

**ORIGINAL RESEARCH**

# The Impact of Multiple Exercise Modes on the Quality of Life of Stroke Patients: A Network Meta-Analysis

Yongtao Fan, MEd, Zhikai Qin, PhD, Kuiliang Liu, PhD, Yingxu Pan, PhD, and Junsheng Wang, PhD

**Purpose:** This study aimed to evaluate the impact of 6 exercise therapies on the quality of life of stroke patients.

**Methods:** A systematic search was conducted on PubMed, the Web of Science, PsycINFO, and the Cochrane Library to retrieve peer-reviewed articles written in English. The inclusion criteria consisted of (1) experimental or quasi-experimental studies, (2) utilization of different exercise therapies as experimental interventions, (3) inclusion of stroke patients as the target population, and (4) assessment of quality of life as an outcome measure.

**Results:** The analysis included 25 studies involving 1243 subjects aged 18 years or older. The network meta-analysis revealed that among the 6 exercise therapies examined, Virtual Reality Training (82.3%) had the most significant impact on improving the quality of life in stroke patients. This was followed by Resistance Training (77.3%), Mind-Body Training (61%), Underwater Exercise (52%), Aerobic Exercise Training (44.1%), and High-Intensity Interval Training (19.2%).

**Conclusions:** Virtual reality training was found to be highly effective in improving the quality of life in stroke patients. In addition, when combined with other exercise therapies, it enhanced physical function and overall quality of life. (J Am Board Fam Med 2025;38:431–450.)

**Keywords:** Exercise Therapy, Health Promotion, Movement, Network Meta-Analysis, Quality of Life, Resistance Training, Stroke

## Introduction

Stroke is a significant global health concern and a major contributor to disability and mortality worldwide.<sup>1</sup> The Global Burden of Disease project reports that stroke is the second leading cause of death globally, accounting for 11.8% of all deaths.<sup>2</sup> The impact of stroke can vary from mild to severe and persistent disability. Impaired

motor function, gait disturbances, low levels of fitness, and other impairments collectively restrict poststroke activity, resulting in a diminished health-related quality of life (HRQOL).<sup>3</sup> Stroke survivors often report a lower HRQOL than the general population.<sup>4</sup> HRQOL is a multidimensional concept encompassing physical and psychological attributes related to overall health status.<sup>5</sup> However, many of these disabilities can be improved through professional rehabilitation if stroke patients receive timely intervention.<sup>6</sup> Therefore, it is crucial to assess and treat the function and disabilities of stroke patients as core aspects of health care and stroke rehabilitation.<sup>7</sup> One effective rehabilitative exercise therapy is aquatic exercise, also known as hydrotherapy, which allows stroke patients to initiate exercise earlier than they can on land due to reduced weight-bearing requirements.<sup>8</sup> The buoyancy of water enables more efficient movement of limbs with minimal effort, thereby enhancing coordination.<sup>9</sup> Qi Gong, based on the concept of ‘qi’ or energy flow through the body’s meridian system, is believed to promote overall health by facilitating energy flow throughout the

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From the Capital University of Physical Education and Sports, Beijing 100191, China (YT, ZQ, KL, YX, JS).

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**Corresponding authors:** Yingxu Pan, PhD, Capital University of Physical Education and Sports, No. 11 North Third Ring West Road, Haidian District, Beijing 100191, China (E-mail: panyingxu1969@163.com); Junsheng Wang, PhD, Capital University of Physical Education and Sports, No. 11 North Third Ring West Road, Haidian District, Beijing 100191, China (E-mail: wangjunsheng1110@163.com).

body.<sup>10</sup> According to traditional Chinese medicine principles, health and well-being must maintain a continuous flow of qi. Mind-Body Exercises involve movements that transcend an individual's support base, alter their standing positions, and perform actions in sustained squat positions<sup>11</sup>. These movements focus on balance and require muscle strength, making them a potentially effective method for improving balance and leg strength. This, in turn, may yield benefits for other related functions such as quality of life. In addition, High-Intensity Interval Training (HIIT) is a feasible exercise mode for stroke patients as it requires low time investment. HIIT programs tailored for typical impairments can improve cardiorespiratory fitness, engagement in physical activity, and quality of life in stroke survivors.<sup>12</sup>

While Virtual Reality (VR) gained popularity in the late 1980s and 1990s, its potential as an assessment and therapeutic tool has only recently been explored in the past decade.<sup>13</sup> VR is being widely studied and developed as a multidisciplinary tool in clinical medicine, with applications ranging from pain management and assessment of neurocognitive impairments to medical technology training and physical rehabilitation.<sup>14</sup> According to research literature, Virtual Reality (VR) is helpful in various learning applications, including visual, auditory, tactile, and kinesthetic learning. It has also shown positive effects on individual rehabilitation and has been used to improve motor skills in poststroke patients.<sup>15</sup> One of the main advantages of VR interventions compared with traditional therapies is that patients perceive them as enjoyable exercise games rather than treatments, which increases their motivation and compliance with the treatment. Meta-analyses have been conducted on interventions for poststroke patients, such as Qi Gong,<sup>16</sup> Hydrotherapy,<sup>17</sup> Resistance Training,<sup>18</sup> Virtual Reality Training,<sup>19</sup> and High-Intensity Interval Training.<sup>20</sup> These meta-analyses evaluate the effects of these interventions on physical function and quality of life. Building on this existing foundation, this study aims to quantitatively rank and evaluate the therapeutic effects of interventions on the quality of life of stroke patients.

## Materials and Methods

### Protocol and Registration

This article presents a systematic review of randomized controlled trials (RCTs) following the Preferred

Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.<sup>21</sup> The study protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO) before screening the search results (registration number: CRD42024506954) and adhered to the PRISMA statement. In addition, the study did not require ethical approval and patient consent because all the data used in this study were based on previously published studies.

### Search Strategy and Study Selection

A systematic search was conducted across the PubMed, Web of Science, PsycINFO, and Cochrane Library databases to identify research articles assessing the effects of exercise therapy on quality-of-life interventions in stroke patients. All relevant articles published globally in any language from the inception of the databases until January 11, 2024, were included. In addition, previously published reviews and meta-analyses were manually searched to uncover further references. The search strategy utilized the following medical subject terms and keywords: "stroke," "quality of life," "HRQOL," "randomized controlled trial," "clinical trial," "controlled study," "comparative study," "mental component scale," "SF-36," "European Quality of Life 5 Dimensions," "EQ-5 Days," "stroke-specific quality of life," "SS-QOL," "stroke impact scale," "SIS," "SF-8 health survey," "exercise therapy," "physical activity," "High-Intensity Interval Training," "Mind-Body Training," "Underwater Exercise," "Virtual Reality Training," "Resistance Training," and "Aerobic Exercise Training." For detailed information on the search strategy, please refer to Appendix 2.

The search results were imported into Zotero 6.0. After the removal of duplicates, 2 reviewers (YT, YX) independently screened the titles and abstracts of the studies. Studies that did not meet the eligibility criteria were excluded. The full texts of all relevant studies were obtained, downloaded, and further assessed for eligibility. Any disagreements between the 2 reviewers regarding the inclusion of specific studies were resolved through consultation with a third independent reviewer (ZQ) to minimize bias in the decision making process. Data were independently extracted from each study by the 2 reviewers (YT, YX), and any discrepancies were addressed by consulting the third independent reviewer.

### Eligibility Criteria

Studies were included if they met the following criteria:

1. Adults (aged  $\geq 18$  years) who had experienced a stroke, with no restrictions on gender, race, or socioeconomic status.
2. Randomized controlled trials (RCTs) evaluating structured exercise interventions compared to a standard control group (e.g., usual care) or a sham exercise intervention. Exercise interventions were defined as planned, purposeful, and repeatable physical activities.
3. Quality-of-life outcomes were assessed through validated measurement tools and reported in the studies.
4. Full-text articles published in English and accessible through peer-reviewed journals.
5. Interventions with a duration of at least one week to ensure stable therapeutic effects and the assessment of sustained outcomes.

