and only one study has examined the

composite gait ability. In addition, the obstacle avoidance ability (e.g., success rates, avoidance reaction time, and foot clearance) was not measured in selected RCT for individuals with stroke. A previous systematic review for elderly individuals showed that the effect of physical training was evaluated by obstacle avoidance ability.[28] A previous observational study on individuals with stroke reported that obstacle-crossing training led to improved obstacle avoidance ability as one aspect of the gait adaptability training of individuals with stroke.[29] However, no outcome from the obstacle avoidance performance was reported in this systematic review and meta-analysis. Therefore, this study suggests that obstacle avoidance training alone may have little or no effect on improving walking or balance ability.

Strengths and limitations

The strengths of this study were as follows: the first systematic review and meta-analysis of the evidence on obstacle avoidance training effects in individuals with stroke and its careful and rigorous screening, extraction, and scoring process.

Its limitations were as follows: most studies had a high or unclear risk of bias and the number of RCT studies was small. Although a well-designed study[13] showed an improvement in gait endurance and objective balance ability, the effects in the obstacle avoidance training group were not superior to those in the control group in this systematic review and meta-analysis. Based on these results, determining its influence on improved walking and balance abilities was difficult. Another limitation is that none of the two studies included in this study evaluated obstacle avoidance ability itself (e.g., toe clearance, success rate of obstacle-crossing). Therefore, the intervention effect of obstacle avoidance training may have been masked. In the future, trials with a low risk of bias,

including an assessment of obstacle avoidance itself, should be accumulated to verify our findings. Since rehabilitation aimed to improve walking ability under various environmental constraints, the effect of obstacle avoidance training, other than step over training, should be confirmed. In the future, RCT studies on obstacle avoidance training of walking through apertures, including the occurrence rate of falling, and obstacle avoidance ability in the outcomes, should be conducted.

As a clinical limitation, the obstacle avoidance training as a single task is not useful from best available evidence, and other interventions, such as using combinations or increasing the amount of walking training, should also be considered.[30-32]

Clinical implications and recommendations

Confirming the effects of obstacle avoidance training in participants with stroke is highly clinically important because participants are more likely to fall while avoiding an obstacle. However, none of the outcomes was found to be significantly altered after obstacle avoidance training. We currently recommend that rehabilitation workers allow participants with stroke to practice other walking training as well as obstacle avoidance training.

Conclusions

This review shows that obstacle avoidance training in addition to normal gait training, among individuals with stroke may have little or no effect. The failure of finding the effectiveness of the obstacle training alone may be due to the insufficient amount of training in the intervention and the lack of well-designed studies that measured relevant outcomes, such as fall incidence, composite gait abilities, and obstacle avoidance abilities.

Further research is required to identify the effects of obstacle avoidance training alone.

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Contributors: DM, YK, MB, YT, and HT conceived the study. The protocol manuscript was drafted by DM, and revised by all authors. DM and YK designed the search strategies, and DM and SO performed the searches and screened studies for inclusion, extracted the data, and assessed the risk of bias of included studies. YK arbitrated disagreements between reviewers. DM, SO, and YK analyzed and interpreted the data. All authors have provided conceptual and/or methodological expertise. DM, YK, MB, YT, and TH have contributed to the critical revision of this manuscript for important intellectual content. All authors agree to be accountable for all aspects of the work and have read and approved the final manuscript.

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Patient consent: Not required.

Provenance and peer review: Not commissioned; externally peer reviewed.

Data sharing statement: Our data is not in a repository. All data relevant to the study are included in the article or uploaded as supplementary information. If you want to get

in touch, please contact: muroi.daisuke@kameda.jp.

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Figure Legends

Fig. 1. Preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow diagram

Fig. 2. Primary outcomes

a. Effects of training with obstacle avoidance on gait speed

b. Effects of training with obstacle avoidance on composite gait ability (TUG)

c. Effects of training with obstacle avoidance on objective balance ability (BBS score)

Fig. 3. Secondary outcomes

a. Effects of training with obstacle avoidance on subjective balance ability (ABC scale)

b. Effects of training with obstacle avoidance on gait endurance (6MWT)

Fig 1.

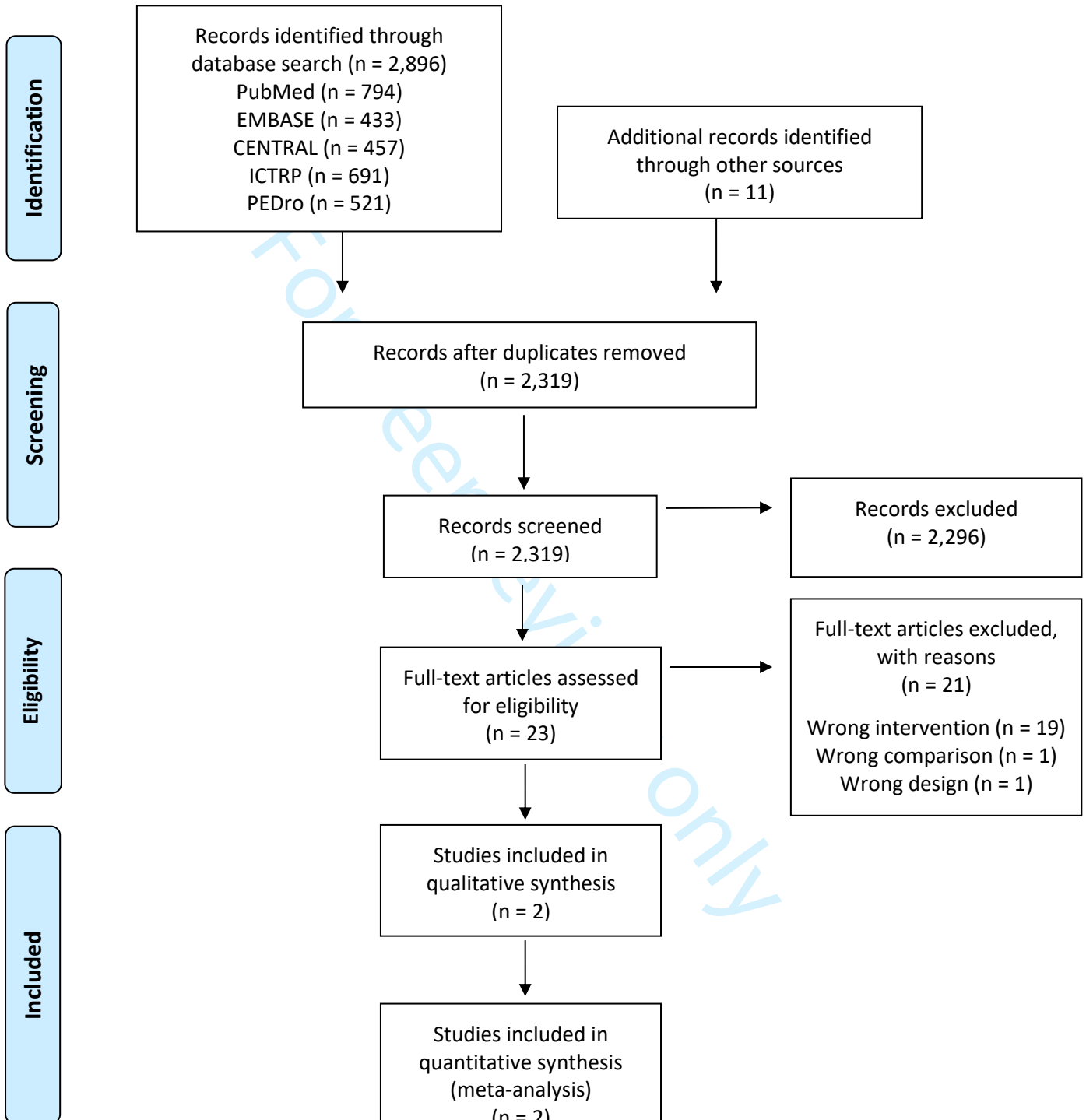
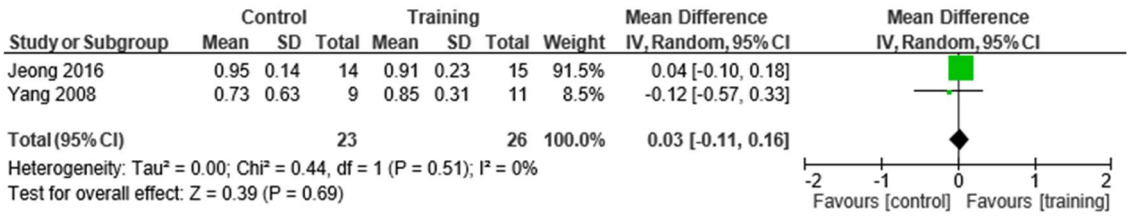
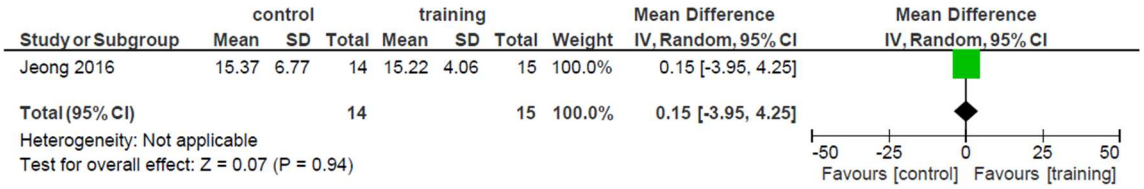


