Systematic Review and Meta-Analysis

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Effectiveness of backward walking for people affected by stroke

A systematic review and meta-analysis of randomized controlled trials

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Abstract

Background: Backward walking (BW) training is increasingly used in rehabilitation for stroke, but relevant evidence remains unclear.

Objective: To determine the effect of BW training on patients with stroke.

Methods: A keyword search was conducted in PubMed, EMBASE, CINAHL, and China National Knowledge Infrastructure database for articles published until November, 2019. Two investigators screened the articles and extract data from each included study. Meta-analysis was performed to estimate the effect of BW on stroke. In addition, the quality of evidence was evaluated by GRADE (grading of recommendations, assessment, development, and evaluation; version:3.6) approach.

Results: A total of ten studies were included according to the inclusion and exclusion criteria in the review. All included studies described some positive influences of BW on stroke relative to the control group (forward walking or conventional treatment). Compared to control group, there is a statistically significant improvement for BW group in gait velocity (mean difference [MD] = 6.87, 95%CI: [1.40, 12.33], $P = .01$, $I^2 = 3\%$), Berg balance score (MD =3.82, 95%CI: [2.12, 5.52], $P < .0001$, $I^2 = 0\%$), and walk test (MD =0.11, 95%CI: [0.02, 0.20], $P = .02$, $I^2 = 36\%$).

Conclusions: For patients with stroke, BW training, as an adjunct an adjunct to conventional treatment, can improve Berg balance score (moderate evidence), walk test performance (very low evidence), gait velocity (very low evidence). More large-scale and high-quality studies are warranted.

Abbreviations: 95% CI = 95% confidence intervals, BBS = Berg balance score, BG = backward walking group, BW = backward walking, CG = control group, FW = forward walking, MD = mean difference, TUG= time up to go.

Keywords: backward walking, meta-analysis, stroke, systematic review

1. Introduction

Stroke, as an acute neurological injury, including ischemic stroke and hemorrhagic stroke, which results in the sudden loss of focal brain function due to the death of cells caused by the interruption of blood flow or hemorrhage in the brain.[1] As a leading cause of death and disability, it has become a major health problem in China and the United States.[2,3] Among stroke survivors, disability is a common sequela.[4] They are often accompanied

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by reduced proprioception,[5] balance impairment,[6] gait alteration,[7] coordination deterioration[8] and high risk of falling.[9]

Backward walking (BW) is a simple and effective method for adjuvant treatment and rehabilitation.[10] On 1 hand, BW is helpful for improving proprioception,[11,12] muscle strength,[13] intralimb coordination[14] and balance.[15] On the other hand, it can also assess the severity of impairment of coordination and motor ability, and serve as a predictor of falls in the elderly.[16] Different from forward walking (FW), the gait and lower extremity biodynamics of stroke patients will significantly change during BW.[17] DeMark L et al[18] found that BW can improve walking function, balance, and prevent fall-risk in acute stroke.

There are 4 meta-analyses studies on BW in the previous articles.[19–22] It is reported that BW training can not only be a potentially useful tool to improve balance performance,[19] but also to change the spatial-temporal gait characteristics and useful for neurological rehabilitation.[20] And Elnahhas AM et al[21] reported that backward gait training had a good effect on improving motor function, balance, walking velocity and step length in children with cerebral palsy. Furthermore, Denissen S et al[22] documented interventions could reduce falling for post stroke more than exercises such as walking program. However, Balasukumaran T et al[23] suggested there was insufficient evidence to support the idea that BW is effective for balance, gait parameters and stability in people with gait impairments. In the light of the above-mentioned knowledge, what is the impact of the post-stroke patients who also have limb dysfunction? There is no evidence-based basis so far. Consequently, a meta-analysis of randomized controlled trial was carried out to investigate the effectiveness of BW on the stroke.

2. Methods

This meta-analysis was fulfilled according to the Preferred Reporting Items for Systematic Review and Meta-analyses.[24]

2.1. Ethics statement

Because all analyses were conducted according to previously published studies, no ethical approval or patient consent was required in this review.

2.2. Selection criteria

In this study, all the included literatures should meet the following criteria: ②Study design: clinical randomized controlled study; ②Patients: people affected by stroke; ③Intervention: BW, BW+ other treatments; ④Outcomes: at least one efficacy index, ⑤Language: English, Chinese and Korean. A literature would be excluded if it met any of the following criteria: ①Protocols, case reports, observational studies, cohort studies; full-text unavailable articles, such as a poster, studies in other languages except for Chinese and English, unpublished literatures; ②Repeated publications, animal experimental studies, reviews.

