Eye-Tracking Technology Applications for Post-Stroke Hemispatial Neglect: A Systematic Review

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Abstract

Background: Hemineglect, or hemispatial neglect, is commonly experienced in individuals following a stroke, making it difficult for them to recognize half of their field of vision and causing them to be visually unaware of the side opposite the brain lesion. This causes frustration and difficulty in those experiencing it, thus highlighting a need for effective ways of assessing the issue and offering beneficial treatment. Current research aims at updating the technology associated with assessing and treating hemineglect in such patients. This systematic review studied the effectiveness of eye-tracking and virtual reality (VR) technology in both assessing severity and as a form of treatment to retrain the participants to acknowledge their neglected side.

Importance: Roughly 30% of stroke patients experience hemispatial neglect. Current standardized clinical assessments to evaluate spatial neglect are either paper and pencil tests or behavioral tests. While this method does work, with the advancements of technology assessments and treatments clinicians are able to more effectively assess and treat spatial neglect. Eye-tracking technology can be a reliable, accurate, and effective assessment or intervention for hemispatial neglect in individuals post stroke.

Objective: To identify, evaluate, and synthesize the current literature concerning eye-tracking technologies to determine the efficacy of hemineglect detection and reduction in individuals post-stroke.

Data Sources: A literature search occurred between May 8, 2025 and May 22, 2025. Follow up searches were conducted on June 20, 2025. Databases included EBSCO, Academic Search Complete, and Google Scholar using Hawai'i Pacific University's online library databases. Search terms included "eye tracking" OR "eye-tracking technology"; "spatial neglect" OR "hemispatial neglect" OR "unilateral neglect"; "stroke" OR "post-stroke", as well as combinations of these terms.

Study Selection and Data Collection: This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Published studies on eye-tracking applications for hemispatial neglect were included in the systematic review. Data from presentations, non-peer reviewed literature, and dissertations were excluded.

Findings: Six studies were included (one Level IB, one Level IIB, three Level IIIB, and one Level IV according to the American Occupational Therapy Association's Levels of Evidence). The outcomes of these studies indicate that virtual eye-tracking systems are feasible, well-tolerated, can replicate findings of established hemineglect assessments, and may be able to retrain eye movement towards the affected side.

Conclusion and Relevance: Virtual eye-tracking technologies may be effective to improve hemineglect for individuals post-stroke.

What This Systematic Review Adds: There are limited high quality studies that evaluate the use of eye-tracking technology to address hemineglect in individuals post-stroke. This systematic review provides a starting point for evaluating the efficacy of eye-tracking technology to address hemineglect in individuals post-stroke in OT practice. More research is needed to understand differences in stroke subtypes, standardize eye movement protocols, and understand real-world barriers to implementation.

Key words: Assessment, Eye movements, Gaze-contingent displays, Hemispatial neglect, Rehabilitation, Saccadic eye movement, Spatial neglect, Stroke, Unilateral spatial neglect, Video-oculography, Virtual reality, Visual fields, Visuospatial attention

Technology surrounding eye-tracking and virtual reality (VR) is becoming more prevalent and advanced in today's society. There are many uses of this technology including gaming, assessments, and, as new research suggests, a method of rehabilitation. Because of the ability of devices to track eye movement, there are opportunities to utilize them to assess sight patterns in individuals who have suffered a stroke experiencing hemineglect in their vision (Hong et al., 2024; Kudo et al., 2021; Perez-Marcos et al., 2023). Those who experience hemineglect find it difficult to recognize one side of their field of vision. Information from eye-tracking can help patients and their healthcare providers have better information on where specifically they struggle to perceive, and this can help to treat the hemineglect of the individual. This leads to utilizing VR and eye-tracking technology to shift visual focus toward the neglected side, thus also becoming an effective form of treatment (Arima et al., 2025; Kunkel gennant Bode et al., 2022; Motomura et al., 2024).