Fig 2.

a.



b.



c.

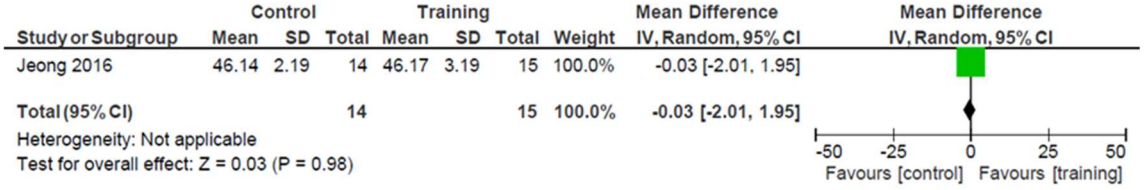
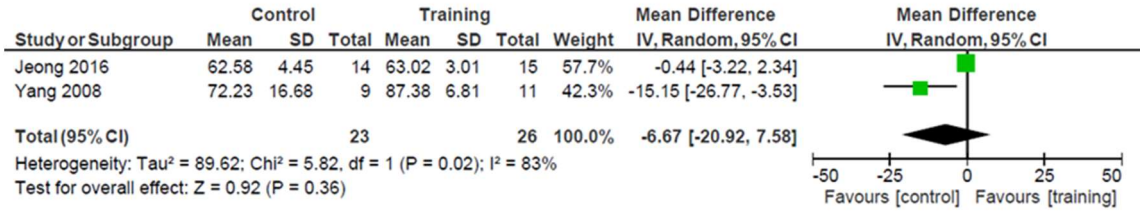
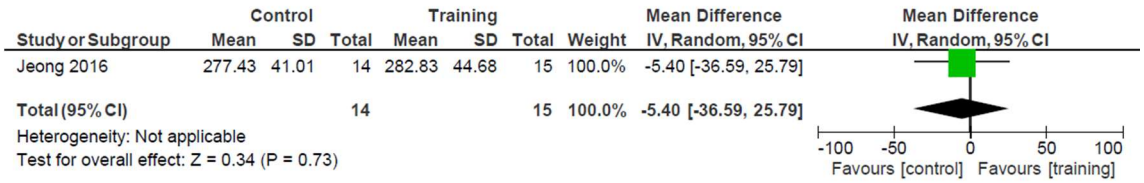


Fig 3.

a.



b.



PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	#1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	#2-4
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	#5-6
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	#5-6
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	#6-7
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	#7-8
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	#6-7
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	supplementary material
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	#7-8
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	#7-8
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	#7-9
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	#9-10
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	#9-10
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	#9-10

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	#9-10
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	#9-10
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	#11-12
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	#12-13
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	#12-13
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	#10-11
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	#13-14
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	#12-13
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	#13-14
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	#14-15
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	#16-17
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	#17-18
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	#18

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: **www.prisma-statement.org**.

Supplementary file 1: Search Strategy

MEDLINE via PubMed	Search Date: Dec/18/2018	No. trials
#1	cerebrovascular disorders[mh]	340098
#2	stroke [tiab]	214501
#3	poststroke[tiab]	4481
#4	post-stroke[tiab]	7607
#5	cva[tiab]	2562
#6	apoplex* [tiab]	3051
#7	apoplexy* [tiab]	2951
#8	SAH	11418
#9	#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8	447589
#10	obstacle*[tiab]	42292
#11	avoidance*[tiab]	63634
#12	task*[tiab]	326509
#13	circuit*[tiab]	111076
#14	#10 OR #11 OR #12 OR #13	526921
#15	Exercise[mh]	172629
#16	Exercise therapy[mh]	44691
#17	rehabilitation[mh]	280813
#18	Physical Fitness[mh]	26565
#19	physical therapy modalities[mh]	140062
#20	#15 OR #16 OR #17 OR #18 OR #19	450023
#21	rehabilitation[tiab]	148672
#22	physical fitness[tiab]	8980
#23	training[tiab]	358168
#24	mobilization[tiab]	48140
#25	mobilisation[tiab]	5339
#26	physical therapy[tiab]	18559
#27	physiotherapy[tiab]	17248
#28	treadmill[tiab]	29617
#29	#21 OR #22 OR #23 OR #24 OR #25 OR #26 OR #27 OR #28	593233
#30	#20 OR #29	916879
#31	#14 AND #30	58502
#32	#9 AND #31	3671
#33	randomized controlled trial[pt]	473479
#34	controlled clinical trial[pt]	561431
#35	randomized[tiab]	463598