2.3. Search strategy

We performed the literature search in PubMed, EMBASE, CINAHL and China National Knowledge Infrastructure database. A keyword such as “backward”, “step”, “walking”, “gait”, “locomotion”, “retro” and so on was used to search without restrictions, up to November 13, 2019. The search algorithm was detailed described in the supporting. All the literatures in this study were screened by 2 investigators (ZH Chen and XL Ye). First, literatures were preliminarily selected after careful reading of the topics and abstracts. Second, the uncertain documents were screened strictly according to the inclusion and exclusion criteria after reading the full text. Finally, the data and materials in the included literatures were extracted without controversy.

2.4. Data extraction

We collected the main information of the articles, including authors’ names, publication year, age, and gender of patients, poststroke duration, study design, intervention type, intervention dose, main outcomes and sample size.

2.5. Quality assessment

According to 5.1.0[25] of Cochrane manual, 2 reviewers (ZH Chen and WJ Chen) assessed the quality of the literature by the risk of bias table. The literature was evaluated from 7 aspects: sequence generation, allocation concealment, blind of participants and personnel, blind of outcome, incomplete outcome data, selective reporting and other biases. The risk of bias is divided into 3 levels: high, unclear and low. In addition, the quality of evidence was evaluated by GRADE (grading of recommendations, assessment, development, and evaluation; version:3.6) approach.[26]

2.6. Statistical analysis

The review manger 5.3 software was used to make a meta system analysis of the observation indicators in the included literature, and the results were illustrated by the forest map intuitively. In this study, all parameters were continuous variables. They were pooled by standard mean difference (MD) or MD with 95% confidence intervals. Heterogeneity was assessed by the Cochran Q-test and I^2 index.[27] A random-effect model would be used when a high heterogeneity ($I^2 >$ 50% and $P_{\text{Q-test}} < .1$) was detected, otherwise a fix-effect model was prime to be evaluated. The difference was statistically significant when P-values $< .05$.

3. Results

3.1. Study selection

A total of 547 related records were obtained by searching Chinese and English databases. The literatures were imported into EndNote X8 (Bld, 10063) to remove duplicate literature. After removing 242 duplicates and eliminating 292 articles through the preliminary screening, reading summary and full text, remaining 13 full-text articles were reviewed. According to the inclusion criteria and exclusion criteria, 10 articles[28–37] were selected and 255 stroke patients were included. Three studies were excluded: a poster, a protocol and one without full-text. All included studies described some positive influences of BW on stroke relative to the control group (CG) treated with FW or balance training or conventional methods focusing on strengthening, function, mobility activities and gait training. The selection flowchart is shown in Figure 1, and the basic information of each included literature is shown in Table 1.