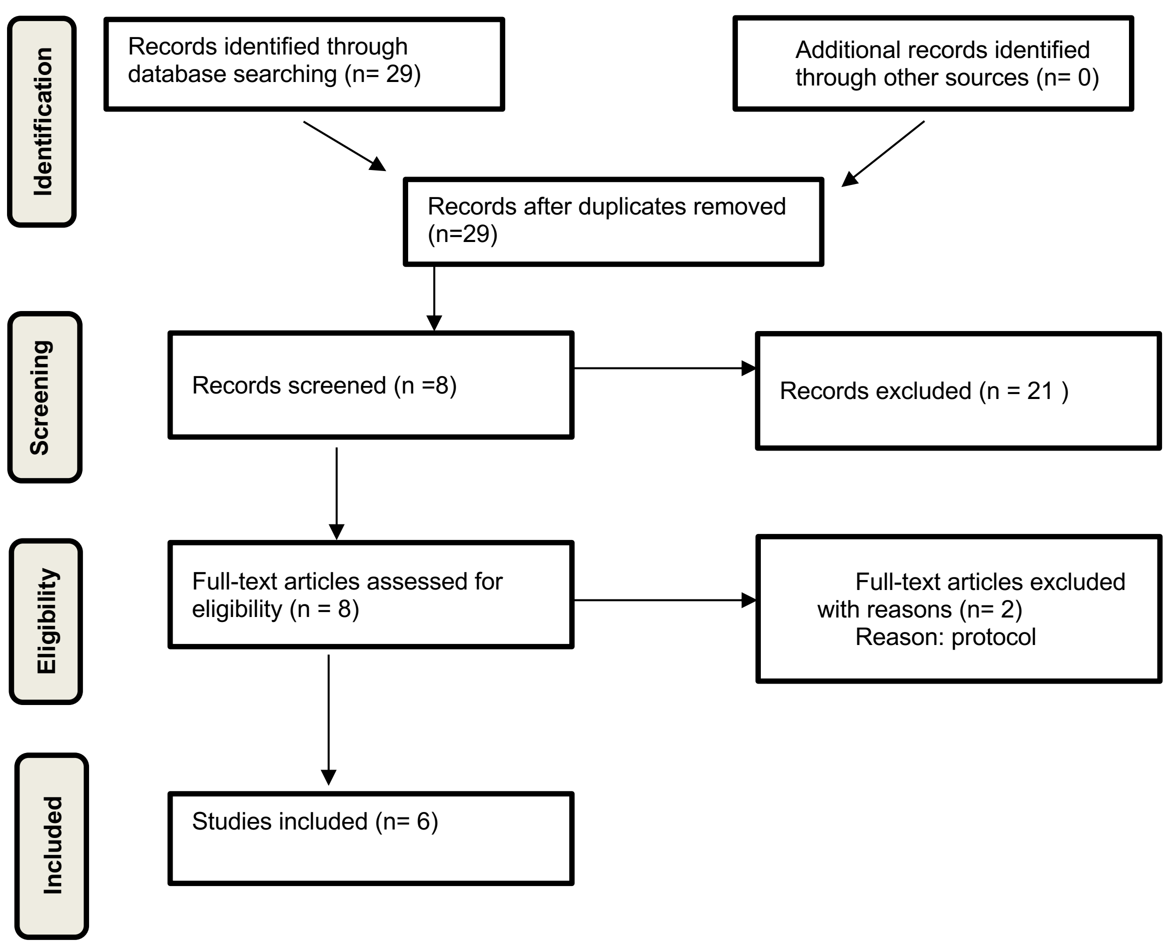
Considering the possible implications of this research, we conducted a systematic review addressing the question, "Does the use of eye-tracking technology improve spatial neglect post-stroke?" This question was expanded to include validity of assessments using eye-tracking technology due to a limited number of studies that met the search criteria. The purpose of this systematic review was to gain an understanding of the current research on the topic that may lead to better assessment and treatment of hemineglect in persons post-stroke, as well as keep healthcare providers updated on possible creative uses of technology not initially intended for rehabilitation. By reviewing current publications on the use of eye-tracking and VR technology, we aimed to highlight its potential benefits and gaps in the research that may be filled by future studies.

Method

The systematic review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) and incorporated recommended processes for conducting a systematic review. A broad search of the literature occurred between May 8, 2025, and May 22, 2025. An additional search was conducted on June 20, 2025, to ensure all relevant research was included. The inclusion criteria for studies in this systematic review were as follows: peer-reviewed, published in English, and dated between 2020-2025. Exclusion criteria, in addition to those studies that did not meet the inclusion criteria, included articles that were systematic reviews, scoping reviews, dissertations, and presentations. A search for relevant literature was completed using electronic databases: EBSCO, Academic Search Complete, and Google Scholar through Hawai'i Pacific University's online library database. Search terms included: "eye tracking" OR "eye-tracking technology"; "spatial neglect" OR "hemispatial neglect" OR "unilateral neglect"; "stroke" OR "post-stroke", as well as combinations of these terms. Appendix A provides an extensive list of all search terms used for this systematic review. The initial search included 29 articles related to the research topic (Figure 1). Three independent reviewers completed the screening and selection of the studies, assessed their quality, and extracted the data.