Studies were excluded if they met the following criteria:

1. Narrative reviews, systematic reviews, preclinical studies (e.g., animal models), duplicate publications, editorials, opinion articles, grey literature (e.g., unpublished theses or reports), or conference abstracts without peer-reviewed full-text versions.
2. Short-term interventions lasting less than one week or studies lacking follow-up data.
3. Studies with insufficient details about the intervention protocols.
4. Study protocols or acute studies not designed to assess sustained therapeutic effects.

### Data Extraction

Data extraction was systematically performed for all eligible studies, capturing the following details: authorship, publication year, sample size, participants' demographic characteristics (age, gender), study design, detailed intervention protocols (including type, frequency, duration, and primary components), description of the control group, specified outcome measures and assessment time points, reported results, drop-out rates, and methods employed to address missing data. Emphasis was placed on extracting consistent and comparable data to facilitate robust synthesis and minimize bias. If data were unavailable, we

contacted the corresponding author of the article in question up to 3 times within 3 weeks.

### Risk of Bias and Certainty of Evidence

The quality of each included study was evaluated using the Cochrane risk-of-bias tool for randomized trials. This tool assessed various domains, including random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other biases.<sup>22</sup> Two independent authors conducted the quality assessment, and a third reviewer resolved.

### Measures of Treatment Effect

The study results included the mean differences between the intervention and control groups postassessment. The data were independently extracted and recorded. Any discrepancies were resolved through consensus or consultation with a third reviewer. Manuscripts were included in the meta-analysis only if the anxiety scale had been adequately reported.

### Statistical Analysis

The Der Simonian-Laird random-effects and fixed-effects models were used to compute summary estimates of the weighted mean differences between the treatment and control groups, along with 95% confidence intervals (CIs). STATA software (version 15) was employed for this purpose. The effect sizes were calculated using Hedges'  $g$  statistic for standardized mean differences, and their corresponding 95% CIs were also determined. The magnitude of Hedges'  $g$  was interpreted as small ( $g=0.3$ ), medium ( $g=0.5$ ), and large ( $g=0.8$ ). Heterogeneity was assessed using the  $c^2$  test to evaluate the null hypothesis that all studies assessed the same effect. The inconsistency index ( $I^2$ ) was used to quantify the total variation in heterogeneity among studies, ranging from 0% to 100%. A  $P$ -value  $< 0.10$  from the Chi Square test and an  $I^2 > 50\%$  indicated significant heterogeneity.<sup>23</sup> Inconsistency testing was conducted using STATA software (version 15). If  $P > .05$ , a consistency model was used for analysis. Node-splitting was performed for local inconsistency testing. When inconsistency between direct and indirect evidence was found, reference was made to the direct comparison results. Ranking indicators were reflected by the surface under the cumulative ranking (SUCRA), ranging from 0% to 100%. A SUCRA value of 100% represented the

most effective exercise therapy, while a value of 0 indicated the least effective or ineffective therapy.<sup>24</sup> Funnel plots were drawn to assess possible publication bias, with effect sizes for each trial plotted against standard errors. The asymmetry of the funnel plot was evaluated using the regression-based Egger's small-sample effect test.

## Results

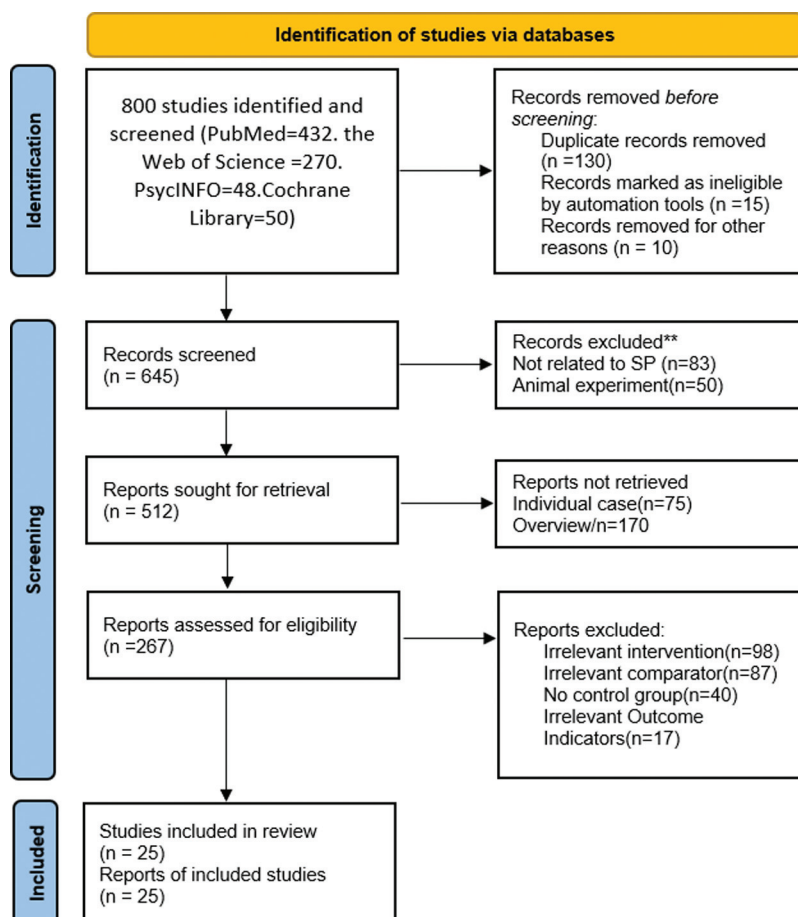
### Study Selection

An initial search yielded 800 articles from 4 databases, with 155 duplicates identified. After screening the titles and abstracts of 645 articles, 378 were excluded as they did not meet the inclusion criteria. The remaining 267 articles underwent a full-text review, and out of these, 242 articles were excluded for various reasons, as outlined in Figure 1. Ultimately, 25 studies were included in this systematic review.<sup>16,25-48</sup>

### Risk of Bias of Included Studies

All studies included in this article adequately described the generation of random allocation sequences. Thus, the risk of selection bias related to generating random allocation sequences was considered low. Eleven trials reported specific details regarding the concealment of sample allocation and were assessed as low risk.<sup>26,31,36,38-40,42-44,46,48</sup> The remaining studies lacked detailed descriptions and transparent information about the procedures and were categorized as unclear. Regarding performance bias, the nature of these studies and the number of personnel made blinding difficult for coaches or researchers.<sup>25,26,30,32,33,37</sup> However, blinding of assessment outcomes was crucial in intervention studies involving stroke patients. In addition, 4 studies reported measures taken for blinding outcomes assessment.<sup>16,34,39,48</sup> The evaluation of attrition and reporting bias was heavily influenced by these 5 studies.<sup>29,31,36,39,45</sup> The risk of bias graph was shown in Figure 2.