#36	placebo[tiab]	199269
#37	clinical trials as topic[mesh: noexp]	185546
#38	randomly[tiab]	302662
#39	trial[ti]	191297
#40	#33 OR #34 OR #35 OR #36 OR #37 OR #38 OR #39	1195880
#41	animals[mh] NOT humans[mh]	4525626
#42	#40 NOT #41	1100461
#43	#32 AND #42	794

Embase via Elsevier	Dec/18/2018	No. trials
S1	(EMB.EXACT.EXPLODE("cerebrovascular disease"))	610770
S2	(ab(stroke) OR ti(stroke))	338926
S3	(ab(poststroke) OR ti(poststroke))	5825
S4	(ab(post-stroke) OR ti(post-stroke))	14810
S5	(ab(cva) OR ti(cva))	5705
S6	(ab(apoplex*) OR ti(apoplex*))	4311
S7	(ab(SAH) OR ti(SAH))	14060
S8	S7 OR S6 OR S5 OR S4 OR S3 OR S2 OR S1	733656
S9	(ab(obstacle*) OR ti(obstacle*))	53177
S10	(ab(avoidance*) OR ti(avoidance*))	84655
S11	(ab(task*) OR ti(task*))	401172
S12	(ab(circuit*) OR ti(circuit*))	133632
S13	S12 OR S11 OR S10 OR S9	651421
S14	EMB.EXACT("physiotherapy")	91246
S15	EMB.EXACT.EXPLODE("exercise")	367581
S16	EMB.EXACT.EXPLODE("kinesiotherapy")	79363
S17	EMB.EXACT("rehabilitation")	273604
S18	(EMB.EXACT("occupational therapy"))	23582
S19	(EMB.EXACT.EXPLODE("feedback system"))	131460
S20	(EMB.EXACT("joint mobilization"))	1212
S21	S20 OR S19 OR S18 OR S17 OR S16 OR S15 OR S14	830974
S22	(ab(rehabilitation) OR ti(rehabilitation))	213069
S23	(ab("physical fitness") OR ti("physical fitness"))	11052
S24	(ab(training) OR ti(training))	483139
S25	(ab(mobili*ation) OR ti(mobili*ation))	73822
S26	(ab("physical therapy") OR ti("physical therapy"))	25118
S27	(ab(physiotherapy) OR ti(physiotherapy))	31310
S28	(ab(treadmill) OR ti(treadmill))	38903
S29	S28 OR S27 OR S26 OR S25 OR S24 OR S23 OR S22	812943
S30	S29 OR S21	1348815
S31	S30 AND S13 AND S8	5748
S32	(EMB.EXACT("double blind procedure"))	162431
S33	(ab(double NEAR/1 blind*) OR ti(double NEAR/1 blind*))	198715
S34	(ab(placebo*) OR ti(placebo*))	287000
S35	(ab(blind*) OR ti(blind*))	394051

S36	S35 OR S34 OR S33 OR S32	566534
S37	S36 AND S31	433

CENTRAL	Nov/27/2017	No. trials
#1	cerebrovascular disease	7564
#2	stroke	54497
#3	poststroke	3367
#4	post-stroke	3131
#5	cva	509
#6	apoplex*	505
#7	SAH	906
#8	#1 or #2 or #3 or #4 or #5 or #6 or #7	57849
#9	obstacle*	1374
#10	avoidance*	4997
#11	task*	29218
#12	circuit*	3773
#13	#9 or #10 or #11 or #12	38053
#14	physiotherapy	10877
#15	exercise	70707
#16	kinesiotherapy	2422
#17	rehabilitation	46793
#18	occupational therapy	5089
#19	feedback system	5032
#20	joint mobilization	919
#21	#14 or #15 or #16 or #17 or #18 or #19 or #20	114870
#22	rehabilitation	46793
#23	"physical fitness'	6746
#24	training	62855
#25	mobili$ation	10
#26	"physical therapy'	42478
#27	physiotherapy	10877
#28	treadmill	6453
#29	#22 or #23 or #24 or #25 or #26 or #27 or #28	131896
#30	#21 or #29	167041
#31	#8 and #13 and #30	2017
#32	(double next/1 blind*) or placebo*:ab,ti or blind*:ab,ti	371794
#33	#31 and #32	790
	Trials	457

ICTRP	Dec/18/2018	No. trials
#1	obstacle* OR avoidance*	538
#2	task oriented OR circuit training	153
Total		691

PEDro		Dec/18/2018	No. trials
#1	tiab	obstacle*	80
#2	tiab	avoidance*	220
#3	tiab	circuit*	221
Total			521

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Obstacle avoidance training for individuals with stroke: a systematic review and meta-analysis

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Obstacle avoidance training for individuals with stroke: a systematic review and meta-analysis

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(2839 words)

Abstract

Objectives: To accumulate evidence that obstacle avoidance training alone is effective in improving the locomotor ability of individuals with stroke

Design: Systematic review and meta-analysis

Setting: MEDLINE, EMBASE, CENTRAL, ICTRP, and PEDro were searched for related information until December 2018. Two independent reviewers extracted data. Outcome measurement data were subjected to meta-analyses using random-effects

models. Data syntheses were conducted using RevMan 5.3, and the certainty of evidence was determined using the Grading of Recommendations Assessment, Development, and Evaluation approach.

Participants: Participants with various types and phases of stroke were included.

Intervention: The usual gait training including obstacle avoidance training (interventions of any type, intensity, duration, and frequency)

Primary and secondary outcome measures: Primary outcomes were gait speed, composite gait ability, and objective balance ability. Secondary outcomes were subjective balance ability, gait endurance, and fall incidence.

Results: Two randomized controlled trials with a total of 49 participants were used as data sources for this study. The obstacle avoidance training (training) group had lower gait speed than the control group [mean difference (MD) 0.03, 95% confidence interval (CI) (−0.11, 0.16), P = 0.51]. Further, the certainty of evidence was very low. The subjective balance ability (Activities-specific Balance Confidence scale) was not significantly different between the training and control groups [MD 6.65, 95% CI (−7.59, 20.89), P = 0.36], and it showed very low certainty of evidence.

Conclusions: Obstacle avoidance training may have little or no effect on individuals with stroke. The failure to find the effectiveness of obstacle avoidance training alone is

possibly attributable to the insufficient amount of training in the intervention and the lack of well-designed studies that measured relevant outcomes.

PROSPERO registration number: CRD42017060691

Keywords: stroke, obstacle avoidance, systematic review, meta-analysis

Strengths and limitations of this study

This is a systematic review and meta-analysis on evidence of the effects of obstacle avoidance training on individuals with stroke.

This study was conducted based on the Cochrane Handbook and the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines.

Literature search and study selection, data extraction, and risk of bias assessment were conducted by two independent reviewers.

