

REVIEW ARTICLE

Efficacy of Robot-Assisted and Virtual Reality Interventions on Balance, Gait, and Daily Function in Patients With Stroke: A Systematic Review and Network Meta-analysis



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Abstract

Objective: This study aimed to evaluate the comparative effectiveness and ranking of robot-assisted training, virtual reality, and robot-assisted rehabilitation combined with virtual reality in improving balance, gait, and daily function in patients with stroke.

Data Sources: PubMed, EMBASE, the Cochrane Library, Physiotherapy Evidence Database, CINAHL, Web of Science, and ProQuest Dissertations and Theses abstracting and indexing databases were comprehensively searched to include randomized controlled trials published through August 31, 2022.

Study Selection: Randomized controlled trials comparing robot-assisted training, virtual reality, robot-assisted rehabilitation combined with virtual reality, and conventional therapy to assess the effects on balance, gait, and daily function of patients with stroke.

Data Extraction: The risk of bias was assessed using the Cochrane Risk of Bias tool and the methodological quality of the studies was assessed using the Physiotherapy Evidence Database scale. A network meta-analysis of random effects models was performed for direct and indirect effects. Data were analyzed using Stata SE 17.0 and R 4.2.1.

Data Synthesis: A total of 52 randomized controlled trials involving 1,559 participants were included in this study. Based on the ranking probabilities, robot-assisted rehabilitation combined with virtual reality was most effective in improving balance (surface under the cumulative ranking curve [SUCRA]=82.0%; mean difference [MD]=4.10; 95% confidence interval [CI], 0.43 to 7.67). Virtual reality was most effective in improving velocity (SUCRA=97.8%; MD=−0.15; 95% CI, −0.24 to −0.06) and daily function (SUCRA=92.1%; MD=−7.85; 95% CI, −15.18 to −1.07).

Conclusions: Compared to robot-assisted training and conventional therapy, robot-assisted training combined virtual reality was most likely the best intervention for balance, and virtual reality might be the most helpful in improving daily function for patients after stroke. Further studies are needed to clarify the specific efficacy of robot-assisted training combined with virtual reality and virtual reality on gait.

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Stroke is the second leading cause of death worldwide, affecting approximately 13.7 million people and causing approximately 5.5 million deaths annually.¹ As the population grows and ages, the prevalence of stroke and the number of disabled patients with stroke have increased.² Disabled patients with stroke often suffer from a motor impairment, balance deficits, and gait impairment,³

which not only limit independence, reduce social participation, and decrease the quality of life but also increase the risk of falls, fractures, and death.^{4,5}

Rehabilitation of balance, gait, and daily function after stroke takes a variety of forms, such as training interventions, which involve patients in exercises in the form of strength or task training⁶; neuromodulation interventions, which combine electrical stimulation or stimulation with conventional therapy⁷; and motor imagery, which improves motor performance through repetition

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of imagined body movements.⁸ However, it is often accompanied by difficulties with patient adherence; no additional benefits in combination with conventional care therapies; insufficient evidence to estimate the effect of interventions on balance, gait, and daily function⁸; and overload of nurses and rehabilitators.⁹

As technology advances and robot-assisted training and virtual reality are increasingly used in the medical rehabilitation field for poststroke balance, gait, and daily function rehabilitation.¹⁰ Choosing the right form of rehabilitation may improve the prognosis of patients with stroke.²

Although previous systematic reviews have evaluated the effectiveness of robot-assisted training or virtual reality for rehabilitation, these systematic reviews had conflicting results, and none have quantitatively compared the effectiveness of robot-assisted training and virtual reality for balance, gait, and daily function in patients with stroke. Zhang et al¹¹ found that virtual reality was more effective than conventional rehabilitation in improving balance and gait function; however, de Rooij et al¹² found that virtual reality was not more effective than non-virtual reality in improving gait in patients poststroke. Moucheboeuf et al¹³ found robot-assisted gait training to be effective poststroke, and Bruni et al¹⁴ concluded that functional electrical stimulation-related electromechanical devices could produce more benefits than robot-assisted training alone.

Traditional paired meta-analysis involves a direct comparison of 2 interventions and therefore does not allow for a simultaneous comparison to estimate the relative effectiveness of the available interventions.¹⁵ It is difficult to compare the efficacy of virtual reality and robot-assisted rehabilitation in traditional paired meta-analyses because there are few available head-to-head comparisons in the literature.¹⁵ Network meta-analysis extends the scope of traditional pairwise analysis by simultaneously analyzing direct and indirect evidence from different studies, allowing estimation of relative effectiveness between all interventions and ranking of interventions, even if direct comparison of 2 interventions is lacking.¹⁶

The selection of the best intelligent technology intervention, either 1 intervention or a combined intervention, to manage balance and gait rehabilitation in patients with stroke remains a challenge for medical personnel. Therefore, this network meta-analysis aimed to compare the effects of robot-assisted training, virtual reality, and robot-assisted training combined with virtual reality on balance, gait, and daily function in patients with stroke.