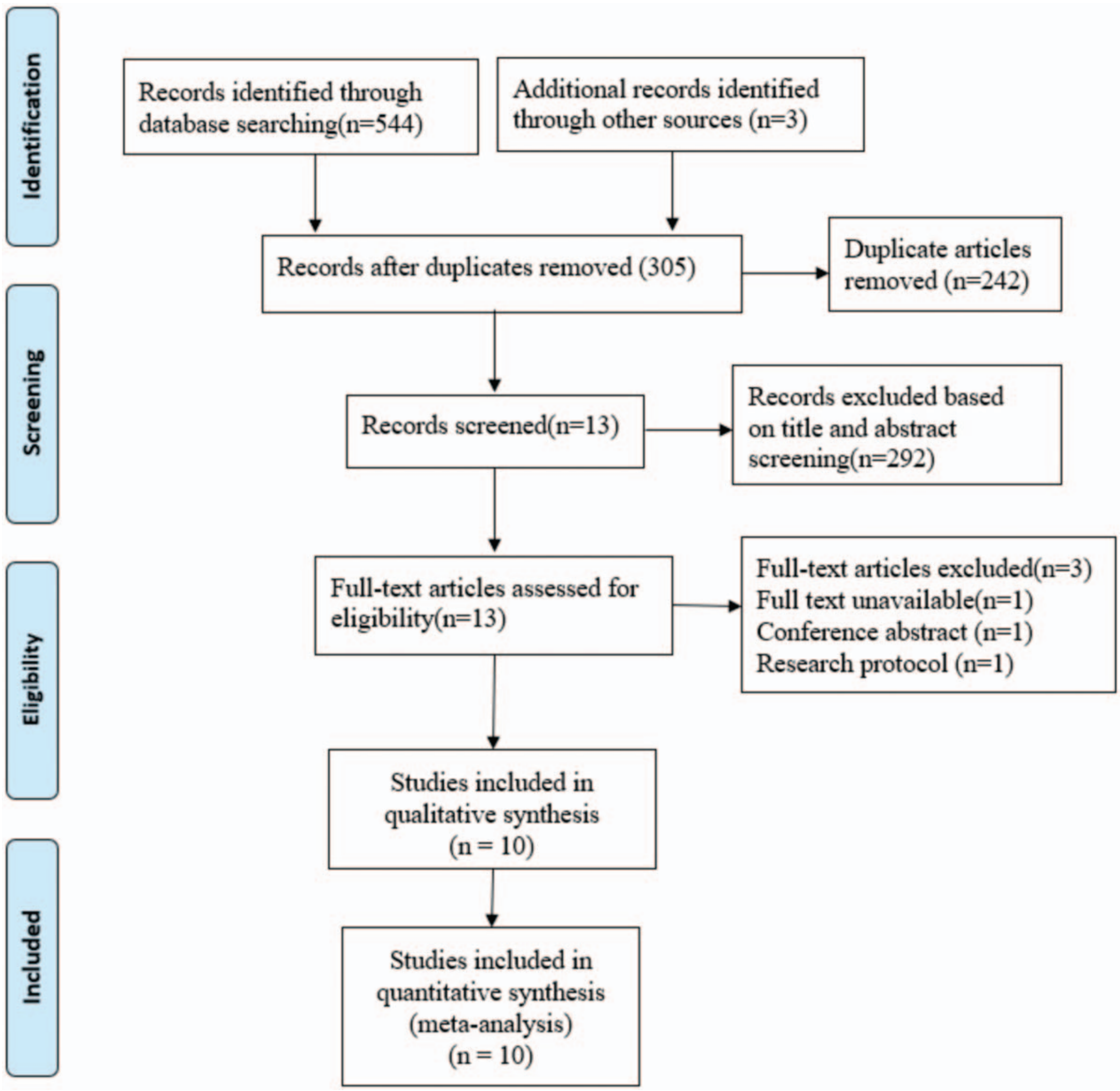

Figure 1. Flowchart of study selection. A total of 10 studies were included according to the inclusion and exclusion criteria in the review.

Table 1

Characteristics of the included studies.

First author	Year	Age (yr)		Sample size	Poststroke duration		Male/Female		Intervention		Study design	Intervention Dose	Main outcome
		BG	CG	(BG/CG)	BG	CG	BG	CG	BG	CG			
Baglary S[28]	2013	59.8+7.8	61.25±9.7	20/20			18/2	18/2	BW + CT	CT	RCT	30min/d, 3/W, 3W	j
Choi HS[29]	2015	61.22±5.95	67.89±5.75	9/9	8.00±1.73 M	8.00±1.73 M	5/4	5/4	BW + CT	CT	RCT	20min/d, 3/W, 4W	ao
Kim CY[30]	2017	63.83±7.27	63.33±11.60	17/17	7.99±3.58 M	7.12±2.32 M	7/10	9/8	BW + CT	CT	RCT	30min/d, 3/W, 3W	abcdef
Kim K[31]	2014	50.25±16.69	52.75±9.21	12/12	11.83±3.46 M	11.00±4.22 M	9/3	8/4	BW	FW	RCT	30min/d, 6/W, 3W	giklmn
Kim KH[32]	2017	48.27±16.05	50.73±13.50	15/15	10.93±3.67 M	11.27±4.10 M	11/4	7/8	BW	FW	RCT	30min/d, 5/W, 4W	bcdfhikl
Lee BH[33]	2014	56.50±10.17	59.40±8.28	10/10	19.20±25.41 M	20.70±28.35 M	5/5	6/4	BW + CT	CT	RCT	10min/d, 5/W, 4W	mn
Rose DK[34]	2018	53.8±12.1	66.6±7.3	8/8	8.5±4.2 d	7.8±3.3 d	4/4	2/6	BW	SB	RCT	30min/d, 8/W, 1M	aj
Takami A[35]	2010	66.1+6.3	66.9±10.6	10/12	13.2±8.4 d	13.7±8.9 d	4/6	5/7	BW + CT	CT	RCT	10min/d, 6/W, 3W	bcji
Weng CS[36]	2006	51±12	50±14	13/13	62±24d	63±34 d	8/5	9/4	BW + CT	CT	RCT	30min/d, 5/W, 3W	aj
Yang YR[37]	2005	63.38+7.7	63.42±11.06	12/14	5.45+3.03 M	7.33+2.42 M	10/3	9/3	BW + CT	CT	RCT	30min/d, 3/W, 3W	bcdgh

BG=backward walking group, BW=backward walking, CG=control group, CT=conventional treatment, FW=forward walking, RCT=randomized controlled trial, SB=standing balance.