**Figure 1. Flowchart of the study.**



**Figure 2. Risk of bias graph.**

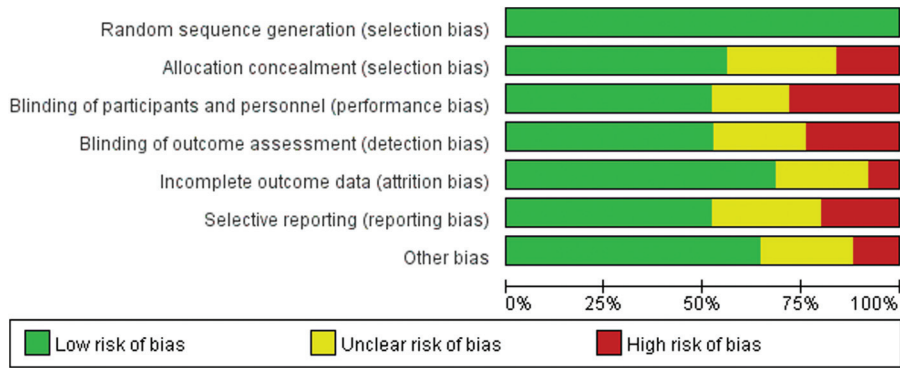
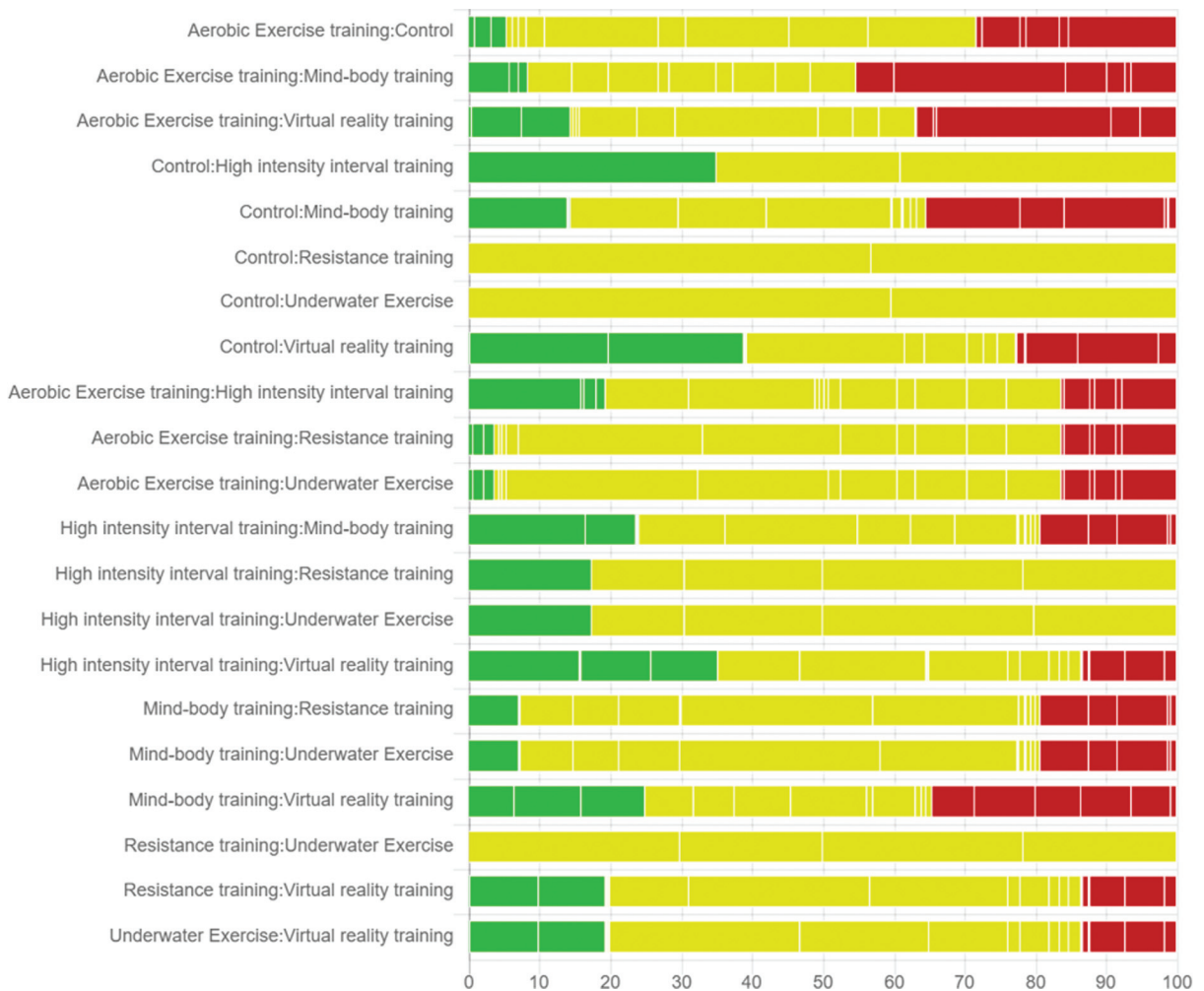


Figure 3 illustrated the distribution of bias risk for pairwise comparisons among 6 exercise interventions. Each row corresponded to a specific intervention comparison, with bar charts categorized into

low (green), moderate (yellow), and high (red) risk of bias, summing to 100%. In most comparisons, a moderate risk of bias predominated, suggesting that most studies were of moderate quality. However,

**Figure 3. Risk of a biased bar chart for the network meta-analysis.**



**Table 1. Characteristics of the Studies in the Systematic Review and Meta-Analysis**

Author/Year	Research Design	Sample Size (T/C)	Age Range	Subject Type	Intervention Design (T/C)	Exercise Prescription	Evaluation Tools/Content
Holmgren,2010 <sup>25</sup>	RCT	15/16	≥55	stroke patient	HIIT/control group	60 minutes/times, 7/week, 5 weeks	SF-36
Munari, 2018 <sup>26</sup>	RCT	8/7	18 to 75	stroke patient	HIIT/control group	60 minutes/times, 3/week, 12 weeks	SIS
Sandberg,2016 <sup>27</sup>	RCT	29/27	≥50	stroke patient	HIIT/control group	60 minutes/times, 2/week, 12 weeks	EQ-5 Days
Immink, 2014 <sup>28</sup>	RCT	12/13	32 to 85	stroke patient	MBT/control group	130 minutes/times, 1/week, 10 weeks	SIS
Kim, 2015 <sup>29</sup>	RCT	11/11	53.45 ± 11.54	stroke patient	MBT/control group	40 minutes/times, 3/week, 6 weeks	SF-36
Schmid, 2012 <sup>30</sup>	RCT	37/10	60.2 ± 8.9	stroke patient	MBT/AET	60 minutes/times, 2/week, 8 weeks	SS-QOL
Song, 2021 <sup>31</sup>	RCT	16/18	57.18 ± 10.65	stroke patient	MBT/control group	40 minutes/times, 2/week, 12 weeks	SS-QOL
Surbala, 2013 <sup>32</sup>	RCT	12/11	57 ± 5.2	stroke patient	MBT/control group	45 minutes/times, 3/week, 8 weeks	SS-QOL
Yuen, 2021 <sup>16</sup>	RCT	29/29	63.1 ± 10.6	stroke patient	MBT/control group	50 minutes/times, 3/week, 8 weeks	SS-QOL
Zhao, 2022 <sup>33</sup>	RCT	11/15	62.98 ± 10.85	stroke patient	MBT/control group	40 minutes/times, 2/week, 12 weeks	SS-QOL
Matsumoto, 2016 <sup>34</sup>	RCT	60/60	62.4 ± 10.7	stroke patient	UE/control group	40 minutes/times, 2/week, 8 weeks	SF-36
Park, 2010 <sup>35</sup>	RCT	10/10	51.80 ± 14.46	stroke patient	UE/control group	30 minutes/times, 4/ week, 6 weeks	SF-8
Cano-Mañas, 2020 <sup>36</sup>	RCT	23/25	65.68 ± 10.39	stroke patient	VRT/control group	35 minutes/times, 3/week, 8 weeks	EQ-5 Days
De Rooij, 2021 <sup>37</sup>	RCT	28/24	57 to 70	stroke patient	VRT/AET	30 minutes/times, 2/week, 6 weeks	SS-QOL
Park, 2023 <sup>38</sup>	RCT	20/20	62.5 ± 4.7	stroke patient	VRT/control group	30 minutes/times, 5/week, 8 weeks	SS-QOL
Rodríguez-Hernández, 2021 <sup>39</sup>	RCT	23/20	62.6 ± 13.5	stroke patient	VRT/control group	50 minutes/times, 5/week, 3 weeks	EQ-5 Days
Zheng, 2015 <sup>40</sup>	RCT	58/54	65.4 ± 13.5	stroke patient	VRT/control group	30 minutes/times, 6/week, 4 weeks	SF-36
Chen, 2015 <sup>41</sup>	RCT	16/15	67.16 ± 11.9	stroke patient	RT/control group	30 minutes/times, 5/week, 4 weeks	SF-36
Aidar, 2016 <sup>42</sup>	RCT	11/11	51.7 ± 8.0	stroke patient	RT/control group	45 minutes/times, 3/week, 12 weeks	SF-36
Gordon, 2013 <sup>43</sup>	RCT	64/64	64.9 ± 11.1	stroke patient	AET/control group	40 minutes/times, 3/week, 12 weeks	SF-36
Hyun, 2021 <sup>44</sup>	RCT	15/15	61.47 ± 11.08	stroke patient	AET/VRT	30 minutes/times, 3/week, 8 weeks	SS-QOL
Langhammer, 2008 <sup>45</sup>	RCT	32/32	71.4 ± 13.5	stroke patient	AET/control group	40 minutes/times, 1/week, 12 weeks	SS-QOL
Mayo, 2013 <sup>46</sup>	RCT	44/43	67.7 ± 14.4	stroke patient	AET/control group	30 minutes/times, 2/week, 12 weeks	SS-QOL
Park, 2017 <sup>47</sup>	RCT	13/13	65.68 ± 10.39	stroke patient	AET/control group	40 minutes/times, 3/week, 4 weeks	SS-QOL
Studenski, 2005 <sup>48</sup>	RCT	40/40	74.0 ± 10.4	stroke patient	AET/control group	40 minutes/times, 3/week, 12 weeks	SIS