Methods

This study is a network meta-analysis of direct and indirect evidence to assess the comparative effectiveness of robot-assisted and virtual reality interventions (alone or in combination) on

balance, gait, and daily function in patients with stroke. The network meta-analysis was conducted according to the guideline of the Preferred Reporting Items for Systematic Review and Meta-Analysis network statement¹⁷ and has been registered on PROSPERO (CRD42022364019).

Search strategy

Two researchers (B.Z. and R.K.) independently and comprehensively searched the following abstracting and indexing databases: PubMed, EMBASE, the Cochrane Library, Physiotherapy Evidence Database (via the PEDro [Physiotherapy Evidence Database] website), CINAHL, Web of Science, and ProQuest Dissertations and Theses, from the date of creation to August 31, 2022. The search terms used were “stroke,” “robotics,” and “virtual reality,” and their free terms. The full search strategy for PubMed is provided in [Supplementary Appendix 1](#) (available online only at <http://www.archives-pmr.org/>). In addition, the reference lists of these relevant studies were manually searched to identify eligible studies and included in our review. Disagreements were discussed and resolved by 3 researchers (B.Z., R.K., and K.P.W.).

Inclusion and exclusion criteria

The inclusion criteria were established according to PICOS principles and included (1) patients with stroke aged 18 years or older (P); (2) robot-assisted rehabilitation training, virtual reality rehabilitation training, and combined robot and virtual reality rehabilitation training (I); (3) conventional therapy (C); (4) outcome indicators responding to the effectiveness of balance, gait, and daily function (O); and (5) randomized controlled trials (S).

The exclusion criteria included (1) ineligible types of publications, such as study protocols, reviewed articles, editorials, guidelines, and case reports; (2) incomplete and inaccessible information for network meta-analysis data analysis; (3) duplicate records; and (4) studies that were not in English.

Study selection and data extraction

Two researchers (B.Z. and R.K.) independently screened potentially eligible studies after removing duplicate articles. Studies that did not meet the inclusion and exclusion criteria were excluded by reading the titles and abstracts. Full text of articles were read to determine final inclusion. Any discrepancies were resolved by 3 researchers (B.Z., R.K., and K.P.W.).

Two researchers (B.Z. and R.K.) extracted the data separately and independently using a predesigned Excel sheet. Information extracted included title, year of publication, journal of publication, authors, participant recruitment method, randomization method, allocation concealment implementation method, sample size, intervention method, blinded implementation, and outcome reported as mean $\pm$ standard deviation. Disagreements were discussed and resolved by 3 researchers (B.Z., R.K., and K.P.W.).

Risk of bias assessment

Two researchers (B.Z. and R.K.) independently assessed the risk of bias using the Cochrane Risk of Bias tool (RoB 2),¹⁸ and the methodological quality of the studies was assessed using the PEDro scale.¹⁹ The RoB 2 assesses the risk of bias based on 6 domains: randomization, allocation of interventions, adherence to

List of abbreviations:

10MWT	10-m walk test
BBS	Berg Balance Scale
CI	confidence interval
MBI	Modified Barthel Index
MD	mean difference
PEDro	Physiotherapy Evidence Database
RoB	Cochrane Risk of Bias tool
SUCRA	surface under the cumulative ranking curve
TUG	Timed Up and Go

interventions, missing outcome data, measurement of outcomes, and selection of reported outcomes. Each domain was considered to have a low risk of bias, some concerns related to the risk of bias, or a high risk of bias. The PEDro scale consists of 11 items, and scores depend on whether the included studies satisfy these items. Each satisfied item (except the first one) contributed 1 point to the total score, which ranged from 0 to 10 points. The total score was graded on 3 levels: (1) high quality (score of 6-10), (2) fair quality (score of 4-5), and (3) poor quality (score ≤ 3). Any discrepancies were resolved through discussion and a consensus was reached.

Treatment outcome

The balance ability of patients with stroke was assessed using the Berg Balance Scale (BBS)²⁰ and the Timed Up and Go (TUG).²¹ Among them, the BBS was the most commonly used measurement tool to assess patients' balance ability and was the criterion standard for clinical balance scales.²⁰ Gait was measured by the 10-m walk test (10MWT),²² velocity, and cadence.²³ Gait speed measured over short distances (within 10 m) is one of the most widely used measures of walking ability in clinical assessment and research and is a reliable measure of walking ability in patients recovering from stroke.²⁴ Daily function was measured by the Modified Barthel Index (MBI),²⁵ which is a common scale used to measure disability or dependence in activities of daily living in patients with stroke with good sensitivity and reliability.²⁶