This study is limited due to the insufficient amount of training in the intervention, and the lack of well-designed studies that measured relevant outcomes.

Introduction

Individuals with stroke often have impaired gait abilities primarily due to motor paralysis of one side of the body.[1-3] They also have difficulty in maintaining balance, particularly when adaptive locomotor adjustments are necessary in response to environmental properties (e.g., obstacle avoidance).[4] In fact, the risk of falling likely increases when individuals with stroke avoid an obstacle.[5-7] Therefore, their gait ability should be improved under various environmental constraints through rehabilitation.

Stroke rehabilitation involves correct recognition of both lost and retained functions. It is also designed to reprogram the brain by relearning through repetitive task training.[8] The mixed task-oriented circuit class training, including obstacle avoidance training, may promote gait relearning.[9] A previous study demonstrated that gait training and task-oriented training related to gait, such as obstacle avoidance training, improved step distance and gait speed,[9] thus reducing the length of hospital stay.[10] Obstacle avoidance training has been performed as part of the circuit class training, and its effect has been reported in a systematic review.[9]

Gait training with adaptive locomotor training, such as obstacle avoidance training, is usually selected in a clinical setting. Several randomized controlled trials (RCTs) supporting the effectiveness of obstacle avoidance training have been conducted on participants with chronic stroke without combining with any other type of training.[11-14] Furthermore, a systematic review showed the effectiveness of obstacle avoidance training combined with other circuit training.[9] However, the effects produced in the absence of adaptive locomotor training (i.e., the intervention effect of the usual gait training) are controversial. To eliminate this issue, whether adaptive locomotor training alone can lead to improved gait ability was investigated in this study. The search for RCTs on obstacle

avoidance training for individuals with stroke was conducted to examine its efficacy compared with that of the usual gait training approaches. This review aimed to collect evidence on whether obstacle avoidance training alone is effective in improving the locomotor ability of individuals with stroke.

Methods

The study protocol has been registered in PROSPERO (CRD42017060691).[15] This systematic review and meta-analysis was conducted based on the Cochrane Handbook[16] [17] and the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines.[18] This study was performed in accordance with the PRISMA checklist (online supplementary table).[19]

The following research question was used: "Regarding individuals with stroke, does obstacle avoidance training alone result in an improved, clinically relevant outcome compared with the usual care without obstacle avoidance training?"

Data sources and searches

Systematic searches were conducted using four academic databases: MEDLINE, EMBASE, CENTRAL, and PEDro (all searched on December 18, 2018). RCTs in ICTRP were searched on December 18, 2018. These processes are presented in more detail in online supplementary file 1. The references of the extracted studies were also searched in accordance with the guidelines of the following organizations: European Stroke Organization, American Heart Association/American Stroke Association, and National Institute for Health and Care Excellence.[20-22]

Study selection

Two independent reviewers (DM and SO) selected and reviewed studies, and they independently screened the titles and abstracts for study selection to determine whether each citation met the inclusion criteria. They assessed eligibility based on a full-text review. The reviewers compared their lists, and any differences in opinion between them were resolved through discussion.

To be eligible for inclusion in this systematic review, studies had to (1) focus on participants with various types of strokes (brain ischemia, intracranial hemorrhage, or subarachnoid hemorrhage) and on all phases of stroke in affected individuals (acute, subacute, or chronic) and (2) perform the usual gait training and include adaptive locomotor training in addition to the usual gait training (interventions of any type, intensity, duration, and frequency; training group). Studies with participants with a disease other than stroke or who underwent multiple gait-related training other than obstacle avoidance training, such as circuit class training, were excluded from the study.

The control criterion was a physical therapy intervention such as usual gait training for participants with stroke (control group). The exclusion criteria for the control group were as follows. The control group underwent interventions other than physical therapy if the training group did not undergo the study intervention. The references of extracted articles were also searched, and the authors of each study were contacted to obtain necessary data. The search was limited to published and unpublished RCTs. Crossover trials, cluster randomized trials, nonrandomized trials, and observational studies were excluded.

The following primary outcomes were measured: (1) gait speed, measured using the 10-m walk test (10MWT) or 6-min walk test (6MWT); (2) composite gait ability,

measured using the Timed Up and Go test (TUG);[23] and (3) objective balance ability, evaluated by researchers and measured according to the Berg Balance Scale (BBS). Secondary outcomes were subjective balance ability, evaluated by participants and measured according to the Activities-specific Balance Confidence scale (ABC); gait endurance, measured using 6MWT; and fall incidence, measured at postintervention 6 months or 1 year.

Data extraction and quality assessment

Data extraction was performed using a standardized form that included participant characteristics (number of participants, number of patients excluded from the analysis, and setting), the intervention environment setup (obstacle avoidance, other rehabilitation training, and using a virtual reality system), types of outcomes (fall incidence, activities of daily living, gait ability, and balance ability), and training program details (types of exercises, duration, and frequency).

Standard data extraction forms were used by the two independent reviewers. Disagreement over data extraction was resolved through discussion. When the information was inadequate, the study authors were contacted to gather sufficient information.

The risk of bias of the included studies was also evaluated using the Cochrane Risk of Bias Tool.[16] [17] Each domain was assessed as high risk, low risk, or unclear. Assessments were compared by the two independent reviewers, and any differences in opinion between them were resolved through discussion and arbitration by a third reviewer (YK) if consensus was not met. During publication bias evaluation, funnel plot asymmetry was not evaluated because the number of studies was <10; rather, publication

bias was evaluated by searching the clinical trial registry.

Data synthesis and analysis

For continuous outcomes (gait speed, TUG, BBS, ABC, and 6MWT), the mean difference (MD) with 95% confidence interval (CI) was calculated. MD was used when data, including meta-analysis data, were derived from the same indicators. We originally planned to use SMD in PROSPERO because the outcomes could be measured on a different scale; however, MD was adopted because the outcomes were measured on the same scale. Adverse events are summarized narratively because the definition of these outcomes varied among studies.

Heterogeneity was assessed by visual inspection of forest plots and calculated using I-squared statistic (I-squared values of 0%–40%: might not be important; 30%–60%: may represent moderate heterogeneity; 50%–90%: may represent substantial heterogeneity; and 75%–100%: considerable heterogeneity).[16 17] Reasons for heterogeneity were investigated whenever identified (I-squared statistic > 50%).

Data syntheses were conducted using RevMan 5.3 (RevMan 2014). A meta-analysis was conducted using a random-effects model. All adverse events were excluded from the meta-analysis. Further, an analysis of intervention versus any other controls was conducted.

Sensitivity analysis was conducted to determine the robustness of the findings. The sensitivity analysis of the primary outcome was planned in the following ways: (1) restricting analysis studies to those with a low risk of selection bias, (2) excluding trials with missing data, and (3) converting the random-effects model to a fixed-effects model. Selection bias that may have the largest effect on our research question was eliminated

through sensitivity analysis as predefined. Finally, only 2 RCTs were identified; therefore, other risks of bias did not have to be assessed.