Figure 1

PRISMA Flow Diagram



Results

Six studies met the inclusion criteria. The articles were assessed according to their risk of bias, level of evidence, and quality. This systematic review included six studies that contained relevant information regarding VR and eye-tracking technology for spatial neglect in individuals post-stroke. The information from these articles was divided into two themes: assessment feasibility and efficacy of specific systems and intervention effectiveness of specific systems. An evidence table is provided in Appendix B. The Cochrane risk-of-bias guidelines were used to assess each article and are provided in Appendix C.

Assessment Feasibility and Efficacy

Three of the six studies on eye-tracking and VR use in post-stroke populations discussed the feasibility and efficacy of specific systems for post-stroke assessment. Two of these studies were Level 3B studies and one was a Level 4 study (see Appendix B). All studies provided evidence that the specific eye-tracking systems tested were effective in post-stroke assessment of the targeted measures.

In 2024, Hong, Jeong, and Kim found that the CoTras Visions System was safe and well-tolerated by post-stroke patients to acquire the same information as the paper-and-pencil Albert's test and Star cancellation tests, which measure unilateral spatial neglect (USN). In 2021, Kudo et al. found that video-oculography measures of eye horizontal saccade and smooth pursuit matched the Behavioral Inattention Test, an existing measure of hemispatial neglect. They claim theirs is the first study specifically characterizing the relationship between eye movements and the tendency for hemispatial neglect in patients with acute stage stroke. In 2023, Perez-Marcos et al. found that the iVR system was well-tolerated to assess visuo-motor and visuo-perceptual exploration. They claim theirs is the first multilevel, VR-based test battery for the assessment of far and near space for both left- and right-sided USN.

Limitations of the studies on specific eye-tracking and VR systems for post-stroke assessment included lack of control group, small sample size, and lack of specificity to stroke type across all three studies. Hong, Jeong, and Kim (2024) noted that due to their study being performed in a specialized stroke hospital, patients were not representative of the general population. Kudo et al. (2021) statedthat the video-oculography system itself had a low sample rate for measuring saccades. Perez-Marcos et al. (2023) reported that their system needed clinical validity as it was only tested on recovered individuals rather than those with symptoms and should be validated on various hardware (e.g., screen sizes, resolutions, processors) before being distributed or marketed.

Eye-Tracking and VR Systems for Post-Stroke Intervention

Three of the six studies on eye-tracking and VR use in post-stroke populations discussed efficacy of systems for post-stroke intervention. One of these studies was Level 1B, another study was Level 2B, and one study was Level 3B (see Appendix B). All studies inferred that their respective systems were effective and potentially beneficial, despite the desired outcomes being somewhat different depending on the study.

Motomura et al. (2024) demonstrated the effects of using VR for patients with unilateral spatial neglect. Their research used a randomized control trial design and provided information on the effectiveness of using VR mixed with stimulus-response tasks to improve the use of the affected eye and that eye's field of vision. VR with stimulus-response tasks was shown to be effective in retraining the participants to reduce the spatial neglect through repetition and the engagement it promoted in treatment.

Kunkel gennant Bode et al. (2022) conducted a study on a similar intervention for hemispatial neglect in individuals post-stroke. Their intervention included the use of VR technology to dim and hide parts of the screen to encourage the participants to expand their field of vision and look in areas affected by visual neglect. This intervention trained the participants to look to the contralateral side, rather than the ipsilateral side. This study showed the intervention to be moderately effective because of the redirection of attention and improved overall visual search behavior. These effects were immediate but were not measured after the initial treatment.

Arima et al. (2025) found that stroke patients showed limited eye movements and impaired vertical visual (VV) perception. To find out why stroke patients with unilateral spatial neglect (USN) struggle with this perception issue, they studied a range of participants' eye movements. Data showed limited eye movement and a tendency to fixate on prominent ends of a bar shown on the screen. This contrasts with participants without USN who fixated towards the center of the bar. Participants who demonstrated longer eye scan paths had better vertical visual perception. This association informed rehab strategies for patients post stroke.