Data synthesis and statistical analysis

The network meta-analysis was performed using the frequency method. We used a multivariate random effects metaregression model for network meta-analysis, which was implemented through the network command suite in Stata SE 17.0^a and R v4.2.1.^b

Due to the potential heterogeneity in the included studies, a random effects model was applied because the results of the

random effects model were relatively conservative and allowed for some heterogeneity between studies.²⁷

We drew network geometry plots where the size of nodes was proportional to the number of participants in that node for the intervention method and the thickness of the connecting line connecting the nodes was proportional to the number of participants in the trial directly comparing the 2 intervention methods.²⁸

The Wald test and the side-splitting method were used to perform consistency assessment and to check whether the treatment effects estimated by direct comparison were consistent with the treatment effects estimated by indirect comparison.

The effects of the interventions were assessed comparatively by random effects pairwise meta-analysis and network meta-analysis of comparisons between interventions and control. All outcomes are reported as mean differences (MDs) and 95% confidence intervals (CIs); when the 95% CI includes 0, the results are not statistically different. These results were reported by creating a league table.

Treatment effects of interventions were ranked using the surface under the cumulative ranking curve (SUCRA),²⁹ with larger areas under the curve being associated with a higher ranking of the effect of that intervention. In addition, forest plots were generated for all comparisons.

Egger's test was used to test for potential publication bias.³⁰ To test the robustness of our findings and to detect whether any particular study resulted in large proportional heterogeneity, a sensitivity analysis was performed.

Results

Literature selection and characteristics of the included studies

We initially identified 77,099 articles. After excluding duplicate and irrelevant articles, 62 articles remained for full-text review. Of these remaining full-text articles, 13 studies were excluded.

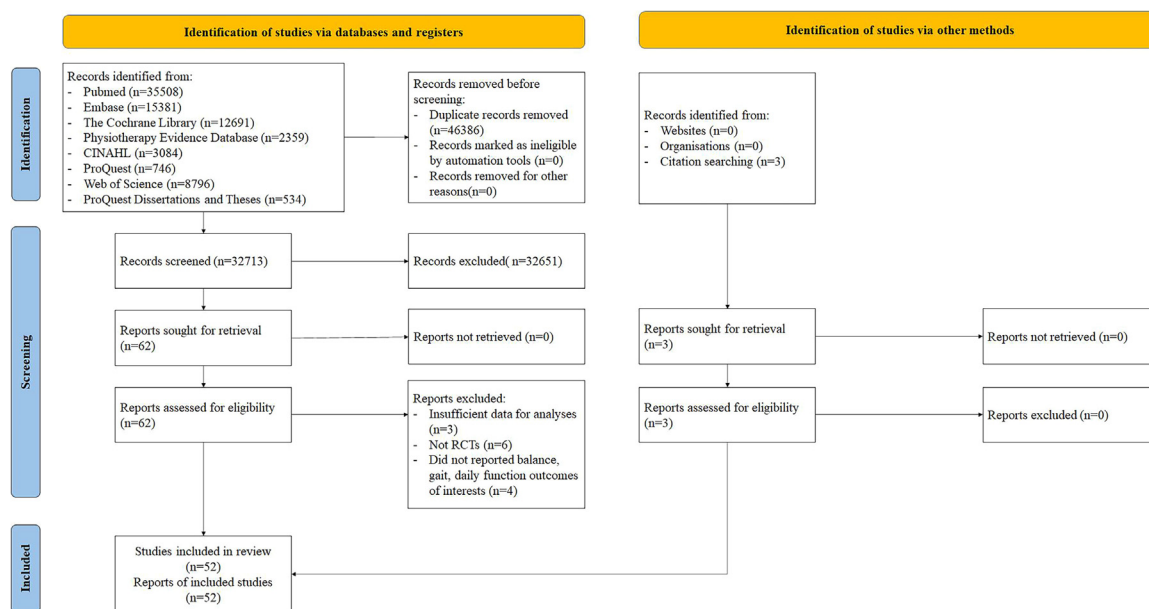


Fig 1 Flow diagram of the literature screening process.

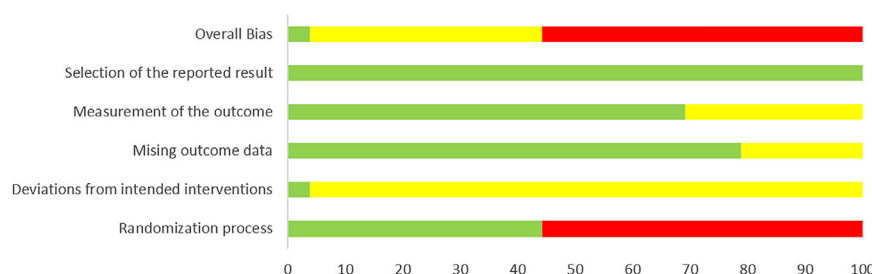


Fig 2 Risk of bias of included randomized controlled trials assessed by RoB 2.