Participant and public involvement

No participants were involved in this study.

Ethical consideration

Institutional review board approval was not necessary because all the data were retrieved from public databases.

Results

Summary of findings

The "Summary of findings table" was created using outcomes including gait speed, composite gait ability, objective balance ability, subjective balance ability, and gait endurance (**Table 1**). The five GRADE considerations (study limitations, consistency of effect, imprecision, indirectness, and publication bias) were used to assess the certainty of evidence because they are related to studies contributing data for the review of outcomes.[16 17 24 25]

Table 1. Summary of findings.

Outcome (time frame)	Number of participants (studies)	Certainty of evidence (GRADE)	Comparator	Training vs. control Mean difference (95% CI)
Gait speed (m/s) (3–4 weeks)	49 (2 RCT)	⊕⊖⊖⊖ Very low [abc]	The mean gait speed after treadmill gait training without obstacle crossing	0.03 m/s (95% CI: −0.11, 0.16) faster in the training group

			in real-life situations ranged from 0.71 to 0.95 m/s.	
Composite gait ability TUG (s) (4 weeks)	29 (1 RCT)	⊕⊕⊖⊖ Low [ab]	The mean time of TUG after treadmill gait training without obstacle crossing in real-life situations was 15.37 s.	0.15 s (95% CI: −3.95, 4.25) faster in the training group
Objective balance ability BBS score (4 weeks) Scale: 0–56	29 (1 RCT)	⊕⊕⊖⊖ Low [ab]	The mean score of BBS after treadmill gait training without obstacle crossing was 46.14.	−0.03 score (95% CI: −2.01, 1.95) higher in the training group
Subjective balance ability ABC score (3–4 weeks) Scale: 0–100	49 (2 RCT)	⊕⊖⊖⊖ Very low [abc]	The mean score of ABC after treadmill gait training without obstacle crossing in real-life situations ranged from 62.58 to 72.23.	−6.67 score (95% CI: −20.97, 7.58) higher in the training group
Gait endurance 6MWT (m) (4 weeks)	29 (1 RCT)	⊕⊕⊖⊖ Low [ab]	The mean gait distance after treadmill gait training without obstacle crossing was 277.43 m.	−5.40 m (95% CI: −36.59, 25.79) longer distance in the training group

GRADE Working Group grades of evidence

High quality: Further research is very unlikely to change our confidence in the estimate of effect.

Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.

Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

Very low quality: The estimate is very uncertain.

[a] Participants and personnel were not blinded.

[b] The number of participants was small.

[c] The outcome data were incomplete for 10% of participants.

PRISMA flow diagram

The process of identifying eligible studies is outlined in **Fig. 1**. A total of 2,319 articles (including titles and abstracts) were identified from MEDLINE, EMBASE,

CENTRAL, ICTRP, PEDro, and manual search using the following search terms: stroke, obstacle, avoidance, task, exercise, rehabilitation, and training. Twenty-three potentially eligible articles were included. After reviewing the full text of these 23 potential articles, 2 articles[13 14] met the inclusion criteria. Nineteen of the remaining 21 articles were excluded because their studies included several other forms of gait training (e.g., circuit class training and task-oriented training). From the remaining 2 studies, 1[11] was excluded because obstacle avoidance training was not compared with the usual gait training; however, both groups participated in obstacle avoidance training (in water vs. on the ground). The other study[12] was excluded because of a wrong design (a cross-sectional study that assessed participant characteristics in various environments including obstacle avoidance). Moreover, there was no related ongoing study.

Insert Figure 1 (PRISMA flow)

Two articles[13 14] with a total of 54 participants met the inclusion criteria, and 2 articles with a total of 49 participants were used as data sources for the present meta-analysis (**Fig. 1**). The discrepancy between the number of participants included in the meta-analysis and the total number of participants is due to some dropouts from the meta-analysis: 4 dropouts from the study by Yang[14] and 1 from the study by Jeong.[13] The characteristics of each included study are presented in **Table 2**. The details of the risk of bias assessment are outlined in **Table 3**. In both studies, participants were not blinded to the intervention. Moreover, the studies had incomplete outcomes. One study[13] reported an unknown risk of bias from published data; therefore, the authors were contacted. According to the authors, they had planned to measure the three-axis accelerometer and

quality of life. However, considering several circumstances and patient conditions, they did not measure these outcomes.

Table 2. Characteristics of the included trials.

Author, Year, Country	Setting	Number of participants (phases of stroke)	Study type	Training (contents, frequency)	Control (standard care)	Outcomes
Yang et al., 2008,[14] Taiwan	Exercise laboratory	24 (chronic) training: 12, control: 12	Pilot RCT	Virtual reality-based treadmill training: scenarios comprised lane gait, street crossing, obstacles striding across, and park stroll. Intervention for 20 min/session, 3 sessions/ week for 3 weeks	Treadmill training without virtual reality	Gait speed (10MWT), community gait time, Walking Ability Questionnaire, and ABC
Jeong et al., 2016,[13] Korea	Exercise laboratory	30 (chronic) training: 15, control: 15	Pilot RCT	Treadmill gait with obstacle crossing in real-life situations. Intervention for 30 min/day, 5 times/week, for 4 weeks.	Treadmill gait without obstacle crossing	10MWT, 6MWT, BBS, TUG, and ABC

Table 3. Risk of bias assessment in the included trials

Trial	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selective reporting
Yang et al., 2008[14]	Unclear	Low	High	Low	High	Unclear
Jeong et al., 2016[13]	Low	Low	High	Low	High	Low

Primary outcomes

Pooling revealed that the group that underwent obstacle avoidance training (training group) was not superior to the control group in terms of gait speed [MD 0.03, 95% CI (−0.11, 0.16), P = 0.51] (**Fig. 2a**). Regarding gait speed, no heterogeneity was observed (Tau^2 = 0.00, I^2 = 0%). Data on composite gait and objective balance abilities were available in 1 of the 3 RCTs. MD (95% CI) for TUG was 0.15 (−3.95, 4.25) (**Fig. 2b**) and

that (95% CI) for the BBS scores was −0.03 (−2.01, 1.95) (**Fig. 2c**). Sensitivity analysis results were approximately the same as the original results (Table 4).