*Notes:* Intervention Group (I); Control Group (C); Randomized controlled trial (RCT); High Intensity Interval Training (HIIT); Mind-Body Training/control group (MBT); Underwater Exercise (UE); Virtual Reality Training (VRT); Resistance Training (RT); Aerobic Exercise Training (AET); Mental Component Scale (SF-36); European Quality of Life 5 Dimensions (EQ-5 Days); Stroke-specific Quality of Life (SS-QOL); Stroke Impact Scale (SIS); SF-8 health survey.

specific comparisons, such as Virtual Reality Training versus the control group, exhibited a higher risk of bias, necessitating cautious interpretation of the results. Conversely, comparisons with a more significant proportion of the low risk of bias, such as Aerobic Exercise versus the control group, indicated relatively higher study quality. This figure served as a visual representation of study quality and sources of bias across various intervention comparisons in the network meta-analysis, thereby supporting the credibility of the results and enhancing the transparency of the research.

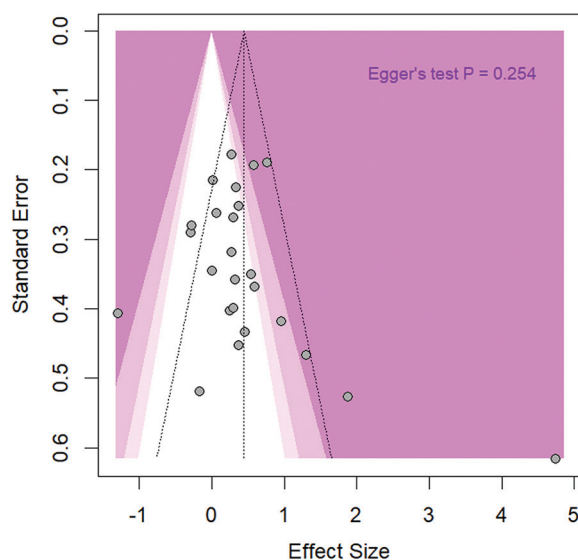
### Study Characteristics

Table 1 presented a comprehensive overview of the randomized controlled trials included in this study. These trials focused on stroke patients who were 18 years or older and examined various interventions, such as High-Intensity Interval Training, Mind-Body Exercises, Underwater Training, Virtual Reality Training, Resistance Training, and Aerobic Training. Further details could be found in Table 1.

### Meta-Analysis

Publication bias was assessed across all included studies using a funnel plot and Egger's test. The Egger's test yielded a  $P$ -value of 0.254 ( $>0.05$ ), indicating no significant evidence of publication bias (see Figure 4). Although sensitivity analyses are typically performed only when  $P < .05$ , they were conducted in this study for thoroughness, with detailed results provided in the supplementary materials.

**Figure 4. Egger's test combined with the funnel plot.**



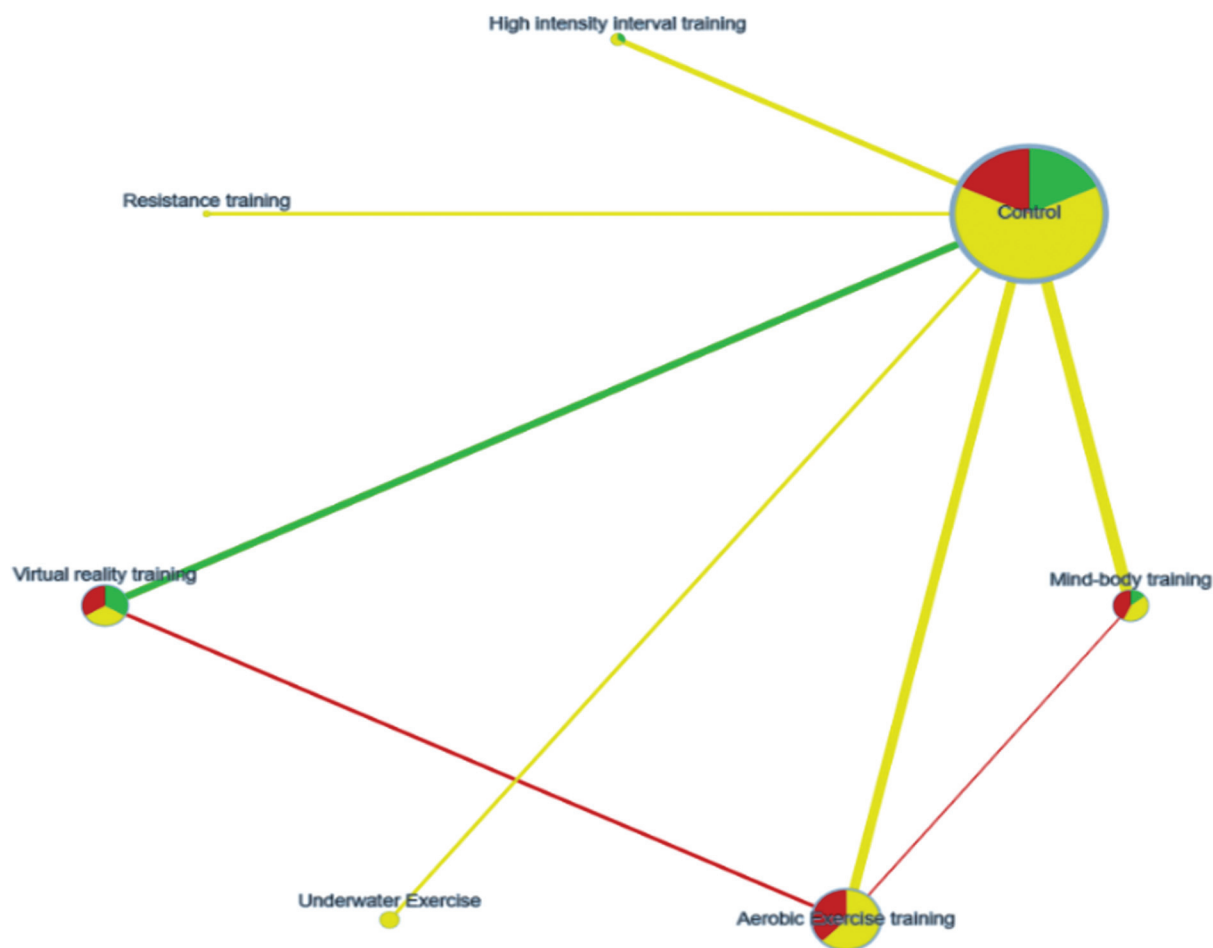
In terms of the intervention analysis, the study evaluated 6 exercise therapies: High-Intensity Interval Training, Mind-Body Training, Underwater Exercise, Virtual Reality Training, Resistance Training, and Aerobic Exercise Training (see Figure 5). A global test for heterogeneity returned a  $P$ -value of 0.80 ( $> 0.05$ ), suggesting consistent direct and indirect effects relative to the control group across these 6 therapies aimed at improving the quality of life in stroke patients.

Following the confirmation of consistent results from the global test and sensitivity analyses, a node-splitting analysis was performed using the *multinma* package in R software. The results (see Figure 6 Node-Splitting Consistency Plot) indicated that all  $P$ -values exceeded 0.05, further supporting the consistency of the findings. These outcomes validated the use of the consistency model for statistical analysis.

This network plot illustrated the evidence for 6 exercise therapies aimed at improving the quality of life in stroke patients. The size of each node represented the sample size for the corresponding intervention, with larger nodes indicating a more significant number of participants. Node colors reflected the risk of bias (RoB), where green denoted low risk, yellow indicated moderate risk, and red signified high risk. The width of the edges connecting the nodes corresponded to the number of studies comparing the 2 interventions, with thicker edges indicating a more significant number of studies. The color of the edges reflected the predominant risk of bias across the connected studies, employing the same green, yellow, and red color scheme. This visual summary provided an overview of the volume and quality of evidence available for each pairwise comparison of exercise therapies.

As illustrated in Figure 7, the table employed the CINeMA (Confidence in Network Meta-Analysis) method to systematically assess the comparisons of various interventions across 6 key domains: within-study bias, reporting bias, indirectness, imprecision, heterogeneity, and incoherence. The level of concern for each domain was indicated using color codes representing no, some, and major concerns.<sup>49</sup> The table was organized into 2 sections: direct and indirect evidence, detailing the number of studies for each comparison and the overall confidence rating of the evidence (eg, moderate, high). The findings revealed that the comparison between High-Intensity Interval Training and the control group

**Figure 5. Evidence network for 6 types of exercise therapy to intervene in the quality of life of stroke patients.**



demonstrated high confidence. In contrast, specific comparisons showed moderate or low confidence due to bias or limitations in the evidence. This provided a precise reference point for selecting interventions and making evidence-based medical decisions.

#### **Publication Bias or Small Sample Effect Test**

An analysis of publication bias was conducted for the 6 types of exercise therapies. The distribution of the included literature was found to be generally symmetrical, indicating a low probability of publication bias or minor sample effects in the current study. Please refer to Figure 8 for more details.

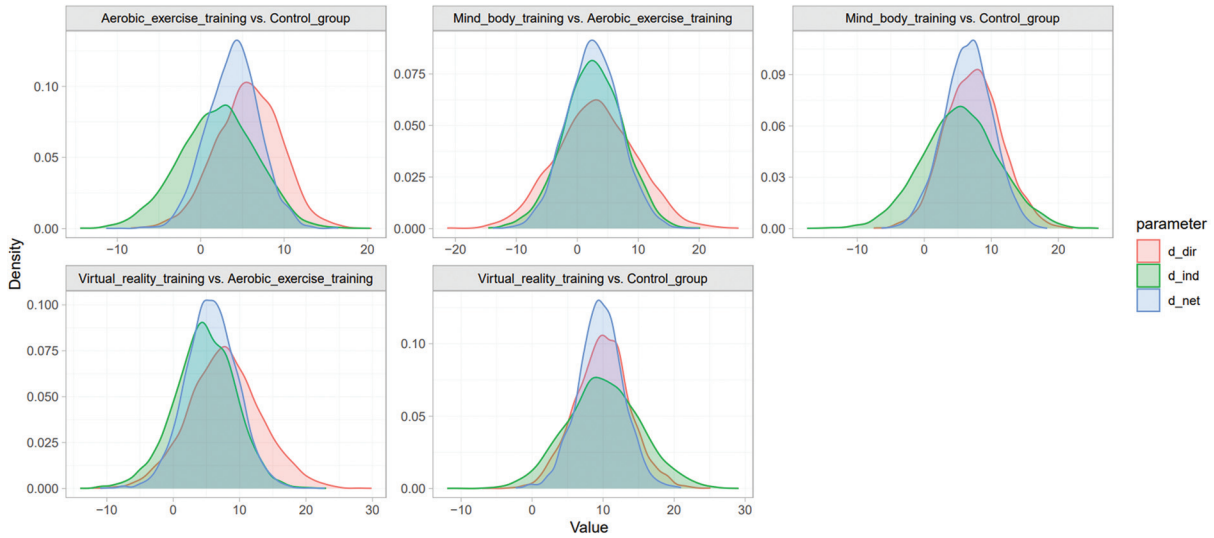
(A: Control group; B: High Intensity Interval Training; C: Mind-Body Training; D: Underwater Exercise; E: Virtual Reality Training; F: Resistance Training; G: Aerobic Exercise Training;)

#### **Traditional Meta-Analysis Results**

Mind-Body Training (SMD = 0.38, 95% CI 0.11 to 0.65,  $P = .006$ ), Underwater Exercise (SMD = 0.71, 95% CI 0.37 to 1.05,  $P = .000$ ), Virtual Reality Training (SMD = 0.37, 95% CI 0.13 to 0.62,  $P = .003$ ), Resistance Training (SMD = 1.04, 95% CI 0.45 to 1.63,  $P = .001$ ), and Aerobic Exercise Training (SMD = 0.37, 95% CI 0.13 to 0.62,  $P = .003$ ) demonstrated significant improvement in the quality of life for stroke patients compared with the control group. However, there was no evidence suggesting that High-Intensity Interval Training (SMD = 0.13, 95% CI  $-0.25$  to 0.52,  $P = .49$ ) effectively enhanced the quality of life in stroke patients (Table 2).

The subgroup analysis revealed that Mind-Body Training, Underwater Exercise, and Virtual Reality Training had significant effects on improving the quality of life in stroke patients aged 50 years or older. These effects were particularly notable when the

**Figure 6. Node-Splitting Consistency Plot.**



intervention duration was >30 minutes but ≤45 minutes, the intervention period was >3 weeks but ≤6 weeks or >10 weeks. Furthermore, the use of the SF-36 Mental Component Scale (MCS) to assess the quality of life demonstrated greater improvements in quality of life scores compared with other scales (Table 2).

**Network Meta-Analysis Results**

The network meta-analysis results indicated that virtual reality training significantly improved the quality of life in stroke patients (SMD = -11.29, 95% CI -18.56 to -4.01). Please refer to Table 3 for more details. The exercise therapies were ranked according to their SUCRA scores, from highest to lowest: Virtual Reality Training (82.3%), Resistance Training (77.3%), Mind-Body Training (61%), Underwater Exercise (52%), Aerobic Exercise Training (44.1%), and High-Intensity Interval Training (19.2%). For a visual representation, please see Figure 9.

To further explore the heterogeneity among studies, all included research was categorized into subgroups based on participants’ age (≥50 years and <50 years). In addition, subgrouping was performed according to factors such as intervention duration (30 minutes; >30 minutes but ≤45 minutes; >45 minutes but ≤60 minutes; >60 minutes), total number of interventions (1 session, 2 sessions, 3 sessions, and >3 sessions), intervention period (>3 weeks but ≤6 weeks; >6 weeks but ≤10 weeks; >10 weeks), intervention types (High-Intensity

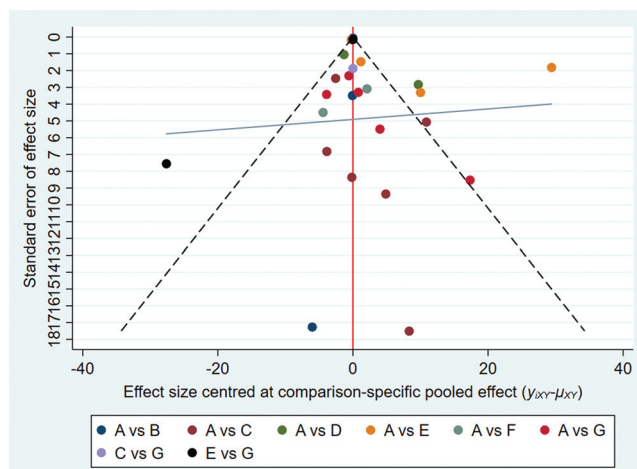
Interval Training, Mind-Body Training, Underwater Exercise, Virtual Reality Training, Resistance Training, Aerobic Exercise Training), and measurement scales.