Main outcome: a:10-m Walk test (m/s); b: gait velocity (cm/s); c: cadence, step/min; d: stride length (affected side), cm; e: gait symmetry ratio (%); f: double support period (%); g: symmetry index; h: gait cycle (%); i: paretic step length (cm); j: BBS, Berg balance score (score); k: affected side single support (%); l: affected side step time (s), m: affected side stance phase (%); n: affected side swing phase (%), o:TUG, time up to go (s).

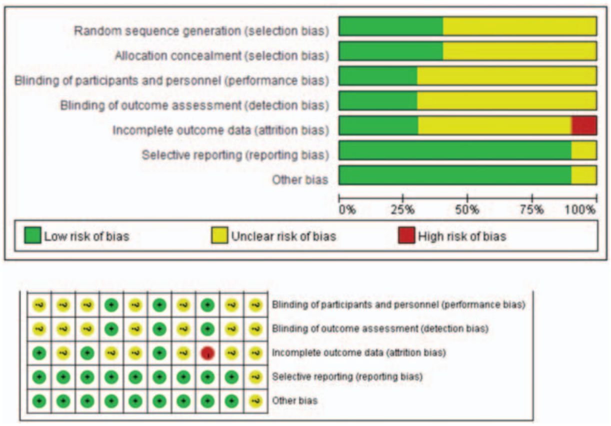

Figure 2. Risk of bias graph.

3.2. Risk of bias

All studies were described as random generation, but only 4 articles[30,32,35,36] recorded the methods of randomization in detail, in which the sealed envelope was selected. Blind methods were detailed in three studies30.32.34, and the drop-out rate was recorded in 4 articles.[30,32,35,37] The drop-out rate of one study[30] was up to 18.19%, which was considered as a high risk in attrition bias. If 2 investigators (ZH Chen and XL Ye) agreed there was not enough information to judge it as a high or low risk, it would be considered as an unknown risk. The detailed results are shown in Figure 2.

3.3. Meta-analysis

We summarize the data and meta-analysis results of gait characteristics, Berg balance score (BBS), walk test, symmetry index and time up to go (TUG) in Table 2.

3.3.1. Gait characteristics. From fixed-effects model, the overall effect showed a statistically significant difference with high heterogeneity between the two groups (MD =-0.33, 95%CI: [-0.40, -0.26], P <.000001, I^2=67%). Therefore, subgroup analysis was carried out for the results. Overall, compared to CG, the results indicated statistically significant improvement for BG group in gait velocity reported in 4 studies[30,32,35,37] (MD=6.87, 95%CI: [1.40, 12.33], P=.01, I^2=3%), cadence used in 4 studies[30,32,35,37] (MD = 4.35, 95%CI: [1.26, 7.44], P=.006, I^2=16%), and paretic step length adopted in three studies[31,32,35] (MD=4.33, 95%CI: [0.38, 8.27], P=.03, I^2= 30%), whereas BG has no significant difference in double support period[30,32] (MD = -1.28, 95%CI: [-4.88, 2.35], P=.006, I^2=16%), gait cycle[32,37] (MD=-0.17, 95%CI: [-0.36, -0.03], P=.09, I^2=53%), stance phase[31,33] (MD=-0.49, 95%CI: [-4.12, 3.15], P=.79, I^2=0%), swing phase[31,33] (MD=0.28, 95%CI: [-3.39, 3.95], P=.88, I^2=0%). When the study[32] compared between BW and FW was excluded, it was further found that, in comparison with conventional therapy (CT), CT combination of BW could significantly improve gait velocity (MD=6.60, 95%CI: [0.90, 12.20], P=.02, I^2=32%) and paretic step length (MD=4.10, 95%CI: [-2.04, 10.23], P=.19, I^2=65%), but cadence (MD=2.94, 95%CI: [-1.26, 7.15], P=0.17, I^2=24%) showed no difference. Meanwhile, there was no significant difference between FW and BW in single support[31,32] (MD=1.75, 95%CI: [-1.33, 4.83], P=.27, I^2= 0%), step time[31,32] (MD=-0.08, 95%CI: [-0.20, 0.05], P=.22, I^2=0%). In addition, affected side stride length in fixed-effects model showed a high-level heterogeneity (MD=5.74, 95%CI: [-0.49, 11.98], Q-test P=.08, I^2=60%), it turned to be a little lower when fixed-effects model was selected (standard MD= 0.44, 95%CI: [-0.16, 1.04], Q-test P=.14, I^2=49%). However, no significant difference was shown in stride length between BG and CG (P=.15). Only 1 study[30] reported the gait symmetry ratio, a significant reduction was shown in BG in comparison to CG (MD=-0.51, 95%CI: [-0.60, -0.42], P <.00001). Meta-analysis and forest plots were shown in Figure 3.

3.3.2. BBS, walk test, symmetry index, and TUG. Overall, the analysis result (Fig. 4) revealed a significant difference between BG and CG (MD=3.82, 95%CI: [2.12, 5.52], P < .0001, I^2= 0%) in BBS reported in 4 studies[28,34,35,36]; 4 of the 10 included studies documented the walk test,[29,30,34,36] evaluated by a fix-effect model, a significant improvement (MD=0.08, 95%CI:

Table 2

Summary of meta-analysis outcomes.

		Sample	Effect		Heterogeneity	
Outcomes	**N**	**BG/CG**	**MD/SMD (95% CI)**	***P***	**I^2 (%)**	***P***
Gait velocity (cm/s)	4	55/56	6.87 (1.40, 12.33)	.01	3%	.38
Cadence (step/min)	4	55/56	4.35 (1.26, 7.44)	.006	16%	.31
Stride length (affected side)	3	45/44	5.74 (-0.49, 11.98)	.07	60%	.08
Gait symmetry ratio (%)	1	17/17	−0.51 (−0.60, −0.42)	.000	NA	NA
Double support period (%)	2	32/32	−1.28 (−4.88, 2.35)	.49	0%	.88
Gait cycle (%)	2	28/27	−0.17 (−0.36, −0.03)	.09	53%	.15
Paretic step length (cm)	3	37/39	4.33 (0.38, 8.27)	.03	30%	.24
Affected side single support (%)	2	27/27	1.75 (−1.33, 4.83)	.27	0%	.46
Affected side step time (s)	2	27/27	−0.08 (−0.20, 0.05)	.22	0%	.54
Affected side stance phase (%)	2	22/22	−0.49 (−4.12, 3.15)	.79	0%	.63
Affected side swing phase (%)	2	22/22	0.28 (−3.39, 3.95)	.88	0%	.73
Berg balance score (score)	4	51/53	3.82 (2.12, 5.52)	.000	0%	.51
Walk test (m/s)	4	47/47	0.08 (0.04, 0.11)	.000	36%	.20
Symmetry index	2	25/24	0.59 (−6.34, 7.53)	.87	0%	.39
TUG (s)	1	9/9	−2.14 (−3.81, -0.47)	.01	NA	NA

BG=backward walking group, CG=control group, CI=confidential interval, MD=mean difference, N=number of studies, NA=not applicable, SMD=standard mean, TUG=time up to go.

