Posturography in Post-stroke Balance Management: A Literature Review

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Abstract. Posturography had a role in numerous works of literature as a measurement, analysis of posture control, and body balance control. However, various literature also applied posturography as post-stroke therapy that affected balance. Accordingly, the objective of this review was to determine the utility of posturography in the treatment of post-stroke balance. For the period 2012 to 2022, relevant English-language study strategies such as "posturography", "balance," and "stroke" were available through databases such as ScienceDirect, PEDro, and PubMed. The inclusion criteria for this review were an article with an RCT method for stroke patients who had more than one week of treatment with posturography. The study applied the PICO (Population, Intervention, Comparison, and Outcome) framework, which was developed as a critical component in the review process. A total of six articles correspond to the criteria, with an average PEDro score of 5.6. Posturography can analyze and identify the patients' balance control. Posturography for the intervention revealed a significant improvement in balance as measured by the Berg Balance Scale (BBS) and Falling Index (FI) with $p < 0.05$ when comparing before and after treatment. Posturography was generally applied to measure balance in post-stroke patients, but it can be employed as an intervention. However, the reason was that limited articles focused on the role of posturography as a post-stroke intervention. Thus, more research is required.

Keywords: Posturography · Balance · Stroke

1 Introduction

Stroke is a non-communicable chronic disease [1]. Stroke is also a cardiovascular disease that affects blood flow to the brain through the arteries. Blood vessels that carry oxygen and nutrients to the brain undergo blockages, clots, or blood vessel ruptures, which block blood in the brain and cause brain cells to die [2]. Stroke is a potentially fatal disease, but some people recover completely while most have residual symptoms [3]. Stroke is one of the leading causes of death and disability in the world, with more than 13 cases each year [4]. Patients with a stroke are characterized by muscle weakness or imbalance, decreased postural control, muscle flexibility, and body misalignment [5]. Post-stroke patients are at risk of falling because of sensory disturbances, including decreased body coordination

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ability and decreased muscle function in the lower extremities. Furthermore, it causes a decreased ability to balance body mass and less muscle speed control to maintain body balance [6].

Based on the diagnosis of Indonesian health workers, the prevalence of stroke in Indonesia is seven per mile, and stroke with symptoms is 12.1 per mile [7]. Regarding the diagnosis, the highest prevalence of stroke was in North Sulawesi (10.8‰), DI Yogyakarta (10.3‰), Bangka Belitung, and DKI Jakarta, each obtaining 9.7 per mile [18]. In 2018, Basic Health Research Data (Riskesdas) presented the prevalence of stroke in Indonesia according to doctors' diagnoses in the general population aged 15 years old, as much as 10.9 per 1,000 Indonesian population suffered from a stroke. This figure increased compared to 2007, which was 8.3 per 1,000 population [8].

The balance of stroke patients is an essential factor hindering the ability to stand or walk, and the patients' sway is twice as high as that of healthy people. Those with hemiplegia have a decreased balance. In addition, it causes a patients' stability margin to decrease. Patients must increase their torso stabilization to improve their balance ability [9]. Balance is the ability to keep the body balanced in static and dynamic conditions. Balance is obtained when the body occupies the centre of mass (COM) or centre of gravity (COG) and is maintained above the base of support (BOS) [10]. Factors that affect human balance ability are the centre of gravity, the line of gravity, and the base of support [11]. Decreased visual, vestibular, and somatosensory abilities will impair balance. The body will have difficulty perceiving the base of support. Furthermore, musculoskeletal conditions deteriorate, affecting muscle and postural abilities. Posture changes will change the fulcrum of the body's centre of gravity (COG) [12].

Posturography is a method of measuring postural sway that intensely records the centre of the foot pressure transfer with a force platform [13]. The center of pressure (CoP) is the most applied posturographic measure in assessing postural control (CoP). The point of application of the total gravitational reaction force or pressure on the bearing surface is referred to as the CoP [14]. Posturography can be employed in the functional evaluation of postural control and stability, which are mediated by interactions between sensory systems in the forms of visual, vestibular, and somatosensory. Moreover, it is assessable under static or dynamic conditions. Posturography employs a computerized system that measures postural control or stability under static and dynamic conditions [15]. Posturography measures variations in the vertical force of the heel and toe, which can characterize body sway according to the displacement of the individual center of pressure [16].