**Discussion**

De Wit et al. conducted a study on stroke survivors and found significant variability in their quality of life. Only 8% of the survivors had a higher health-related quality of life (HRQoL) compared with the population standard.<sup>50</sup> Similarly, Gunaydin et al. observed a decrease in the quality of life among stroke survivors 3 months after the stroke when compared with the general population.<sup>51</sup> Rønning et al. also conducted a study on stroke patients and found a significant decrease in all dimensions of the SF-36, with the physical and emotional roles being the most affected<sup>52</sup>. In addition, Gunaydin et al. reported no significant difference in quality of life between elderly and nonelderly stroke patients.<sup>51</sup> Naess et al. found no difference in QoL between stroke patients above and below 40 years, except for lower physical function scores in those above 40.<sup>53</sup> However, Mackenzie noted that age was not associated with QoL assessment 3 months poststroke<sup>54</sup>. Previous studies on stroke quality of life (QoL), including cross-sectional, short-term, or long-term follow-ups, commonly identified the level of functional disability as the primary determinant of QoL.<sup>51</sup> However, recent research suggested that age was not a determining factor in the quality of

**Figure 7. Comparison of interventions and confidence rating based on the CINeMA method.**

Comparison	Number of Studies	Within-study bias	Reporting bias	Indirectness	Imprecision	Heterogeneity	Incoherence	Confidence rating
Mixed evidence								
Aerobic Exercise training vs Control	5	Some concerns	Some concerns	No concerns	Major concerns	No concerns	No concerns	Moderate
Aerobic Exercise training vs Mind-body training	1	Some concerns	Some concerns	No concerns	Major concerns	No concerns	No concerns	Moderate
Aerobic Exercise training vs Virtual reality training	2	Some concerns	Some concerns	No concerns	Major concerns	No concerns	No concerns	Moderate
Control vs High intensity interval training	3	Some concerns	Low risk	No concerns	Major concerns	No concerns	No concerns	High
Control vs Mind-body training	6	Some concerns	Some concerns	No concerns	Major concerns	No concerns	No concerns	Moderate
Control vs Resistance training	2	Some concerns	Low risk	No concerns	No concerns	Major concerns	No concerns	High
Control vs Underwater Exercise	2	Some concerns	Low risk	No concerns	Major concerns	No concerns	No concerns	High
Control vs Virtual reality training	4	No concerns	Some concerns	No concerns	No concerns	Major concerns	No concerns	High
Indirect evidence								
Aerobic Exercise training vs High intensity interval training	--	Some concerns	High risk	No concerns	Major concerns	No concerns	No concerns	Low
Aerobic Exercise training vs Resistance training	--	Some concerns	Some concerns	No concerns	Major concerns	No concerns	No concerns	Moderate
Aerobic Exercise training vs Underwater Exercise	--	Some concerns	Some concerns	No concerns	Major concerns	No concerns	No concerns	Moderate
High intensity interval training vs Mind-body training	--	Some concerns	Low risk	No concerns	Major concerns	No concerns	No concerns	High
High intensity interval training vs Resistance training	--	Some concerns	Low risk	No concerns	Major concerns	No concerns	No concerns	High
High intensity interval training vs Underwater Exercise	--	Some concerns	Low risk	No concerns	Major concerns	No concerns	No concerns	High
High intensity interval training vs Virtual reality training	--	Some concerns	Low risk	No concerns	Major concerns	No concerns	No concerns	High
Mind-body training vs Resistance training	--	Some concerns	Low risk	No concerns	Major concerns	No concerns	No concerns	High
Mind-body training vs Underwater Exercise	--	Some concerns	Low risk	No concerns	Major concerns	No concerns	No concerns	High
Mind-body training vs Virtual reality training	--	Some concerns	Low risk	No concerns	Major concerns	No concerns	No concerns	High
Resistance training vs Underwater Exercise	--	Some concerns	Low risk	No concerns	Major concerns	No concerns	No concerns	High
Resistance training vs Virtual reality training	--	Some concerns	Low risk	No concerns	Major concerns	No concerns	No concerns	High
Underwater Exercise vs Virtual reality training	--	Some concerns	Low risk	No concerns	Major concerns	No concerns	No concerns	High

**Figure 8. Publication bias funnel plot.**

life of stroke patients. This emphasizes the urgent need to improve the quality of life for stroke survivors.

The network meta-analysis conducted in this study found that Virtual Reality (VR) Training (82.3%) and Resistance Training (77.3%) were the most effective interventions for improving the quality of life in stroke patients. Virtual Reality (VR) offers several advantages over other interventions, making it a promising tool for physical intervention. These advantages include low cost, portability, compatibility with other systems, and the ability to increase participant motivation and provide direct feedback through game-based interactions.<sup>55</sup> Furthermore, home-based VR rehabilitation is effective.<sup>56</sup> In individuals with chronic stroke, combining VR-based interventions with rehabilitation demonstrated superiority in overall cognition, attention, and executive function.<sup>57</sup> A study by Manuli et al. indicated significant improvements in cognitive and behavioral outcomes, with notable increases in FIM and SF-12 scores after VR therapy, suggesting a better quality of life.<sup>58</sup> Subgroup analysis conducted by Gao et al. revealed that higher doses of VR therapy (over 20 hours of intervention), higher frequency (more than 4 times per week), and higher daily intensity (over 60 minutes per day) resulted in better outcomes in cognitive, motor function, emotional well-being, and activities of daily living rehabilitation.<sup>57</sup> When used alongside traditional therapy, VR interventions proved effective in improving upper limb motor function and activities of daily living after a stroke. Improved upper limb function can potentially enhance participation in daily activities, leading to an

overall improvement in quality of life.<sup>19</sup> Dual-task Training through virtual reality may achieve better cognitive-motor-behavioral outcomes and functional activities of daily living.<sup>58</sup> The use of Virtual Reality (VR) therapy has shown promise in enhancing the quality of life for stroke patients. However, its implementation in home-based health care encounters several challenges. First, the cost of equipment and accessibility for patients, particularly in economically disadvantaged regions, remains a significant barrier. With advancements in technology, portable and affordable devices have gradually emerged, expanding possibilities for home use.<sup>12</sup> Second, the absence of professional support and personalized guidance in home environments poses another challenge. Remote technical training and support services have helped mitigate this limitation, while intuitive and user-friendly interfaces have improved patient adherence, especially among elderly patients.<sup>59</sup> Furthermore, home-based therapy must be flexible enough to accommodate individual patient needs and social backgrounds. This adaptability can be achieved by integrating telemedicine platforms and home care plans to provide personalized treatment options and reduce health care costs.<sup>60</sup> Future research should focus on optimizing the cost-effectiveness of VR therapy and exploring its implementation strategies across different socio-economic contexts to facilitate its broader adoption.<sup>12,60</sup>

Physical exercise is commonly used as a rehabilitation method and has shown effectiveness in stroke patients.<sup>61</sup> Specifically, resistance training has been recommended for individuals recovering from

**Table 2. Subgroup Analysis**

Feature	Category	Number of Literature	SMD	95%CI	P	I <sup>2</sup>	Effect Model
Years	<50	2	0.09	-0.54, 0.71	0.79	0%	Random
	≥50	25	0.42	0.16, 0.67	0.001	77%	Random
Different exercise times (minutes)	30 minutes	7	0.06	-0.36, 0.48	0.77	73%	Random
	>30 minutes, ≤45 minutes	11	0.52	0.25, 0.79	0.0002	56%	Random
	>45 minutes, ≤60 minutes	6	0.78	-0.17, 1.72	0.11	91%	Random
	>60 minutes	1	0.24	-0.55, 1.03	0.55	0%	Random
Different Intervention times (minutes)	>3 weeks, ≤6 weeks	8	0.82	0.12, 1.52	0.02	88%	Random
	>6 weeks, ≤10 weeks	8	0.17	-0.29, 0.63	0.47	77%	Random
	>10 weeks	9	0.33	0.10, 0.56	0.005	33%	Random
Intervention dose/frequency	1	2	0.33	-0.09, 0.75	0.12	0%	Random
	2	7	0.29	-0.01, 0.58	0.06	52%	Random
	3	10	0.30	-0.12, 0.71	0.16	76%	Random
	>3	6	0.97	0.11, 1.84	0.03	90%	Random
Intervention type	High Intensity Interval Training	3	0.13	-0.25, 0.52	0.49	0%	Random
	Mind-Body Training	7	0.37	0.10, 0.64	0.008	0%	Random
	Underwater Exercise	2	0.70	0.36, 1.05	<0.0001	0%	Random
	Virtual Reality Training	5	0.86	-0.17, 1.89	<0.00001	94%	Random
	Resistance Training	2	1.17	-0.08, 2.43	0.07	75%	Random
	Aerobic Exercise Training	6	0.14	-0.25, 0.54	0.48	73%	Random
Scale type	MCS	7	0.56	0.26, 0.85	0.0002	52%	Random
	EQ-5 Days, European Quality of Life 5 Dimensions	3	1.49	-0.60, 3.59	0.16	96%	Random
	SS-QOL	9	0.19	-0.20, 0.57	0.34	71%	Random
	Stroke Impact Scale domains	1	0.24	-0.55, 1.03	0.55	0%	Random
	SIS	2	0.26	-0.15, 0.66	0.22	0%	Random
	The SF-8 health survey	1	0.37	-0.52, 1.25	0.42	0%	Random
	The Stroke-Specific QoL	1	0.32	-0.38, 1.02	0.37	0%	Random
	HRQoL	1	0.27	-0.36, 0.89	0.40	0%	Random