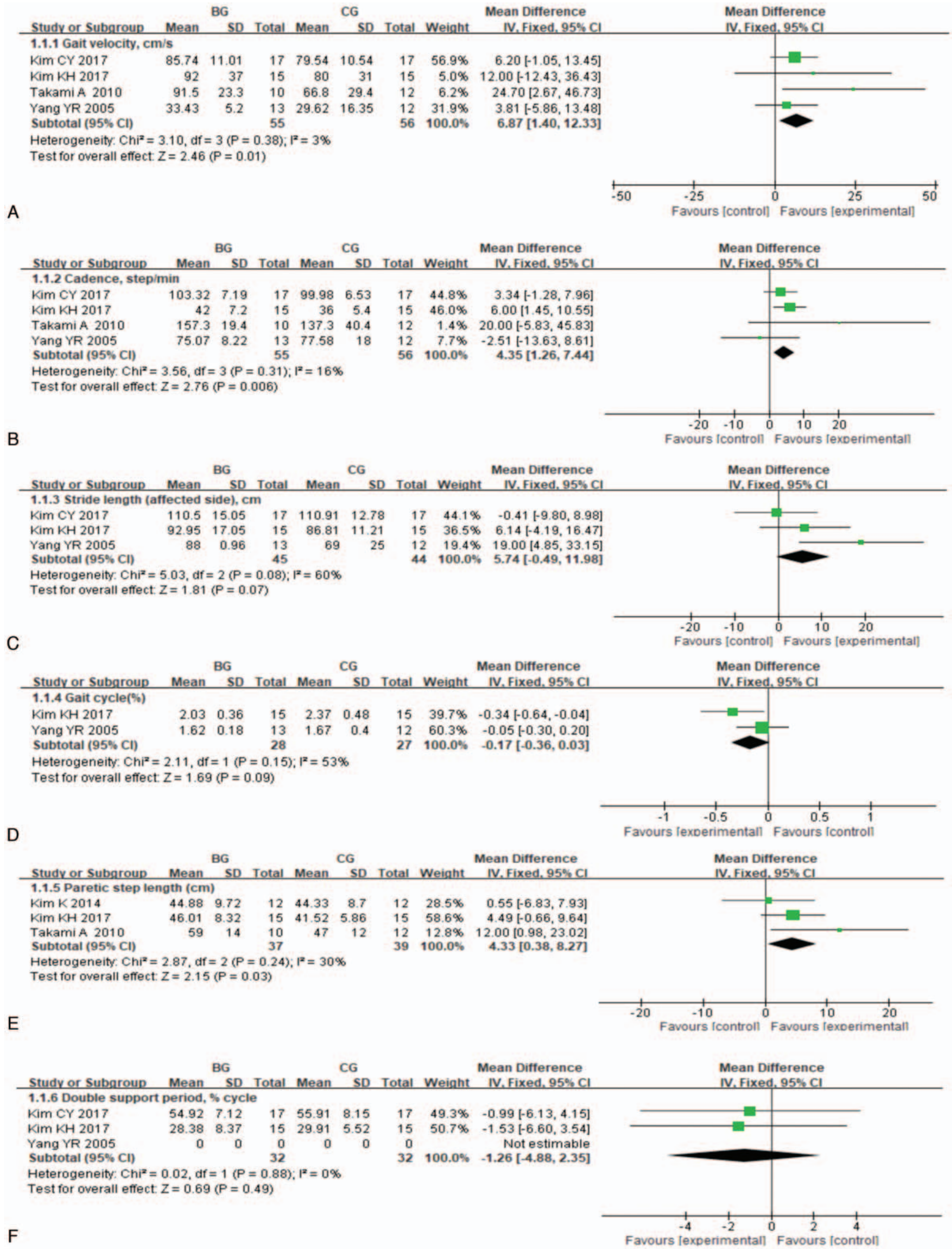

Figure 3. Meta-analysis and forest plot and for gait characteristics. Compared to CG, there is a statistically significant improvement for BG in gait velocity (MD=6.87, 95%CI: [1.40, 12.33], P=.01, I^2=3%), cadence (MD=4.35, 95%CI: [1.26, 7.44], P=.006, I^2=16%), paretic step length (MD=4.33, 95%CI: [0.38, 8.27], P=.03, I^2=30%). BG=backward walking group, CG=control group.

[0.04, 0.11], P <.0001, I^2=36%) was found in BG in comparison to CG (Fig. 5). When the study[34] recording a comparison between BW and standing balance was excluded, the other 3 studies still demonstrated a significant difference between BW combination of CT and CT in BBS (MD=3.78, 95%CI: [2.06, 5.50], P< .0001, I^2=9%) and walk test (MD=0.07, 95% CI: [0.03, 0.11], P <.0002, I^2=0%). Data from the 2 studies,[31,37] no differences in symmetry index were observed

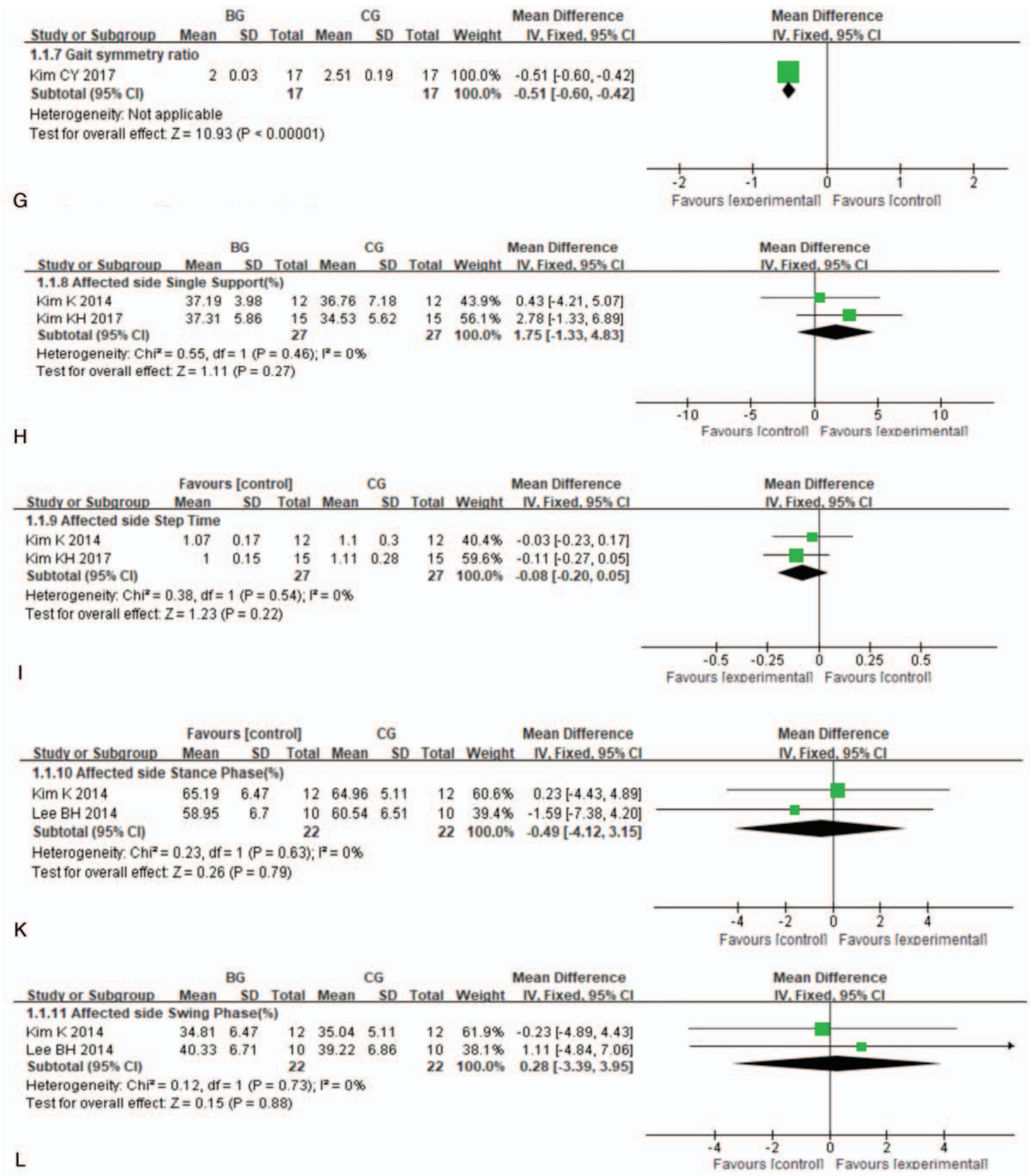

Figure 3. (Continued).

between BG and CG (MD = 0.59, 95%CI: [-6.34, 7.53], P = .87, I^2 = 0%). One study[29] focused on the effect of BW on TUG, a significant reduction in TUG was found in BG (MD = -2.14, 95% CI: [-3.81, -0.47], P = .01). Frost plots from meta-analysis for symmetry index and TUG were shown in Supplementary eFigure 1,Available at: http://links.lww.com/MD/E428 and eFigure 2, http://links.lww.com/MD/E428 respectively.

3.3.3. Sensitivity analysis. In this study, the heterogeneity of each index was acceptable. Therefore, the overall heterogeneities and results were stable, when gait velocity was selected for sensitivity analysis (Supplementary Table 1, Available at: http://links.lww.com/MD/E428). The study[28] with all unclear biases were excluded when we conducted the evaluation of sensitivity analysis.

3.3.4. Evidence quality assessment according to GRADE. According to GRADE guidelines, the quality of evidence is evaluated from 5 aspects: risk of bias, inconsistency, indirectness, imprecision, publication bias. In the comparison between the BG and CG, there is moderate evidence in BBS, low evidence in symmetry index and cadence, and very low evidence in the remaining. Corresponding information was shown in Supplementary efigure 3, http://links.lww.com/MD/E428.

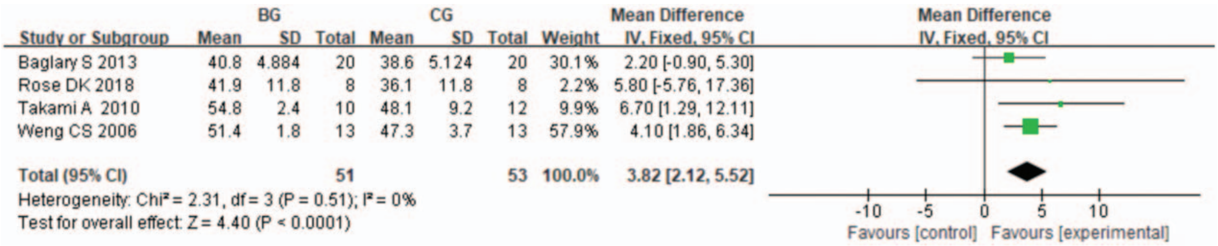

Figure 4. Meta-analysis and forest plot and for BBS. Compared to CG, BBS showed a significant improvement for BG (MD=3.82, 95%CI: [2.12, 5.52], $P<.0001$, $I^2=0\%$). BBS=Berg balance score, BG=backward walking group, CG=control group.

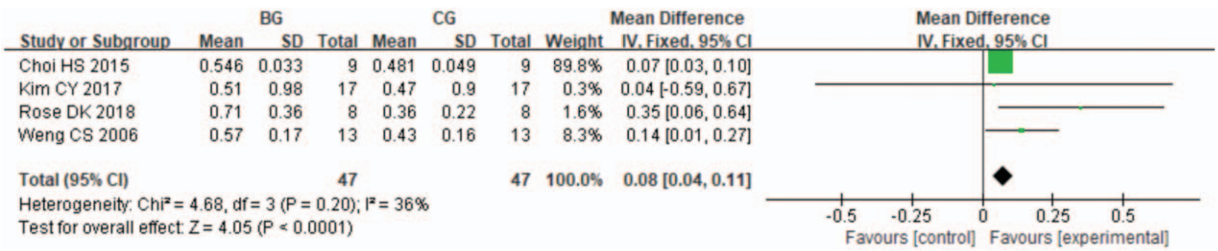

Figure 5. Meta-analysis and forest plot and for walk test. Compared to CG, BG demonstrated a greater improvement in walk test (MD=0.11, 95%CI: [0.02, 0.20], $P=.02$, $I^2=36\%$). BG=backward walking group, CG=control group.

4. Discussion

BW is increasingly used in rehabilitation and sports because of its different movement patterns.[38] To the best of our knowledge, it has been reported that BW exhibits a positive effect on the rehabilitation of post stroke,[18] knee osteoarthritis,[39] diabetic foot syndrome,[16,40] Parkinson's,[41] pediatric cerebral palsy,[42] low back pain,[43] and anterior cruciate ligament reconstruction.[12] morever, Thomas KS et al[44] suggested that greater cardiovascular, neuromuscular, perceptual and metabolic demands were required for BW. In addition, it is also proven to be beneficial to improve cardiopulmonat function.[45,46]

Different from Balasukumaran T's study,[21] we selected the studies in which people suffering from stroke severed as observation objects. It greatly eliminated the interference of different subgroups. Most importantly, more literatures on the treatment with BW for stroke were included, which was helpful for us to analyze the impact of BW on stroke. In our study, overall, it was found that gait characteristics indices-gait velocity, cadence and paretic step length- significantly increased after a period of BW training added in comparison to CG. This is inseparable from the fact that BW training can improve the flexibility and coordination of the lower limbs. Improved gait velocity is beneficial to improve walking ability. The larger paretic step length maybe related to the factor[47] that BW can increase muscle strength. However, when compared to CT, BW combination of CT showed no significant improvement in cadence and paretic step length. It may be explained by the reason that CT included some exercise which also could contribute to cadence and paretic step length for stroke patients. In addition, BBS and walk test performance in BG became better than that in the CG. BBS can reflect the degree of walking improvement for patients with stroke,[48] and predict the risk of falls.[49] All in all, it is suggested that BW can be used as an effective method to improve some gait indices, balance and walking ability of stroke patients.

There are some limitations in this review. First, there is a lack of large-scale studies in the 10 literatures included, and random and blind methods are rarely used. Second, the treatment cycle and exercise intensity of reverse walking are not consistent, which will affect the results. Third, the effect for stroke by training on the treadmill and the ground with BW will also be different. Fourthly, different machines selected in the measurement of gait parameters will also have different degrees of impact on the analysis results.

5. Conclusion

In this paper, the effect of BG on stroke patients was systematically reviewed and quantified. For patients with stroke, BW training, as an adjunct an adjunct to conventional treatment, can improve BBS (moderate evidence), walk test performance (very low evidence), gait velocity (very low evidence). More large-scale and high-quality studies are warranted.

Author contributions

ZH-C and XM-X designed the study.
ZH-C and XL-Y did the literature searches and designed the data-extraction form
ZH-C, XL-Y and GQ-C selected studies.
ZH-C, JT-W and WJ-C extracted the data.
GQ-C and H-W did statistical analyses.
XM-X supervised the study.
H-W did the language editing.
All authors read and approved the submitted version.

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