Insert Figure 2

Table 4. Results of the sensitivity analysis for each primary outcome

	Analysis 1: restricting the analyses on studies with low risk of selection bias		Analysis 2: excluding trials imputed with missing data		Analysis 3: converting a random-effects model to a fixed-effects model	
Primary outcomes	Number of RCTs	Result	Number of RCTs	Result	Number of RCTs	Result
Gait speed	1 RCT (Jeong, 2016[13])	0.04 (−0.10, 0.18)	2 RCTs (Yang, 2008[14], Jeong, 2016[13])	0.03 (−0.11, 0.16)	2 RCTs (Yang, 2008[14], Jeong, 2016[13])	0.03 (−0.11, 0.16)
TUG	1 RCT (Jeong, 2016[13])	0.15 (−3.95, 4.25)	1 RCT (Jeong, 2016[13])	0.15 (−3.95, 4.25)	1 RCT (Jeong, 2016[13])	0.15 (−3.95, 4.25)
BBS	1 RCT (Jeong, 2016[13])	−0.03 (−2.01, 1.95)	1 RCT (Jeong, 2016[13])	−0.03 (−2.01, 1.95)	1 RCT (Jeong, 2016[13])	−0.03 (−2.01, 1.95)

Secondary outcomes

The subjective balance ability (ABC scale) was not significantly different between the training and control groups (MD −6.67, 95% CI [−20.92, 7.58], P = 0.36) (**Fig. 3a**), and substantial heterogeneity was observed (Tau^2 = 89.62, I^2 = 83%). Data on gait endurance were available for 1 of the 2 studies,[13] whereas data on fall incidence were not available from any study. MD (95% CI) for 6MWT was −5.40 (−36.59, 25.79) (**Fig. 3b**).

There were no reports of adverse events during the intervention in any of the 3 studies.

Insert Figure 3

Discussion

Summary of findings

Two RCTs that met the inclusion criteria were found. Their certainty of evidence was low or very low due to serious study limitations and imprecision. The present meta-analysis showed that obstacle avoidance training alone cannot improve gait speed or subjective balance ability compared with the usual gait training.

Comparison with the literature

There are at least two reasons for the failure to determine the effectiveness of obstacle avoidance training alone. First, the amount of training was insufficient for both included RCTs. According to a systematic review on circuit class training, the duration of the training was approximately 60 min in a single session, and various gait-related training tasks were continuously performed.[9] In contrast, the duration of obstacle avoidance training was only 20–30 min in the present study (**Table 2**). No difference was observed in training frequency (3–5 times/week) was observed between the circuit class training and obstacle avoidance training groups. A previous RCT showed that their lower limb training group (gait training in addition to usual gait training; upper and lower limb training for the functional recovery of activities of daily living or gait training) significantly differed from their control group (upper limb training or no training in addition to the usual gait training) in terms of gait ability.[26] In the meta-analysis, the momentum of the lower limbs increased to improve gait speed and endurance.[10 27] Therefore, an insufficient trial period may not be able to demonstrate the effectiveness of

obstacle avoidance training alone.

The second reason would be the lack of well-designed studies that measured relevant outcomes such as fall incidence and composite gait ability. Indeed, to date, no study has examined fall incidence, whereas only 1 study has examined composite gait ability. In addition, obstacle avoidance ability (e.g., success rate, avoidance reaction time, and foot clearance) was not measured in the included RCTs for individuals with stroke. A previous systematic review on elderly individuals showed that the effect of physical training was evaluated based on obstacle avoidance ability.[28] A previous observational study on individuals with stroke reported that obstacle-crossing training led to improved obstacle avoidance ability as one aspect of the gait adaptability training for individuals with stroke.[29] However, no outcome related to obstacle avoidance ability is reported in this systematic review and meta-analysis. Therefore, this study suggests that obstacle avoidance training alone has little or no effect on improving gait or balance ability.

Strengths and limitations

The strengths of this study are (1) that, to the best of our knowledge, this is the first systematic review and meta-analysis on the evidence of effects of obstacle avoidance training on individuals with stroke and (2) its careful and rigorous screening, extraction, and scoring.

This study has certain limitations. Most studies had a high or unclear risk of bias, and the number of RCTs was small. Although a well-designed study[13] showed an improvement in gait endurance and objective balance ability, the effects of the intervention on these parameters in the training group were not superior to those in the control group in the present systematic review and meta-analysis. Based on these results,

determining the influence of the intervention on improved gait and balance abilities was difficult.

Another limitation is that none of the 2 included RCTs evaluated obstacle avoidance ability itself (e.g., toe clearance and success rate of obstacle-crossing training). Therefore, the intervention effect of obstacle avoidance training may have been masked. In the future, RCTs with a low risk of bias, including an assessment of obstacle avoidance ability, should be accumulated to verify our findings. Because stroke rehabilitation aimed to improve gait ability under various environmental constraints, the effect of obstacle avoidance training (other than those of step over training) should be confirmed. In the future, RCTs on obstacle avoidance training including gait through apertures (including the fall incidence and obstacle avoidance ability) should be conducted.

As a clinical limitation, obstacle avoidance training as a single task is not useful according to the best available evidence; accordingly, other interventions such as using combinations of training and increasing the amount of gait training should be considered.[30-32]

Clinical implications and recommendations

Confirming the effects of obstacle avoidance training on individuals with stroke is highly clinically important because these individuals are more likely to fall while avoiding an obstacle. However, none of the outcomes was found to be significantly altered after obstacle avoidance training. We currently recommend that rehabilitation workers should allow individuals with stroke to practice other gait training and obstacle avoidance training.

Conclusions

This systematic review and meta-analysis showed that obstacle avoidance training in addition to the usual gait training for individuals with stroke may have little or no effect. The failure to determine the effectiveness of obstacle avoidance training alone may be due to the insufficient amount of training in the intervention and the lack of well-designed studies that measured relevant outcomes, such as fall incidence, composite gait ability, and obstacle avoidance ability. Further research is required to identify the effects of obstacle avoidance training alone.

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Contributors: DM, YK, MB, YT, and HT conceived the study. DM drafted the protocol manuscript, and all authors revised it. DM and YK designed the search strategies, and DM and SO performed the searches and screened studies for inclusion, extracted the data, and assessed the risk of bias of included studies. YK arbitrated disagreements between reviewers. DM, SO, and YK analyzed and interpreted the data. All authors have provided conceptual and/or methodological expertise. DM, YK, MB, YT, and TH have contributed to the critical revision of this manuscript for important intellectual content. All authors agree to be accountable for all aspects of the work and have read and approved the final manuscript.

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Figure Legends

Fig. 1. Flow diagram for Preferred Reporting Items for Systematic Reviews and Meta-Analysis

Fig. 2. Primary outcomes

a. Effects of obstacle avoidance training on gait speed

b. Effects of obstacle avoidance training on composite gait ability (TUG)

c. Effects of obstacle avoidance training on objective balance ability (BBS score)

Fig. 3. Secondary outcomes

a. Effects of obstacle avoidance training on subjective balance ability (ABC scale)

b. Effects of obstacle avoidance training on gait endurance (6MWT)

Fig 1.

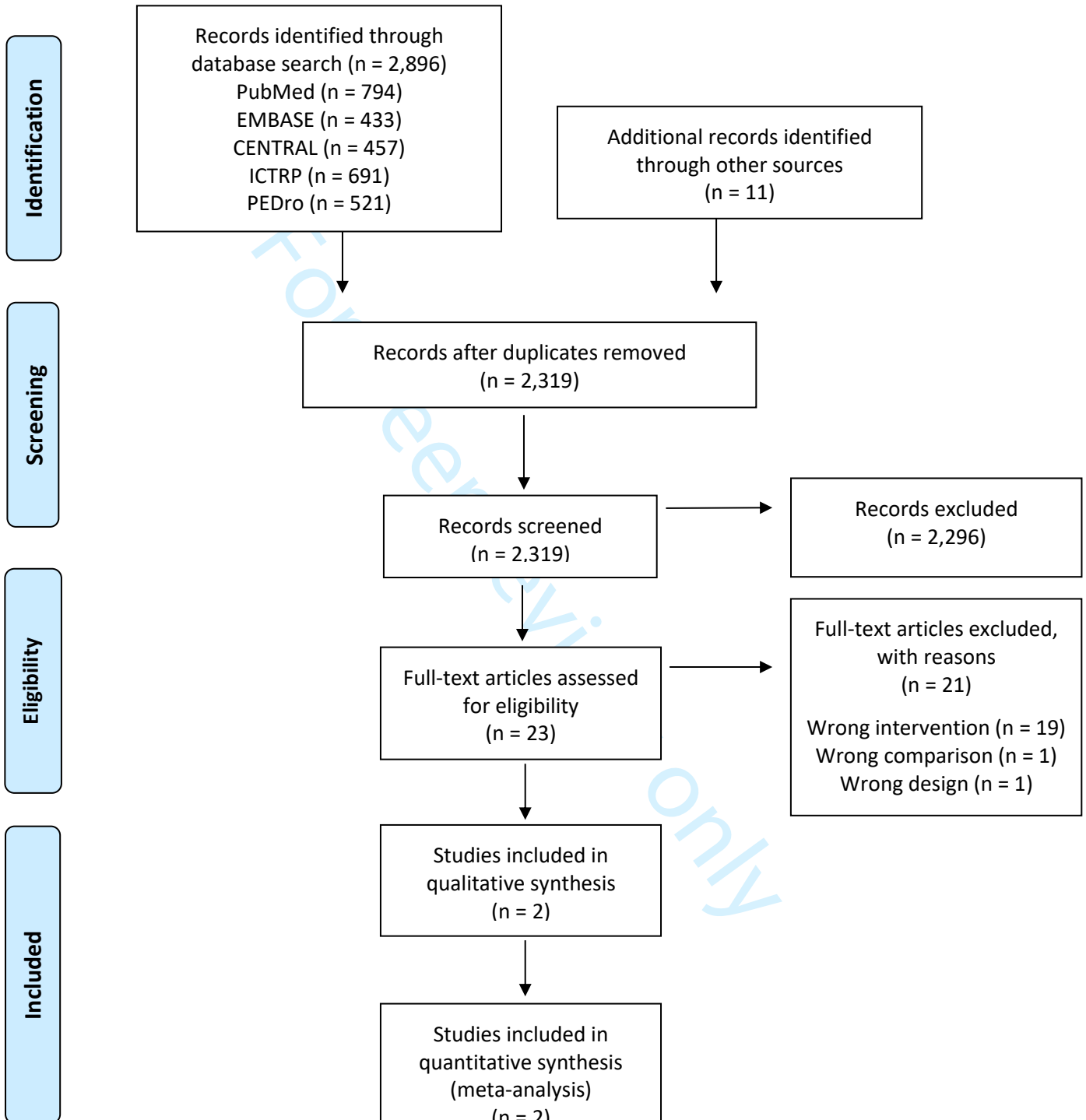
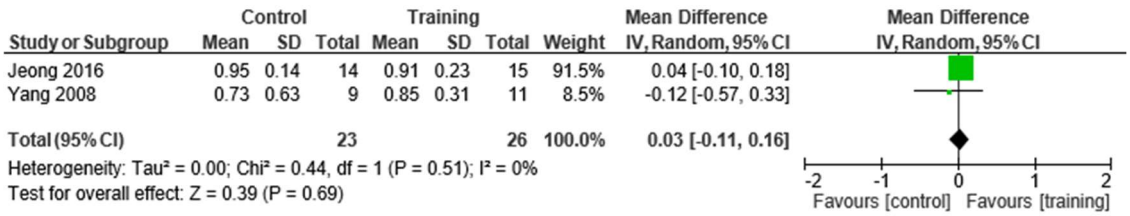


Fig 2.

a.



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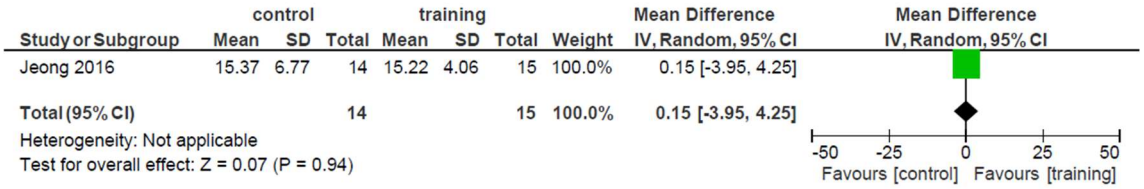

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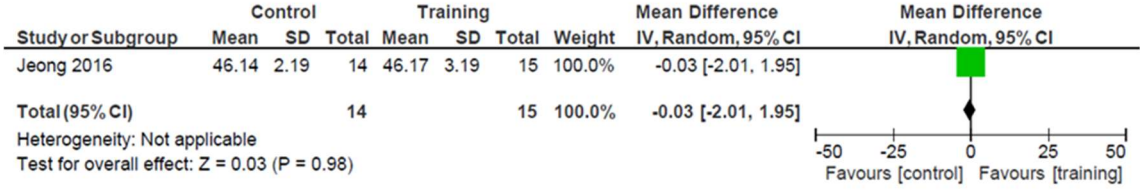
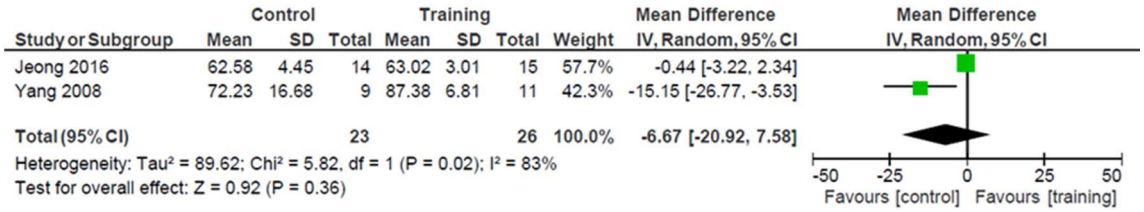
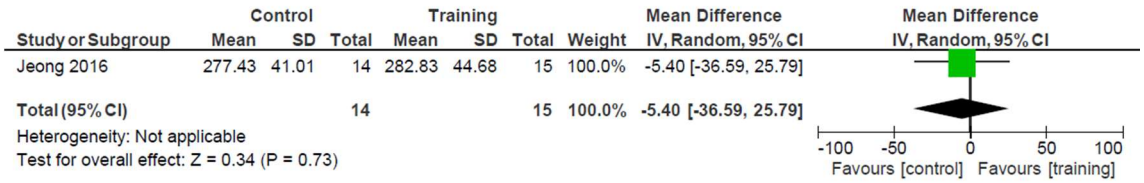


Fig 3.

a.



b.



PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	#1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	#2-4
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	#5-6
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	#5-6
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	#6-7
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	#7-8
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	#6-7
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	supplementary material
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	#7-8
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	#7-8
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	#7-9
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	#9-10
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	#9-10
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	#9-10

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	#9-10
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	#9-10
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	#11-12
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	#12-13
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	#12-13
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	#10-11
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	#13-14
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	#12-13
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	#13-14
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	#15-16
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	#16-17
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	#18
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	#19

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: **www.prisma-statement.org**.

Supplementary file 1: Search Strategy

MEDLINE via PubMed	Search Date: Dec/18/2018	No. trials
#1	cerebrovascular disorders[mh]	340098
#2	stroke [tiab]	214501
#3	poststroke[tiab]	4481
#4	post-stroke[tiab]	7607
#5	cva[tiab]	2562
#6	apoplex* [tiab]	3051
#7	apoplexy* [tiab]	2951
#8	SAH	11418
#9	#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8	447589
#10	obstacle*[tiab]	42292
#11	avoidance*[tiab]	63634
#12	task*[tiab]	326509
#13	circuit*[tiab]	111076
#14	#10 OR #11 OR #12 OR #13	526921
#15	Exercise[mh]	172629
#16	Exercise therapy[mh]	44691
#17	rehabilitation[mh]	280813
#18	Physical Fitness[mh]	26565
#19	physical therapy modalities[mh]	140062
#20	#15 OR #16 OR #17 OR #18 OR #19	450023
#21	rehabilitation[tiab]	148672
#22	physical fitness[tiab]	8980
#23	training[tiab]	358168
#24	mobilization[tiab]	48140
#25	mobilisation[tiab]	5339
#26	physical therapy[tiab]	18559
#27	physiotherapy[tiab]	17248
#28	treadmill[tiab]	29617
#29	#21 OR #22 OR #23 OR #24 OR #25 OR #26 OR #27 OR #28	593233
#30	#20 OR #29	916879
#31	#14 AND #30	58502
#32	#9 AND #31	3671
#33	randomized controlled trial[pt]	473479
#34	controlled clinical trial[pt]	561431
#35	randomized[tiab]	463598

#36	placebo[tiab]	199269
#37	clinical trials as topic[mesh: noexp]	185546
#38	randomly[tiab]	302662
#39	trial[ti]	191297
#40	#33 OR #34 OR #35 OR #36 OR #37 OR #38 OR #39	1195880
#41	animals[mh] NOT humans[mh]	4525626
#42	#40 NOT #41	1100461
#43	#32 AND #42	794

Embase via Elsevier	Dec/18/2018	No. trials
S1	(EMB.EXACT.EXPLODE("cerebrovascular disease"))	610770
S2	(ab(stroke) OR ti(stroke))	338926
S3	(ab(poststroke) OR ti(poststroke))	5825
S4	(ab(post-stroke) OR ti(post-stroke))	14810
S5	(ab(cva) OR ti(cva))	5705
S6	(ab(apoplex*) OR ti(apoplex*))	4311
S7	(ab(SAH) OR ti(SAH))	14060
S8	S7 OR S6 OR S5 OR S4 OR S3 OR S2 OR S1	733656
S9	(ab(obstacle*) OR ti(obstacle*))	53177
S10	(ab(avoidance*) OR ti(avoidance*))	84655
S11	(ab(task*) OR ti(task*))	401172
S12	(ab(circuit*) OR ti(circuit*))	133632
S13	S12 OR S11 OR S10 OR S9	651421
S14	EMB.EXACT("physiotherapy")	91246
S15	EMB.EXACT.EXPLODE("exercise")	367581
S16	EMB.EXACT.EXPLODE("kinesiotherapy")	79363
S17	EMB.EXACT("rehabilitation")	273604
S18	(EMB.EXACT("occupational therapy"))	23582
S19	(EMB.EXACT.EXPLODE("feedback system"))	131460
S20	(EMB.EXACT("joint mobilization"))	1212
S21	S20 OR S19 OR S18 OR S17 OR S16 OR S15 OR S14	830974
S22	(ab(rehabilitation) OR ti(rehabilitation))	213069
S23	(ab("physical fitness") OR ti("physical fitness"))	11052
S24	(ab(training) OR ti(training))	483139
S25	(ab(mobili*ation) OR ti(mobili*ation))	73822
S26	(ab("physical therapy") OR ti("physical therapy"))	25118
S27	(ab(physiotherapy) OR ti(physiotherapy))	31310
S28	(ab(treadmill) OR ti(treadmill))	38903
S29	S28 OR S27 OR S26 OR S25 OR S24 OR S23 OR S22	812943
S30	S29 OR S21	1348815
S31	S30 AND S13 AND S8	5748
S32	(EMB.EXACT("double blind procedure"))	162431
S33	(ab(double NEAR/1 blind*) OR ti(double NEAR/1 blind*))	198715
S34	(ab(placebo*) OR ti(placebo*))	287000
S35	(ab(blind*) OR ti(blind*))	394051

S36	S35 OR S34 OR S33 OR S32	566534
S37	S36 AND S31	433

CENTRAL	Nov/27/2017	No. trials
#1	cerebrovascular disease	7564
#2	stroke	54497
#3	poststroke	3367
#4	post-stroke	3131
#5	cva	509
#6	apoplex*	505
#7	SAH	906
#8	#1 or #2 or #3 or #4 or #5 or #6 or #7	57849
#9	obstacle*	1374
#10	avoidance*	4997
#11	task*	29218
#12	circuit*	3773
#13	#9 or #10 or #11 or #12	38053
#14	physiotherapy	10877
#15	exercise	70707
#16	kinesiotherapy	2422
#17	rehabilitation	46793
#18	occupational therapy	5089
#19	feedback system	5032
#20	joint mobilization	919
#21	#14 or #15 or #16 or #17 or #18 or #19 or #20	114870
#22	rehabilitation	46793
#23	"physical fitness'	6746
#24	training	62855
#25	mobili$ation	10
#26	"physical therapy'	42478
#27	physiotherapy	10877
#28	treadmill	6453
#29	#22 or #23 or #24 or #25 or #26 or #27 or #28	131896
#30	#21 or #29	167041
#31	#8 and #13 and #30	2017
#32	(double next/1 blind*) or placebo*:ab,ti or blind*:ab,ti	371794
#33	#31 and #32	790
	Trials	457

ICTRP	Dec/18/2018	No. trials
#1	obstacle* OR avoidance*	538
#2	task oriented OR circuit training	153
Total		691

PEDro		Dec/18/2018	No. trials
#1	tiab	obstacle*	80
#2	tiab	avoidance*	220
#3	tiab	circuit*	221
Total			521