Notes: MCS: SF-36 Mental Component Scale (MCS); SS-QOL: Stroke-specific Quality of Life (SS-QOL); HRQoL: health-related quality of life; EuroQol Five Dimensions Questionnaire (EQ-5 Days); Stroke Impact Scale (SIS); Short Form 8 Health Survey Questionnaire (SF-8).

stroke<sup>62</sup>. Studies have reported that high-intensity and progressive resistance training can enhance muscle strength in stroke survivors<sup>63</sup>. Engaging in regular resistance exercise often leads to improvements in quality of life, work performance, and leisure abilities<sup>64</sup>. In a study by Aidar et al., the impact of strength training on the quality of life of stroke survivors and individuals with cerebrovascular events was assessed, and significant improvements in quality-of-life indicators were observed.<sup>42</sup> Another study demonstrated that a 6-month combined aerobic and resistance training program significantly improved cognitive function and reduced the proportion of patients with mild cognitive

impairment.<sup>65</sup> Similarly, a Cochrane review by Saunders et al. found that resistance exercise contributes to improved muscle strength, enhanced quality of life, and better performance in daily activities for stroke patients.<sup>66</sup> Meta-analyses conducted by Chen et al. also support the notion that exercise improves health-related quality of life in chronic stroke patients.<sup>18</sup> Therefore, strength training, in particular, has been recommended as a valuable approach to enhance functionality in stroke patients.<sup>67</sup>

### Limitations

This study conducted a systematic evaluation of the therapeutic effects of 6 types of exercise

**Table 3. Mesh Meta-Analysis of Quality of Life**

Intervention Mode	Control Group	Aerobic Exercise Training	Resistance Training	Virtual Reality Training
Aerobic Exercise Training	-4.89 (-11.64, 1.87)			
Resistance Training	-11.06 (-23.57, 1.45)	-6.17 (-20.39, 8.05)		
Virtual Reality Training	-11.29 (-18.56, -4.01)*	-6.40 (-14.88, 2.08)	-0.23 (-14.71, 14.26)	
Underwater Exercise	-6.13 (-17.84, 5.58)	-1.25 (-14.76, 12.27)	4.93 (-12.21, 22.07)	5.15 (-8.62, 18.93)
Mind-Body Training	-7.52 (-15.42, 0.38)	-2.63 (-12.00, 6.73)	3.54 (-11.26, 18.34)	3.77 (-6.68, 14.21)
High-Intensity Interval Training	0.50 (-10.76, 11.77)	5.39 (-7.74, 18.53)	11.57 (-5.27, 28.40)	11.79 (-1.64, 25.22)
		Underwater Exercise		Mind-Body Training
Mind-Body Training		-1.39 (-15.51, 12.74)		
High-Intensity Interval Training		6.64 (-9.61, 22.89)		8.02 (-5.74, 21.78)

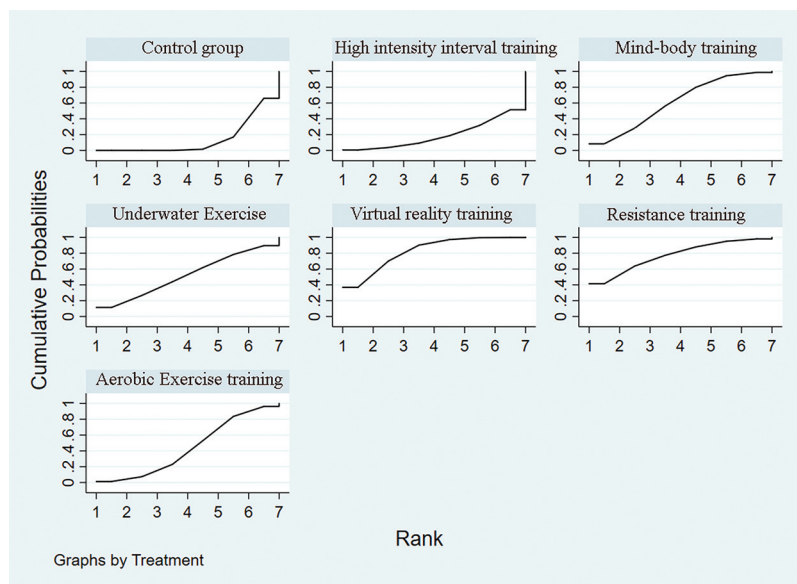
Notes: The study output is presented in a table format, where Standardized Mean Difference (SMD) > 0 indicates that the intervention in the row is better than the intervention in the column. SMD < 0 suggests that the intervention in the column is better than in the row. Additionally, an asterisk (\*) indicates that the difference between the two interventions is statistically significant ( $P < .05$ ).

interventions on the quality of life of stroke patients using network meta-analysis. However, there are some limitations regarding the categorization and settings of these interventions. In addition, there is a lack of literature on resistance exercise interventions for improving the quality of life of stroke patients, which could have influenced the results. Furthermore, the inclusion criteria only considered English-language articles from controlled trials, potentially excluding relevant literature published in other languages.

### Conclusions

This study aimed to compare the effectiveness of 6 exercise interventions in improving stroke patients' quality of life. The results showed that both Virtual Reality (VR) Training (82.3%) and Resistance Training (77.3%) were significantly more effective than conventional treatments. Among these, VR Training (82.3%) was the most effective intervention. Therefore, health care professionals should consider incorporating VR Training, either alone or in combination with other traditional exercise

**Figure 9. Cumulative probability plot of quality of life.**



therapies, based on the individual patient's condition and preferences. This approach will help achieve the dual goals of improving physical function and enhancing quality of life, as supported by the findings of this study.

To see this article online, please go to: <http://jabfm.org/content/38/3/431.full>.

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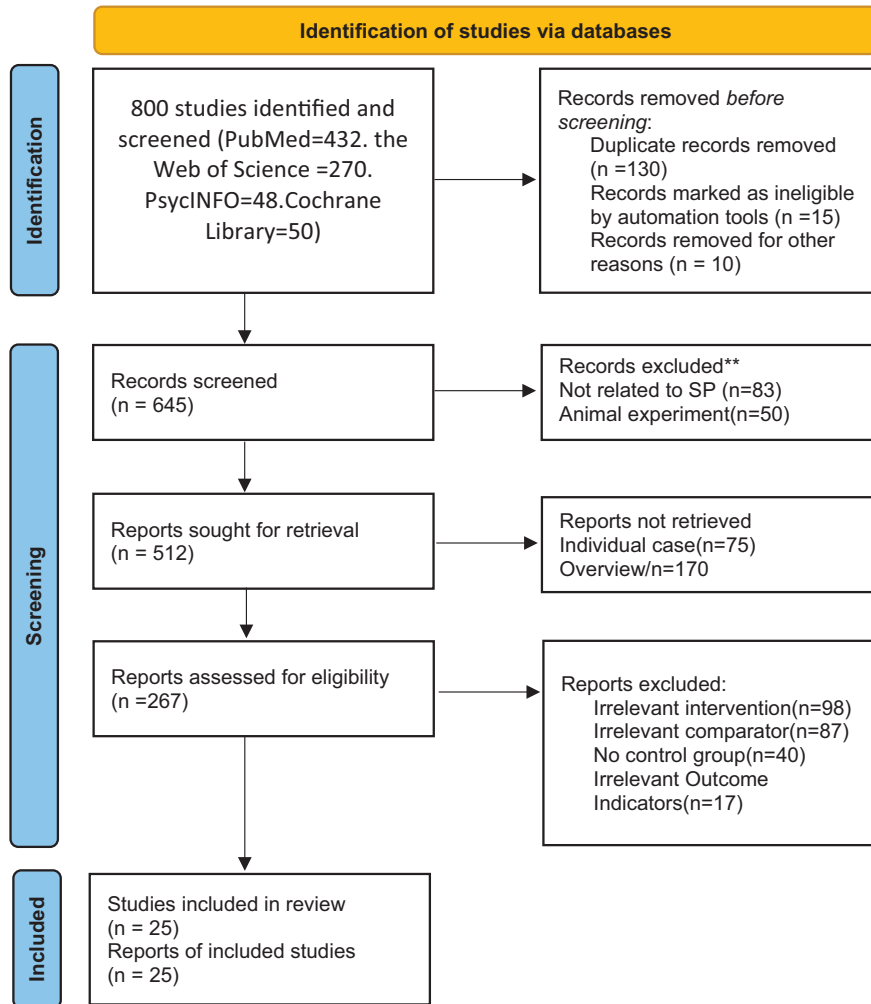
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## Appendix 1. PRISMA 2020 Flow Diagram for New Systematic Reviews Including Searches of Databases and Registers Only.

PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only



\*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).

\*\*If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021; 372:n71. doi: 10.1136/bmj.n71

For more information, visit: <http://www.prisma-statement.org/>

## Appendix 2. Search Strategy for Identifying Relevant Studies.

### The Impact of Multiple Exercise Modes on the Quality of Life of Stroke Patients: A Network Meta-Analysis

#### 1. Search strategy

#1 "Diabetes Mellitus, Type 2"[Mesh]

#2 (Diabetes Mellitus, Noninsulin-Dependent[Title/Abstract]) OR (Diabetes Mellitus, Ketosis-Resistant[Title/Abstract]) OR (Diabetes Mellitus, Ketosis Resistant[Title/Abstract]) OR (Ketosis-Resistant Diabetes Mellitus[Title/Abstract]) OR (Diabetes Mellitus, Non Insulin Dependent[Title/Abstract]) OR (Diabetes Mellitus, Non-Insulin-Dependent[Title/Abstract]) OR (Non -Insulin-Dependent Diabetes Mellitus[Title/Abstract]) OR (Diabetes Mellitus, Stable[Title/Abstract]) OR (Stable Diabetes Mellitus[Title/Abstract]) OR (Diabetes Mellitus, Type II[Title/Abstract]) OR (NIDDM[Title/Abstract]) OR (Diabetes Mellitus, Noninsulin Dependent[Title/Abstract]) OR (Diabetes Mellitus, Maturity - Onset[Title/Abstract]) OR (Diabetes Mellitus, Maturity Onset[Title/Abstract]) OR (Maturity-Onset Diabetes Mellitus[Title/Abstract]) OR (Maturity Onset Diabetes Mellitus[Title/Abstract]) OR (MODY[Title/Abstract]) OR (Diabetes Mellitus, Slow-Onset[Title/Abstract]) OR (Diabetes Mellitus, Slow Onset[Title/Abstract]) OR (Slow-Onset Diabetes Mellitus[Title/Abstract]) OR (Type 2 Diabetes Mellitus[Title/Abstract]) OR (Noninsulin -Dependent Diabetes Mellitus[Title/Abstract]) OR (Noninsulin Dependent Diabetes Mellitus[Title/Abstract]) OR (Maturity -Onset Diabetes[Title/Abstract]) OR (Diabetes, Maturity -Onset[Title/Abstract]) OR (Maturity Onset Diabetes[Title/Abstract]) OR (Type 2 Diabetes[Title/Abstract]) OR (Diabetes, Type 2[Title/Abstract]) OR (Diabetes Mellitus, Adult-Onset[Title/Abstract]) OR (Adult-Onset Diabetes Mellitus[Title/Abstract]) OR (Diabetes Mellitus, Adult Onset[Title/Abstract])

#3 "Exercise"[Mesh]

#4 (Exercises[Title/Abstract]) OR (Physical Activity[Title/Abstract]) OR (Activities, Physical[Title/Abstract]) OR (Activity, Physical[Title/Abstract]) OR (Physical Activities[Title/Abstract]) OR (Exercise, Physical[Title/Abstract]) OR (Exercises, Physical[Title/Abstract]) OR (Physical Exercise[Title/Abstract]) OR (Physical Exercises[Title/Abstract]) OR (Exercise, Acute[Title/Abstract]) OR (Exercises, Acute[Title/Abstract]) OR (Exercise, Isometric[Title/Abstract]) OR (Exercises, Isometric[Title/Abstract]) OR (Isometric Exercises[Title/Abstract]) OR (Isometric Exercise[Title/Abstract]) OR (Exercise, Aerobic[Title/Abstract]) OR (Aerobic Exercise[Title/Abstract]) OR (Aerobic Exercises[Title/Abstract]) OR (Exercises, Aerobic[Title/Abstract]) OR (Exercise Training[Title/Abstract]) OR (Exercise Trainings[Title/Abstract]) OR (Training, Exercise[Title/Abstract]) OR (Trainings, Exercise[Title/Abstract])

#5 "Glycated Hemoglobin"[Mesh]

#6 (Hemoglobin, Glycated[Title/Abstract]) OR (Glycohemoglobin[Title/Abstract]) OR (Glycohemoglobins[Title/Abstract]) OR (Glycated

Hemoglobins[Title/Abstract] OR (Hemoglobins, Glycated[Title/Abstract]) OR (Hemoglobin, Glycosylated[Title/Abstract]) OR (Glycosylated Hemoglobin[Title/Abstract]) OR (Glycated Hemoglobin A1c[Title/Abstract]) OR (Hemoglobin A1c, Glycated[Title/Abstract]) OR (Glycosylated Hemoglobin A1c[Title/Abstract]) OR (Hemoglobin A1c, Glycosylated[Title/Abstract]) OR (Hb A1a-2[Title/Abstract]) OR (Hemoglobin, Glycated A1a-2[Title/Abstract]) OR (A1a-2 Hemoglobin, Glycated[Title/Abstract]) OR (Glycated A1a -2 Hemoglobin[Title/Abstract]) OR (Hemoglobin, Glycated A1a 2[Title/Abstract]) OR (Glycated Hemoglobin A[Title/Abstract]) OR (Hemoglobin A, Glycated[Title/Abstract]) OR (Hb A1a+b[Title/Abstract]) OR (Hb A1c [Title/Abstract]) OR (HbA1[Title/Abstract]) OR (Glycosylated Hemoglobin A[Title/Abstract]) OR (Hemoglobin A, Glycosylated[Title/Abstract]) OR (Hb A1[Title/Abstract]) OR (Glycohemoglobin A[Title/Abstract]) OR (Hemoglobin A(1)[Title/Abstract]) OR (Hemoglobin, Glycosylated A1a-1[Title/Abstract]) OR (A1a-1 Hemoglobin, Glycosylated[Title/Abstract]) OR (Glycosylated A1a-1 Hemoglobin[Title/Abstract]) OR (Hemoglobin, Glycosylated A1a-1 [Title/Abstract]) OR (Hb A1a -1[Title/Abstract]) OR (Hemoglobin, Glycated A1b[Title/Abstract]) OR (A1b Hemoglobin, Glycated[Title/Abstract]) OR (Glycated A1b Hemoglobin[Title/Abstract]) OR (Hb A1b[Title/Abstract]) OR (Hemoglobin, Glycosylated A1b[Title/Abstract]) OR (A1b Hemoglobin, Glycosylated[Title/Abstract]) OR (Glycosylated A1b Hemoglobin[Title/Abstract]) OR (Fructated Hemoglobins[Title/Abstract]) OR (Hemoglobins, Fructated [Title/Abstract])  
 #7 randomized controlled trial[Publication Type] OR randomized[Title/Abstract] OR placebo[Title/Abstract]  
 #8 #1 OR #2  
 #9 #3 OR #4  
 #10 #5 OR #6  
 #11 #8 AND #9 AND #10 AND #7

### Appendix 3. Leave-One-Out Sensitivity Analysis of Meta-Analysis Results.