Posturography is basically divided into static posturography and dynamic posturography [17]. Static posturography is the ability to maintain balance on a fixed platform with the eyes open and/or closed. In addition, it can reveal three main patterns: asymmetry against the load, an increase in the direction of sway, and reflecting instability. There is a small limit of stability in which the centre of pressure cannot move further, affecting a loss of balance. Dynamic Posturography measures postural reactions in response to a straight movement or position displacement from the starting point on the support surface, which aims to analyze postural reflexes and sensory re-weighing abilities [13].

In a study with specific intervention in post-stroke patients, the antero-posterior and medio-lateral postural swing speeds with eyes open or closed did not increase significantly before and after the intervention [18]. In another study, posturography examined the static control of standing balance after administering specific exercises, yielding effective results in standing stability in various positions [19]. Posturography could also assess posture control, which revealed a significant improvement in postural stability [3]. Furthermore, posturography is a treatment to improve stability, balance, fall risk, and weight distribution. The objective of this review is to identify the various applications of posturography in the management of post-stroke balance [9].

2 Method

The keywords "posturography" and "balance" and "stroke" were applied to find relevant English articles. Articles published in the last ten years, from the period 2012 to 2022, were searched in three databases: Pubmed, PEDro, and ScienceDirect. First, titles and abstracts corresponding to the inclusion criteria were screened. Second, filtering is continued by reading the entire text.

Following the screening process, articles are reviewed with the PICO method as a framework in the review process to determine whether the articles are suitable for a research basis. The PICO standard has four points, namely (Population, Intervention, Comparison, and Outcome). The population is the entire subject to investigate; Intervention is the treatment provided to the patient; Outcomes are accomplishments or results in studies related to the treatment provided to research subjects [20]. The subjects in this article are stroke patients, and the intervention is in the form of exercises to improve function, particularly balance. A comparison of interventions is administered to improve the function of stroke patients, including strength training and balance training. The outcome of a measurement is the progress of functional improvement or decline, particularly the patients' balance.

The data extracted included age, time since stroke onset, intervention, and outcome. With 11 items, the PEDro scale was applied to evaluate the quality of the methodology. The following classifications are used to rate studies: 9-10 is considered very good, 6-8 is considered good, 4-5 is considered fair, and less than 4 is considered poor. The author independently assessed the quality of the articles in the study [20].

This review included articles that employed randomized controlled trials, post-stroke patients older than 18 years old, with a time since stroke of more than one week, and were treated with posturography. Articles were excluded if the patients' stroke onset was $<$ 1 week, because less than one week is the subacute period; some patients occasionally show an unstable condition [21]. This research resource includes interventions such as posturography, balance exercises, and physical therapy. This study showed the results of measuring balance or control of body position in static and dynamic conditions. Measuring tools in research data sources can be in the form of the Berg Balance Scale, Time Up and Go test, or posturography [22].