Limitations of the studies on intervention effectiveness of VR include small sample sizes (Arima et al., 2025; Kunkel gennant Bode et al., 2022; Motomura et al., 2024), effects were not measured long-term (Arima et al., 2025; Kunkel gennant Bode et al., 2022; Motomura et al., 2024), and a lack of understanding of how the results translate into real world practice (Kunkel gennant Bode et al., 2022; Motomura et al., 2024). Also, standardized eye movement tasks would be helpful in revealing the fundamental mechanisms associated with hemispatial neglect and the difference in severity with which individuals experience it (Arima et al, 2025).

Discussion

The results of this systematic review suggest that eye-tracking technologies may be effective to assess and improve spatial neglect for individuals post-stroke. Recent research into assessment validity of various eye-tracking systems aims to correlate measurements in various systems to existing established stroke assessments. The specific systems tested demonstrated safety, feasibility, and validity (Hong et al., 2024; Kudo et al., 2021). Cutting edge eye-tracking systems aim to define novel measures of eye movement that can detect hemineglect earlier or at lower detection thresholds than existing measures

(Perez-Marcos et al., 2023). Overall, the research suggests that eye-tracking could be a possible assessment tool for spatial neglect patients post-stroke.

Informed by these biomarkers, additional systems seek to intervene in hemineglect by expanding eye movement performance by measuring eye scan and gaze. In doing so, the researchers were able to visually compare characteristics with eye movement patterns with spatial neglect and normal vision. This can be proposed as a possible intervention strategy to incorporate the VV assessment to gain insight into patients' unique difficulties and where to put more focus during intervention (Arima et al., 2025). VR and eye-tracking was also effectively reduced hemispatial neglect through different training tactics, leading the participants to look more toward the contralateral side of their vision (Kunkel gennant Bode et al., 2022; Motomura et al., 2024). Eye-tracking and VR technology were shown through these studies to be valid for assessment and intervention for individuals with hemispatial neglect due to stroke, opening up possibilities for future research and treatment.

Strengths and Limitations

When considering strengths of the systematic review process, the incorporation of PRISMA guidelines and flowchart was helpful to identify the inclusions and exclusion criteria and organize research articles. The team of researchers met to determine article inclusion and exclusion and selected articles for relevancy. Through the research process, various types of technology were identified for spatial neglect supported by the advancements of technology such as VR.

The currency of studies, published within the past 5 years (2020-2025), was important due to the rapid advances in technology. When compiling articles for the systematic review, only six studies met the inclusion criteria. Many of these studies were low levels of evidence based on study designs. When analyzing the studies, it was difficult to find information on intervention strategies. Many of the studies focused on eye-tracking technology as a modality for assessments rather than intervention. Therefore, the team of researchers re-framed the research question to apply to both assessment and intervention strategies.

Implications for Occupational Therapy Practice

The findings suggest several implications for occupational therapy practice and future research regarding eye-tracking technology for spatial neglect in individuals post stroke. Eye-tracking technology may allow individuals post-stroke to be accurately assessed and can be incorporated in interventions to improve spatial neglect to return to ADLs such as self-care, driving, and working. There is a need for a more diverse population, larger sample size, and research to provide insight as to how eye-tracking technology could further benefit individuals post-stroke and become a standardized practice for the future. Implementation barriers associated with some VR systems, such as cybersickness (too much screen presence), must also be overcome before these technologies are widely used in practice. Occupational therapists should incorporate other evidence-based assessments and interventions such as standardized vision assessments and functional exercises and awareness training, in addition to the eye-tracking technology. Assessments that are complementary to the post-stroke training are Fugl-Meyer Assessment (FMA), Montreal Cognitive Assessment (MCA), and the Canadian Occupational Performance Measure (COPM).

- Eye-tracking technology is a new modality for assessment and intervention for individuals with visual deficits post-stroke.
- Using eye-tracking technology, occupational therapists can tailor interventions based upon location of spatial neglect/lesion.
- Occupational therapists can incorporate stimulus attention (detection of movement in peripheral vision) with goal directed attention (selective focus and visual searching) through technology to improve performance on ADLs and IADLs.
- Eye-tracking technology is a safe, customizable, immersive environment but more research is needed to demonstrate its impact on spatial neglect.

Conclusion

Studies included within this systematic review provide initial evidence on the effectiveness of eye-tracking technologies for assessment and treatment of hemineglect in individuals post-stroke. There are limited high quality studies that evaluate the use of eye-tracking technology to address hemineglect in individuals post-stroke. Additional research is necessary to understand differences in stroke subtypes, standardize eye movement protocols, associate protocols with functional outcomes, and understand real-world barriers to implementation. These technologies have the potential to inform and expand the sensitivity, specificity, and efficacy of future rehabilitation protocols.