Three articles were included after searching the references in the included studies. Overall, 52 randomized controlled trials were included for this network meta-analysis, as shown in [figure 1](#).

[Supplementary Appendix 2](#) (available online only at <http://www.archives-pmr.org/>) shows the included randomized controlled trials and their participant characteristics. In 26 studies, the intervention method was robot-assisted interventions (n=801); in 22 studies, virtual reality (n=651), and in 4 studies, robot-assisted rehabilitation combined with virtual reality (n=107). A total of 1,559 participants participated in this network meta-analysis, 788 in the intervention group and 771 in the control group. Sample sizes for the intervention and control groups ranged from 5 to 53, with 395 males in the intervention group (50.1%) and 391 males in the control group (50.7%). The sex of participants was not reported in the 4 articles. The mean age of the intervention group was 58.7 and the mean age of the control group was 59.9.

Of the 52 studies, 19 were from Korea; 6 were from the United States; 4 each were from Italy, China, and Turkey; 3 were from Spain; 2 each were from Germany and Japan, and only 1 study was included from each of the following countries: Australia, Brazil, Cyprus, Pakistan, Serbia, Singapore, Thailand, and the UK. Fifty-one studies were 2-arm studies and only 1 study³¹ was a 3-arm study. The duration of the included study interventions ranged from 4 to 12 weeks.

Risk of bias of included randomized controlled trials

The risk of bias for all studies was assessed with the RoB 2 tool; 40.4% of the studies had some concerns about the risk of bias, and 55.8% and 3.8% of the studies had a high and low overall risk of bias, respectively. High risk of bias was mainly due to the randomization process without implementation of allocation concealment ([figure 2](#), [Supplementary Appendix 3](#), available online only at <http://www.archives-pmr.org/>).

The mean PEDro score of the included randomized controlled trials was 6.25 (SD=1.38), ranging from 4 to 9. Of the 52 studies, 35 were highlighted as high quality (67.3%), with the remainder being of fair quality. Because the intervention was virtual reality, robot-assisted rehabilitation, or robot-assisted rehabilitation combined with virtual reality, only 3 randomized controlled trials used participant blinding and none of the studies used therapist blinding. Specific risks of bias are shown in [Supplementary Appendix 4](#) (available online only at <http://www.archives-pmr.org/>).

Effect of robot-assisted and virtual reality interventions on balance

The network plot and the SUCRA for the BBS are shown in [figure 3a](#). For BBS, there were 11 robot-assisted interventions, 17 virtual

reality interventions, and 2 robot-assisted interventions combined with virtual reality, involving 841 participants, all of which were linked through conventional therapy and formed independent network diagrams. According to the SUCRA, the robot-assisted intervention combined with virtual reality was most likely to be ranked as the best intervention (SUCRA=82.0%), followed by virtual reality (SUCRA=69.6%). In [table 1](#) (lower diagonal), robot-assisted training (MD=2.66; 95% CI, 0.95 to 4.36), virtual reality (MD=3.37; 95% CI, 1.94 to 4.80), and robot-assisted intervention combined with virtual reality (MD=4.10; 95% CI, 0.43 to 7.67) were all effective in improving BBS scores compared with the conventional group, with statistically significant differences in the results. Forest plots for a 2 × 2 comparison of all interventions is provided in [Supplementary Appendix 5](#) (available online only at <http://www.archives-pmr.org/>).

There were 9 robot-assisted training studies, 15 robot-assisted studies, and 1 robot-assisted training combined with a virtual reality study that reported TUG as an outcome, which involved 687 participants. According to SUCRA, the robot-assisted intervention combined with virtual reality had the highest likelihood of being ranked as the best intervention (SUCRA=93.3%; MD=−5.58; 95% CI, −11.51 to 0.24), with robot-assisted training second (SUCRA=62.4%; MD=−2.25; 95% CI, −4.48 to 0.04), as detailed in [figure 3b](#). However, the robot-assisted training, virtual reality, and robot-assisted training combined with virtual reality intervention comparisons were not statistically significant, as detailed in [table 1](#) (upper diagonal).

Effect of robot-assisted and virtual reality interventions on gait

The 10MWT was reported by 11 robot-assisted training studies, 5 virtual reality studies, and 1 robot-assisted training combined with a virtual reality study, with a total of 462 participants. According to SUCRA, the robot-assisted training combined with virtual reality intervention was most likely to be ranked as the best intervention (SUCRA=82.7%; MD=3.61; 95% CI, −1.71 to 8.75), followed by virtual reality (SUCRA=72.5%; MD=2.53; 95% CI, −0.18 to 5.36); however, neither was statistically significant compared to conventional treatment ([figure 3c](#); [table 2](#), lower diagonal). The forest plot is provided in [Supplementary Appendix 5](#).