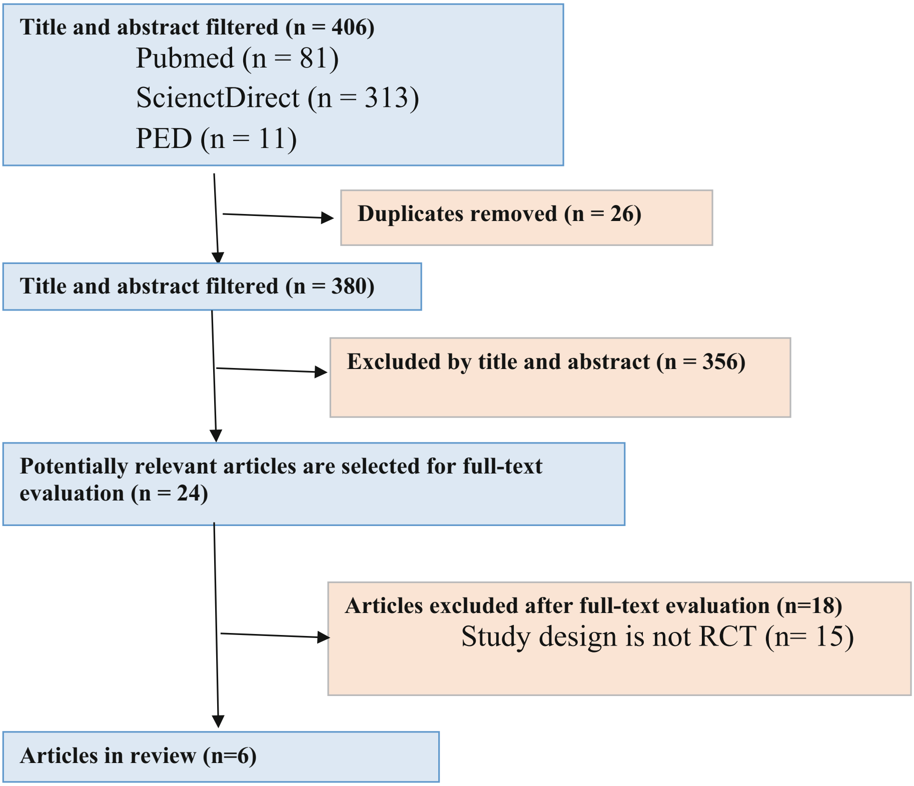

Fig. 1. Survey Strategy Flow

3 Results

3.1 Survey Strategy Flow

From all databases, the search strategy yielded 406 articles. After removing 26 duplicate articles, 380 articles were filtered by title and abstract. After screening titles and abstracts, 356 articles were eliminated, leaving 24 potentially relevant articles for full-text review. According to the evaluation results, 18 articles did not correspond to the inclusion criteria. Furthermore, six articles are in review [Fig. 1].

3.2 Study Qualities

The quality of the study was assessed with the PEDro scale, which contained 11 assessment items. If the item is listed in the article, it is labeled "Yes" and counted as 1 point; if it is not listed, it is labeled "No." and counted as 0 points. The first item (eligibility criteria) is not calculated. Thus, the maximum total score is 10.

The mean PEDro score of the included studies was 5.6. All articles randomly divided participants into groups, reported the same group at baseline reporting estimates of point

Table 1. PEDro scale

Criterion	Song *et al.* [24]	Maciaszek [19]	Kang *et al.* [22]	Cho *et al.* [18]	Tsaih *et al.* [9]	Hung *et al.* [23]
*Eligibility Criteria **	Y	Y	Y	Y	Y	Y
Random Allocation	Y	Y	Y	Y	Y	Y
Concealed Allocation	N	N	N	N	N	Y
Baseline Comparability	Y	Y	Y	Y	Y	Y
Participants Blinding	N	N	N	N	N	N
Therapists Blinding	N	N	N	N	N	N
Assessors Blinding	N	N	N	N	Y	Y
Adequate Follow-Up	Y	Y	Y	Y	Y	Y
Intention-To-Treat Analysis	N	N	N	N	Y	N
Between-Group Comparisons	Y	Y	Y	Y	Y	Y
Point Estimates And Variability	Y	Y	Y	Y	Y	Y
Total Pedro Score	5/10	5/10	5/10	5/10	7/10	7/10

Notes: * = Not counted; N = No; Y = Yes

size and variability, reported results of statistical comparisons between groups, and reported patient prognostic indicators. One article stated the use of hidden allocations, and one article conveyed an "intention to treat" analysis was conducted. Two articles had raters blinding, and no article with blinding of participants and therapists [Table 1].

3.3 Characteristics

Six studies had a sample size of more than 20 participants [9, 18, 19, 22–24], two studies applied posturography in balance training [19, 24], and four studies applied posturography to measure and test the balance of post-stroke patients [9, 18, 22, 23]

3.4 Participants

One study had participants with an average age of 55 years old [9], one study had participants with an average age of 57 years old [9], three studies had participants with an average age of more than 60 years old [18, 19, 24], and one study stated that participants were over the age of 18 years old [23]. All studies included both male and female participants [9, 18, 19, 22–24]. The average time since stroke ranged from two weeks to three years [9, 18, 19, 21, 23, 24].

3.5 Interventions

Regarding interventions in the experimental group to improve balance, two studies provided training with posturography [19, 24], three studies provided training in Virtual reality [18, 23, 24], one study applied treadmill nordic training [23], and one study provided electromyographic biofeedback to improve balance and strength [9]. In the control group, there were three studies provided therapy with the bobath concept [18, 19, 24], one study provided treadmill training [22], one study applied conventional weight-shifting training [23], and one study applied to strengthen exercises for the upper extremities [9]

3.6 Outcome Measurements

Three studies measured balance with the Berg Balance Scale (BBS) [18, 22, 24], five studies provided the Time Up and Go (TUG) test [9, 18, 19, 22, 23], and two study also measured balance with Forward Rech (FR) [9, 18]. One study applied the TUG test to measure mobility [9] and two studies measured mobility with 6 MWT [9, 22]. Two studies measured stability with the stability index [22, 23]. One study also measured the risk of falling with the Falling Index [24] and one study measured the "fear of falling" with the Falls Efficacy Scale Intervational (FES-I) Questionnaire [23] (Table 2).

4 Discussion

According to this literature review, posturography is employed to assess post-stroke balance ability and can be applied as an intervention to improve balance. Two review articles with posturography for intervention established positive results in terms of balance. Posturography intervention is conducted while the patients are standing, and they must move the centre of gravity on the screen. Thus, the patients' body swings to shift the point in the desired direction. While performing these tasks, the patients will attempt to maintain body balance and stability.

Tetra-ataxiometric posturography (tetrax) with eyes closed and open indicated an increase in balance, and standing with eyes closed and standing on a pillow with eyes closed indicated a significant increase in stability [24]. Posturographic platform biofeedback training provided to ischemic stroke patients revealed an increase in static balance as measured by the Time Up and Go test and an increase in body dynamic balance as measured with the one-leg standing test in the right and left legs [19].

Posturography was applied in four review articles to measure and assess dynamic and static balance in post-stroke patients. Postural rocking speed is applied to measure static balance in posturography, and the results are displayed on the computer [18]. Posturography (the Smart Balance Master System with a limit of stability (LOS) test) measurements are acquired by asking the patient to stand up and move the body as quickly and accurately as possible in eight directions. The Excursion Endpoint (EPE), the distance of the first movement toward the specified target, is the parameter employed in the LOS test. [9].

When Nordic Treadmill Training was conducted, measurements with the Tetra-Ataxiometric Posturography test (Tetrax) revealed an increase in balance (NTT). Providing Nordic Treadmill Training (NTT) indicated a swing of both arms as ambulating on the treadmill because the injured arm decreased balance and had to move the injured arm passively. Furthermore, the patient had to control upper body movements and maintain balance while walking [22]. Measurements with the Posturography-Tetrax Balance system revealed that balance training with Wii Fit Training was more effective in standing stability with the head straight and eyes open on the foam surface; standing position on a solid surface with eyes closed and head turned 30° to the left [23].

The use of posturography in post-stroke patients can affect balance and body control. The use of posturography shows a significant improvement in postural stability and the

Table 2. Study Result

Studies	**Participants**	**Interventions**	***Outcome* Measurements**	**Results**
Song et al. [24]	n = 30 Group virtual reality (n = 10): Genders = four males, six females age (years old) = 65.6 ± 13.5 time since stroke (days) = 12.7 ± 3.2 Tetrax group (n = 10): genders = five males, five females age (years old) = 60.6 ± 18.2 time since stroke (days) = 12.8 ± 3.4 Control groups (n = 10): genders = seven males, three females age (years old) = 61.2 ± 13.8 time since stroke (days) = 13.2 ± 3.4	Virtual reality: Frequency = 3x/week, for three weeks Time = 25 min/session Tetra-ataxiometric posturography (Tetrax): Frequency = 3x/week, for three weeks Time = 30 min/session Conventional balance exercises with physical therapy: Frequency = 3x/week, for three weeks Time = 25 min/ session	Berg Balance Scale (BBS), Falling Index (FI), Stability index (SI), Weight Distribution Index (WDI)	There is an increase in SI and WDI scores with virtual reality in the open-eye position compared to the control group. Still, results were no difference between the Tetrax and control groups. Tetrax administration increased SI and WDI scores in the closed-eye position compared to the control group. Still, results were no differences between the Virtual reality and control groups.

(*continued*)

Table 2. (*continued*)

Studies	**Participants**	**Interventions**	***Outcome* Measurements**	**Results**
Maciaszek [19]	n = 20 age = 60–72 years old time since stroke = 2 weeks – 6 months	The experimental group (n = 10): Posturographic Platform Biofeedback Training Control group (n = 10): standard training Biofeedback exercises were performed daily for 15 days, and the standard exercise program for patients from the experimental and control groups was based on the concept of bobath	Time Up and Go (TUG) test, One-leg Standing Test	The experimental group showed increased right leg static balance and dynamic balance compared to the conventionally rehabilitated control group. The provision of Posturographic Platform Biofeedback training showed more significant improvement in body balance observed in the right and left legs.
Kang et al. [22]	n = 30 Nordic Treadmill Training (n = 15): genders = eight males, seven females age = 57.4 years old onset = 11.8 months Treadmill Training (n = 15): genders = nine males, six females age = 57.4 years onset = 11.6 months	Nordic Treadmill Training (NTT): Frequency = 5x a week, for six weeks Time = 30 min every day Treadmill Training (TT): Frequency = 5x a week, for six weeks Time = 30 min every day	BBS, TUG, Tetrax, 10MWT, 6MWT Modified Barthel Index (MBI)	There was an increase in BBS, TUG, and tetrax scores for balance and an increase in the 10MWT and 6MWT measurements in the NTT group compared to the TT group. In the NTT group, the MBI score increased by 43.9% compared to the TT group.

(*continued*)

Table 2. (*continued*)

Studies	Participants	Interventions	*Outcome* Measurements	Results
Cho et al. [18]	n = 24 age = 63.13 years old time since stroke = 6 months	Experimental group (Virtual-Reality Balance Training (VRBT) with Video-Game): Frequency = 3x a week for six weeks Duration = 30 min a day Control group (standard rehabilitation program (physical and occupational therapy)): Frequency = 5x a week for six weeks Duration = 60 min a day	BBS, TUG, Posturografi	BBS (score 4.00 vs. 2.81) and TUG (1.33 vs. 0.52 s) increased more in the VRBT group than in the control group (P0.05).
Tsaih et al. [9]	n = 33 group control (n = 9): genders = seven males, two females age (years) = 56.1 ± 9.0 (42–66) time since stroke (months) = 14.8 ± 8.7 (4–28) group constant (n = 13) genders = nine males, four females age (years) = 55.5 ± 12.4 (29–74) time since stroke (months) = 15.85 ± 11.1 (4–42) Group variables (n = 11): genders = ten males, one female age (years) = 48.6 ± 12.6 (26–68) time since stroke (months) = 11.6 ± 10.7 (3–41)	Control group (upper extremity exercise without EMGBFB): Time = six training sessions for 40 min Group constant (tibialis anterior EMGBFB variable strength training): Frequency = 15-300Hz time = six training sessions for 40 min Group variables (tibialis anterior EMGBFB constant strength training): Frequency = 15-300Hz Time = six training sessions for 40 min	Handheld Dynamometer, Posturography (The Smart Balance Master System with a limit of stability (LOS) test), Timed Up and Go(TUG) test, Six-minute walk test (6MWT)	Measurement of the tibialis anterior muscle strength showed a significant increase in the constant and following variable groups. The balance measurement shows a significant increase only in the variable group. Regarding measurements with TUG test and 6MWT, all groups confirmed improvement in walking speed.

(*continued*)

Table 2. (*continued*)

Studies	Participants	Interventions	*Outcome* Measurements	Results
Hung et al. [23]	n = 30 age > 18 years old time since stroke = 6 months	Control group (Conventional Weight-Shifting Training) Experimental group (Exergame-Wii Fit Training) Note: both intervals are provided two times in one week for 12 min	Stability Index, Forward Rech & Timed Up and Go test, Falls Efficacy Scale Interventional (FES-I) Questionnaire, Physical Activity Enjoyment Scale (PACES), Posturography-Tetrax Balance system	Balance training with Wii Fit Training is more effective in standing stability in multiple positions than Conventional Weight-Shifting Training. There is an increase in the Forward Rech assessment, the Timed Up and Go test, and the FES-I, and PACES showed that the exergame group enjoyed the training more than the control group.

ability of the brain to react continuously to external stimuli, as well as a high diagnostic and follow-up value [25]. Assessment with a posturographic system based on the Wii Balance Board (WBB) demonstrates excellent psychometric properties and sensitivity in identifying the balance performance of post-stroke patients [26].

This review discusses posturography's various functions in assisting with managing balance in post-stroke patients. The six trials included in this review had an average PEDro score of 5.6, considered moderate. The characteristics and gender of the participants were similar, as was the period from subacute to chronic stroke. None of the articles in this review detail the use of posturography in posture control. Three articles did not explain the use of posturography, and one study with interventional posturography had good results, but it is temporary. More research is required to discuss the use of posturography for intervention. The reason is that only a few have focused on the role of posturography as an intervention in post-stroke patients. Due to investigating the effect of posturography on balance in post-stroke patients, re-trials with higher quality and longer follow-ups are required. This review can be administered in clinical practice, and research can be conducted using meta-analysis.

5 Conclusion

This review has limitations in data collection because the authors collect data from three databases. This review shows the various uses of posturography, which will ease the reader to comprehend the information from the results obtained for further research. Posturography on balance in post-stroke patients is generally to measure, identify and analyze balance. Posturography can also be applied as an intervention to improve balance and body stability. However, in one study, the improved outcome was temporary, and few studies focused on posturography's role as a post-stroke intervention, indicating that more research is necessary. Posturography of various types, methods, or positions can have an impact on the balance improvement of post-stroke patients.

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