References

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Appendix A

Search Terms

"eye tracking" OR “eye-tracking” OR "eye tracking technology" OR "eye-tracking technology" AND "spatial neglect" OR "hemispatial neglect" OR "unilateral neglect" OR "unilateral spatial neglect" AND "stroke*" OR "post-stroke" OR "cerebrovascular accident"

Appendix B

Evidence Table

Table 1. *Use of Eye Tracking Technologies in Assessment and Treatment of Post-stroke Hemineglect*

Author/Year	Level of Evidence Study Design Risk of Bias	Participants Inclusion Criteria Study Setting	Intervention and Control Groups	Outcome Measures	Results
Arima et al., 2025	Comparative cohort study Level 3 B Risk of Bias moderate	Inclusion: History of stroke within 40 days, normal controls, first stroke, ages 43-79, right-handed, and approved by the ethic committee Kansai Medical University Exclusion: If patients had brainstem, cerebellar or hemorrhagic stroke, brain tumor, brain lesion, history of previous stroke, other neurological disease, aphasia or cognitive impairments	42 participants with first episode of hemorrhagic or ischemic stroke 17 USN (+) with RHD 25 USN (-) (10 had RHD and 15 and LHD) No control group	Subjective Visual Vertical perception: deficits in visual exploration after stroke, Eve movement patterns (positioning), Neuropsychological test for USN, MRI or CT	Study shows how eye movement affects stroke patients with unilateral neglect called subjective visual vertical (VV). Stroke patients showed greater variability in understanding a true vertical and limited eye movement along the bar. Researchers found that eyes were mainly contrasted to specific areas of the bar, predominantly the ends. The research indicates those with no damage to the FEF (frontal eye field) could improve VV compared to those who damaged their FEFmaking it harder to control their own eye movements.

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Hong et al., 2024	Post-test or instrument validation AOTA level 3B risk of bias: moderate	Inclusion: Admitted to specific hospital First stroke, within past 6 months age 18-85 Exclusion: severe UE weakness, cognitive impairment unable to follow directions, prior diagnosis of psychiatric disease *not filtered by hemineglect, all included*	Intervention group: ten patients with acute stroke No control group	Virtual versions of Albert's test + Star cancellation test compared to paper and pencil Patient-reported modified Intrinsic Motivation Inventory, Patient Satisfaction Survey, and Simulator Sickness Questionnaire	CoTras Vision system is feasible and safe with stroke patients: digital assessments match paper Sufficient patient motivation Lack of adverse effects
Kudo et al., 2021	Post-test or instrument validation AOTA level 3B risk of bias: low	Inclusion: Yokohama Brain and Spine Center, and acute cerebral infarction OR hemorrhage, and isolated unilateral supratentorial stroke Exclusion: Past history of stroke, moderate or severe impairment of consciousness, severe dementia, visual field loss, blurred vision, or limited eye movement upon bedside examination	Intervention group: forty-seven patients with acute unilateral supratentorial stroke No control group	Video-oculography measures of: horizontal saccade (latency, velocity, and amplitude) and smooth pursuit (gain), Existing measure of hemispatial neglect: Behavioral Inattention Test	Video-oculography measurements of eye movements significantly correlated with an existing measure of hemispatial neglect in acute supratentorial stroke patients

Kunkel genannt Bode et al., 2022	Quasi-experimental level 2B risk of bias: moderate	Inclusion: Patients with left hemispatial neglect confirmed by neuropsychosocial testing, 18 years or older, right handed, first ever stroke in the right hemisphere, Study setting: dim lit room in front of a 23” widescreen TFT monitor	19 patients with hemispatial neglect 22 participants in control group	Center of Fixation (CoF), omission rate, reaction time. Feasibility- asked patients whether the tasks were pleasant or annoying (1-10) and if they had observations to share	The use of GCD technology led to a shift in gaze behavior, causing participants with unilateral neglect to shift their focus more toward the neglected side. The control group did not show the same effect
Motomura et al., 2024	RCT Level 1B (did a power analysis) risk of bias: low	Inclusion: No history of previous stroke, supratentorial lesion, right-handed, stable neurologic condition, ability to sit for 20 minutes without support, Catherine Bergego Scale of 1 or more points, and right hemisphere damage. Setting: not described well, sitting wearing VR	SR+BS group-14 SR Group- 14 Control group-14	SAT score using reaction time, BIT-c, CBS, and Straight Ahead Pointing (SAP scores) for change in egocentric center position	Using virtual reality improved reaction time and showed improvement in pre- to post-test that were not observed in the control group for each of the assessments used in the study. VR outperformed traditional therapy in reducing hemineglect.
Perez-Marcos et al., 2023	Cohort single case study Level: 4 risk of bias: moderate	Inclusion: 39 healthy adults, no neurological or psychiatric disease, 39-70 years old, right handed and index greater than 80% according to EHI, normal or corrected vision,	Intervention group: 39 adults No control group	Feasibility of iVR for assessing USN, levels of presence, enjoyment, objective measuring, multi level difficulty,	Participants missed few targets averaging 1 target per level however with iVR the average went down to less than 0.5 per level. Even if they were multitasking or having outside noise, it did not affect the targets missed in paper assessment and iVR. From a questionnaire completed by the