A total of 11 robot-assisted rehabilitation studies, 5 virtual reality studies, and 2 robot-assisted training combined with virtual reality studies demonstrated velocity results (n=517). The network plot did not form a closed loop and therefore was not tested for inconsistency. As shown in [table 2](#) (upper diagonal), robot-assisted training (MD=−0.07; 95% CI, −0.02 to −0.11), virtual reality (MD=−0.15; 95% CI, −0.24 to

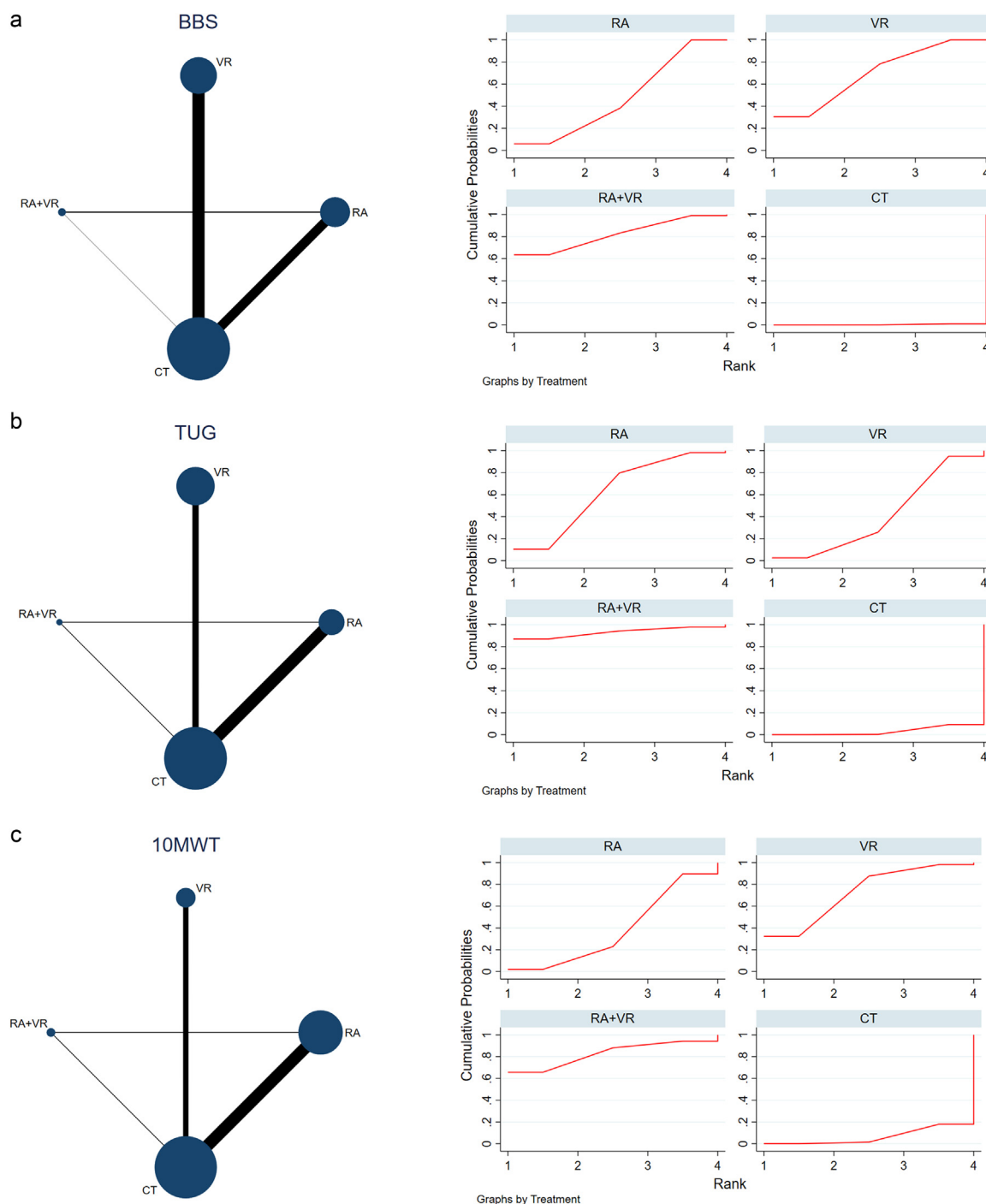


Fig 3 Network plot and the SUCRA curves for robotic and virtual reality measures for (a) the BBS, (b) the TUG test, (c) the 10MWT, (d) velocity, (e) cadence, and (f) the MBI. CT, conventional therapy; RA, robot-assisted; RA+VR, robot-assisted plus virtual reality; VR, virtual reality.

−0.06), and robot-assisted rehabilitation combined with virtual reality (MD=−0.04; 95% CI, 0.16 to 0.07) significantly improved patients' velocity compared to conventional therapy. In addition, virtual reality was more effective than the other 2 interventions. The SUCRA results indicated that the virtual reality intervention (SUCRA=97.8%) was the best in improving gait velocity (figure 3d). Forest plots showed that both robot-assisted training and virtual reality can significantly improve velocity (Supplementary Appendix 5).

Six robot-assisted and 5 virtual reality studies reporting cadence involved 271 participants, and all interventions were connected through conventional therapy to form an independent network. No intervention was superior to other interventions in terms of increasing cadence. Virtual reality (SUCRA=99.8%; MD=12.12; 95% CI, −4.77 to 19.68) appeared to be the best way to improve step frequency under the SUCRA display (figure 3e; table 3, lower diagonal). The forest plots are provided in Supplementary Appendix 5.

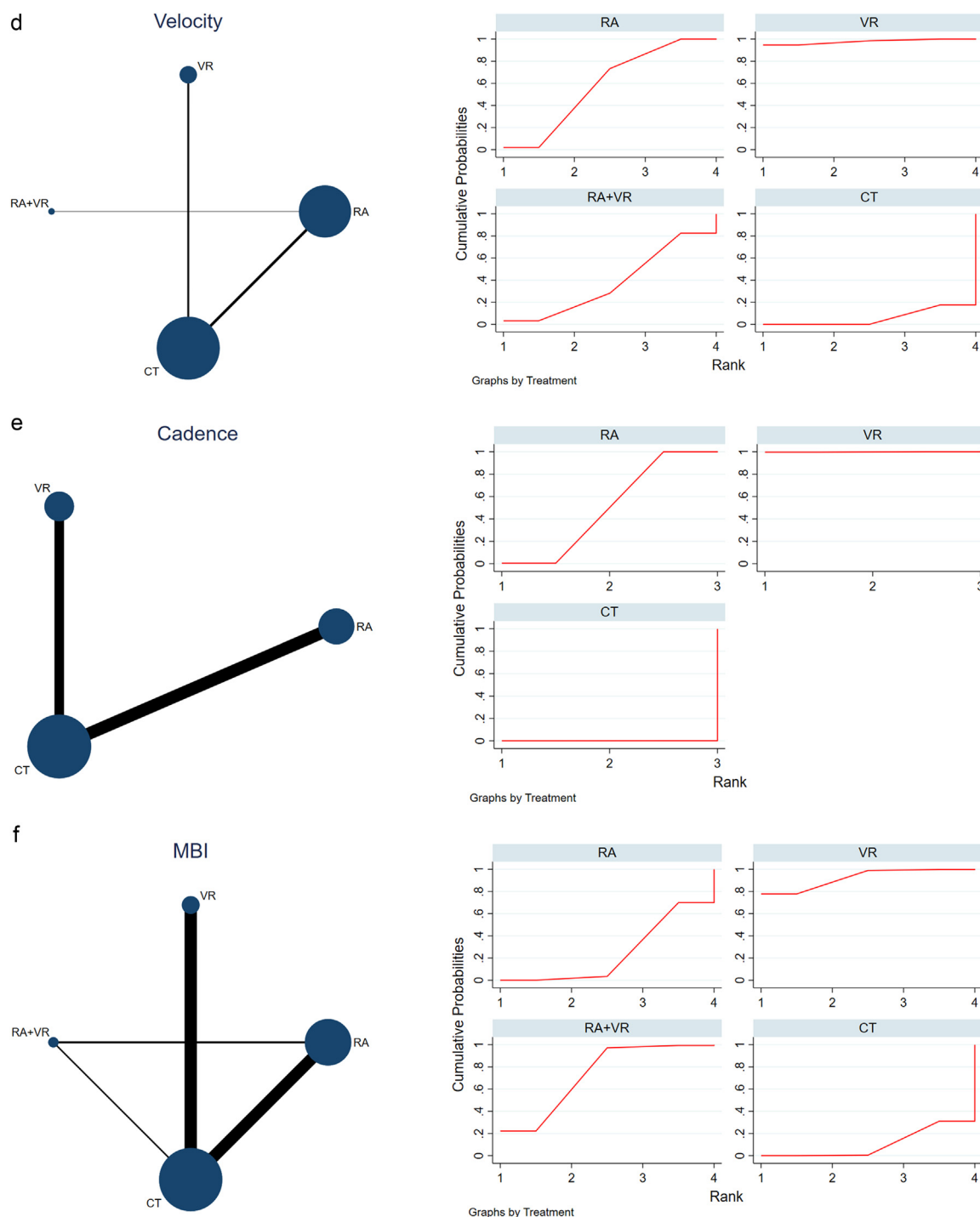


Fig 3 Continued

Table 1 League table of robot-assisted training, virtual reality, and robot-assisted rehabilitation combined with virtual reality on patients' balance

Robot-assisted training	−0.98 (−3.73, 1.93)	3.32 (−2.48, 9.34)	−2.25 (−4.48, 0.04)
−0.73 (−2.92, 1.50)	Virtual reality	4.29 (−1.81, 10.46)	−1.27 (−2.95, 0.36)
−1.45 (−4.91, 2.16)	−0.75 (−4.57, 3.20)	Robot-assisted rehabilitation combined with virtual reality	−5.58 (−11.51, 0.24)
2.66 (0.95, 4.36)	3.37 (1.94, 4.80)	4.10 (0.43, 7.67)	Conventional therapy

NOTE. The lower left triangle gives the results of the BBS network meta-analysis, and the upper right triangle gives the results of the TUG network meta-analysis.

Table 2 League table of robot-assisted training, virtual reality, and robot-assisted rehabilitation combined with virtual reality on patients' gait

Robot-assisted training	0.09 (−0.01, 0.19)	−0.02 (−0.12, 0.08)	−0.07 (−0.02, −0.11)
−1.65 (−5.01, 1.56)	Virtual reality	−0.11 (−0.25, 0.03)	−0.15 (−0.24, −0.06)
−2.73 (−7.98, 2.63)	−1.11 (−6.79, 4.90)	Robot-assisted rehabilitation combined with virtual reality	−0.04 (0.16, 0.07)
0.88 (−0.86, 2.60)	2.53 (−0.18, 5.36)	3.61 (−1.71, 8.75)	Conventional therapy

NOTE. The lower left triangle gives the results of the 10MWT network meta-analysis, and the upper right triangle gives the results for velocity.

Table 3 League table of robot-assisted training, virtual reality, and robot-assisted rehabilitation combined with virtual reality on patients' gait and daily function

Robot-assisted training	7.48 (0.26, 16.42)	4.85 (−2.24, 12.84)	−0.30 (−4.02, 4.17)
−7.98 (−16.87, 2.50)	Virtual reality	−2.71 (−13.44, 6.94)	−7.85 (−15.18, −1.07)
NA	NA	Robot-assisted rehabilitation combined with virtual reality	−5.18 (−12.53, 2.20)
3.94 (−1.25, 11.55)	12.12 (−4.77, 19.68)	NA	Conventional therapy

NOTE. The lower left triangle gives the results of the cadence network meta-analysis, and the upper right triangle gives the results of the MBI network meta-analysis.

Abbreviation: NA, not available.

Effect of robot-assisted and virtual reality interventions on daily function

The network plot and SUCRA are presented in [figure 3f](#). For the MBI, there were 4 robot-assisted interventions, 3 virtual reality interventions, and 1 robot-assisted intervention combined with virtual reality, involving 367 participants. The virtual reality intervention was most likely to be ranked as the best intervention according to the SUCRA (92.1%). In [table 3](#) (upper diagonal), virtual reality had a more significant MBI effect compared to robot-assisted interventions (MD=7.48; 95% CI, 0.26 to 16.42) and conventional therapy (MD=−7.85; 95% CI, −15.18 to −1.07).

Inconsistency testing, publication bias, and sensitivity analysis

Because the closed loops formed in the network plot of BBS, TUG, 10MWT, and MBI were all formed by 1 3-arm study, there was no inconsistency, so we did not perform inconsistency testing.

Egger's test showed significant publication bias for BBS ($P=.001$) and cadence ($P=.029$), with no significant bias for any other outcome indicators ([Supplementary Appendix 6](#), available online only at <http://www.archives-pmr.org/>).

The sensitivity analysis revealed that the results of BBS, TUG, 10MWT, velocity, cadence, and MBI were stable when individual study data were removed on a case-by-case basis. ([Supplementary Appendix 7](#), available online only at <http://www.archives-pmr.org/>).

Discussion

To our knowledge, this is the first network meta-analysis to examine the effects of robot-assisted rehabilitation and virtual reality on balance, gait, and daily function in patients with stroke. In this network meta-analysis, we analyzed a total of 52 randomized controlled trials that included 1,559 stroke participants. We found that virtual reality significantly improved patients' balance, velocity, and daily function compared to conventional therapy, and robot-assisted training and robot-assisted training combined with virtual

reality significantly improved the patients' balance and velocity. The results obtained based on SUCRA curves showed that robot-assisted rehabilitation combined with virtual reality was most likely to be ranked as the best intervention for balance and the 10MWT. Virtual reality was most likely to be ranked as the best intervention for velocity, cadence, and daily function.

A systematic review by Iruthayarajah et al³² found that virtual reality interventions showed more significant improvements in balance in patients with stroke compared to conventional rehabilitation and were becoming a popular alternative to conventional rehabilitation of the lower extremities after stroke. This was consistent with the results of our network meta-analysis. Hsu et al³³ conducted a meta-analysis of robotics and showed that robot-assisted interventions were more beneficial for balance and gait ability in patients with stroke. This was also similar to the results of our study.

Unlike previously paired meta-analyses, a strength of the current network meta-analysis is that it analyzed results beyond randomized controlled trials in which eligible interventions were not directly compared, resulting in an inability to judge more precise methods of efficacy. From a more comprehensive clinical perspective, our meta-analysis added important results to the growing body of evidence indicating which intelligent modern interventions are better for recovery of balance, gait, and daily function in patients with stroke.

Robot-assisted rehabilitation is mostly achieved through physical methods of training. For example, when a patient is unable to support his or her weight independently, weight support training can reduce the effects of balance impairment³⁴ or generate driving torque directly on 1 or more joints through an exoskeleton attached to the patient's leg.³⁵ Virtual reality, on the other hand, is a medium consisting of an interactive computer simulation that helps patients correctly perform rehabilitation actions by detecting their movements and positions, while replacing or augmenting feedback to the patient's sense of vision, sound, and haptics.³⁶

Virtual reality meets the clinical requirements for intensive and repetitive patient training by manipulating training duration or intensity and multisensory feedback to enable new interventions and increase patients' interest in the rehabilitation process by allowing them to experience an immersive (using a head-mounted display) or nonimmersive (a 2D display with a limited field of view) virtual experience, thereby effectively improving patient

compliance with treatment.³⁷ Compared to robotics, virtual reality can better increase patient participation.³⁸

Gait in older adults is affected by advanced age and pathologic conditions.³⁹ This study found that robot-assisted training combined with virtual reality might be the best intervention for enhancing the 10MWT scores and virtual reality was probably the best intervention for improving velocity. A possible reason for this is that gait velocity is the speed at which the sensor captures the patient's comfortable gait speed, whereas the 10MWT is the "flying start" speed of the subject over 10 m, eliminating the acceleration and deceleration phases of walking.⁴⁰ Virtual reality allows participants to exercise without spatial restrictions. Robot-assisted training combined with virtual reality enhances the actual patient experience and obtains stronger visual information by forming a combination of a virtual environment and treadmills or balance boards.⁴¹ The effectiveness of the treatment does not depend solely on the appropriateness of the treatment decision but ultimately on the cooperation of the patient.⁴² Therefore, by enhancing patient participation and giving real-time feedback, patient recovery will be improved. Robot-assisted training combined with virtual reality not only increases participants' motivation but also modifies hip extension and knee flexion, increases the affected side support phase, and improves stability, thus improving the rapid start of the walking speed of the patient.³¹ Further attention needs to be focused on both robot-assisted training combined virtual reality and virtual reality interventions to clarify the specific efficacy and long-term effects on gait of patients poststroke.

Functional recovery in patients with stroke is largely driven by neuroplasticity, which is the ability of the central nervous system to adapt to structural and functional changes based on experience.⁴³ To promote experience-dependent neuroplasticity and functional recovery, the use of intensive, repetitive, and salient task-specific practices is appropriate.⁴⁴ In addition to leveraging the above principles, virtual reality can enrich the training environment by engaging sensory, cognitive, and perceptual-motor pathways. As a result, virtual reality is better able to provide the key components of neuroplasticity described above to support functional recovery outcomes than conventional therapy interventions and robot-assisted rehabilitation.⁴³

Study limitations

The results of this network meta-analysis have some limitations that require attention. First, the network plot of all outcomes is a star-shaped network, and the interventions were mostly compared to conventional therapies and thus did not generate indirect effects to validate our findings. Second, the quality of the included studies determines the quality of the results and may limit the validity of the findings. Most of the included studies did not implement participant or interventionist blinding because of the specific treatment effects. More than half of the studies did not explicitly report or implement an allocation concealment process. Third, the population included in the study was younger patients with stroke, which limited the generalizability of the study results. Finally, because this is the first study adopting network meta-analysis to examine the relative effectiveness of robotics and virtual reality on balance, gait, and daily function in patients with stroke, it is difficult to compare the findings with previous studies.

Conclusions

The current network meta-analysis suggests that robot-assisted training combined virtual reality is the best intervention to improve balance and 10MWT scores, and virtual reality may be a more useful and significant intervention to improve velocity, cadence, and daily function in patients with stroke. More well-designed, large, multicenter randomized controlled trials are needed in the future to strengthen the currently weak evidence.

Suppliers

- a. Stata SE 17.0; StataCorp.
- b. R v4.2.1; R Core Team.

Keywords

Balance; Gait; Network meta-analysis; Rehabilitation; Robotic; Stroke rehabilitation; Virtual reality

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