		Exclusion: participants unable to perform task, technical problems			participants, VR had a slight increase in fatigue, but increased in immersion and stronger sense of control. iVR was more difficult than paper=pen test but more participants preferred iVR with 29 out of 39 prospectively selecting it as their favorite.

Note. Acronyms used.

USN=unilateral spatial neglect

RHD= Right hemispheric damage

LDH- left hemispheric damage

USN= Unilateral spatial neglect

Appendix C

Table 2. *Risk-of-Bias Tables*

Risk-of-Bias Table for Randomized Controlled Trial (RCT) and Non-RCT (Two or More Group Design)										
	Selection Bias (Risk of bias arising from randomization process)			Performance Bias (effect of assignment to intervention)		Detection Bias		Attrition Bias	Reporting Bias	Overall risk-of-bias (low, moderate, high
Citation	Random Sequence Generation	Allocation Concealment (until participants enrolled and assigned)	Baseline difference between interventio n groups	Blinding of Participa-nts During the Trial	Blinding of Study Personnel During the Trial	Blinding of Outcome Assessment: Self-reported outcomes	Blinding of Outcome Assessment: Objective Outcomes (assessors aware of intervention received?)	Incomplete Outcome Data (data for all or nearly all participants	Selective Reporting (results being reported selected on basis of the results?)	
Kunkel gennant Bode et al., 2022	+	-	-	+	-	+	-	+	+	moderate
Motomura et al., 2024	+	+	+	+	+	?	?	+	+	low

Note. Categories for risk of bias are as follows: Low risk of bias (+), unclear risk of bias (?), high risk of bias (–). Scoring for overall risk of bias assessment is as follows: 0–3 minuses, low risk of bias (L); 4–6 minuses, moderate risk of bias (M); 7–9 minuses, high risk of bias (H).

Citation. Table format adapted from Higgins, J. P. T., Sterne, J. A. C., Savović, J., Page, M. J., Hróbjartsson, A., Boutron, I., . . . Eldridge, S. (2016). A revised tool for assessing risk of bias in randomized trials. Cochrane Database of Systematic Reviews 2016, Issue 10 (Suppl. 1), 29–31. https://doi.org//10.1002/14651858.CD201601

Risk of Bias for Before-After (Pre-Post) Studies with No Control Group (One Group Design)

Citation	Study question or objective clear	Eligibility or selection criteria clearly described	Participants representative of real-world patients	All eligible participants enrolled	Sample size appropriate for confidence in findings	Intervention clearly described and delivered consistently	Outcome measures pre-specified, defined, valid/reliable, and assessed consistently	Assessors blinded to participant exposure to intervention	Loss to follow-up after baseline 20% or less	Statistical methods examine changes in outcome measures from before to after intervention	Outcome measures were collected multiple times before and after intervention	Overall risk of bias assessment (low, moderate, high risk)
Arima et al., 2025	Y	Y	Y	Y	N	Y	Y	N	Y	N	N	moderate
Hong et al., 2024	Y	Y	N	Y	N	Y	Y	N	Y	Y	N	moderate
Kudo et al., 2021	Y	Y	Y	Y	N	Y	Y	Y	Y	N/A	N	low

Perez-Marcos et al., 2023	Y	Y	Y	Y	N	Y	Y	N	Y	N	N	moderate

Note. Y = yes; N = no; NR = not reported. Scoring for overall risk of bias assessment is as follows: 0–3 N, Low risk of bias (L); 4–8 N, Moderate risk of bias (M); 9–11 N, High risk of bias (H).

Citation. Table format adapted from National Heart Lung and Blood Institute. (2014). Quality assessment tool for before–after (pre–post) studies with no control group. Retrieved from https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools