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Investigating the influence of nurse-led support programs on rehabilitation and physical activity in stroke patients: a systematic review and meta-analysis

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Abstract

Background: Stroke rehabilitation is a crucial phase for recovery, focusing on improving physical function and independence. Nurse-led support programs have shown promise in aiding stroke survivors during rehabilitation, enhancing physical activity and functional outcomes. This review aims to examine the impact of nurse-led support programs on rehabilitation and physical activity in stroke patients.

Methods: A systematic review and meta-analysis of randomized controlled trials published from 2019 onwards were conducted, focusing on nurse-led interventions for stroke survivors. A comprehensive literature search was performed across multiple databases, selecting studies based on quality criteria. Eight studies were included, evaluating intervention duration, patient demographics, types of stroke (Transient ischemic attack and Acute ischemic stroke), and outcomes related to rehabilitation and physical activity. Meta-analysis was performed using statistical software, calculating effect sizes as mean differences and assessing heterogeneity using a standard statistical test.

Results: The meta-analysis demonstrated that nurse-led interventions significantly improved rehabilitation (mean difference = 6.23, 95% confidence interval 2.05-10.40, P<0.001) and physical activity (mean difference = 11.03, 95% confidence interval 4.88-26.95, P<0.001). Subgroup analysis indicated greater effectiveness in rehabilitation for interventions lasting less than 3 months compared to those longer than 3 months.

Conclusions: Nurse-led support programs have a significant positive impact on rehabilitation and physical activity in stroke patients. Structured, individualized exercise plans and continuous support are key in enhancing patients' physical activity levels and functional mobility, essential for successful rehabilitation.

Keywords: Nurse-Led, Rehabilitation, Physical Activity, Stroke.

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Background

Stroke is one of the most important causes of public health problems worldwide and is responsible for significant morbidity, and long-term disability, and hence a great impact on the quality of life of patients (1). As one of the most important causes of disability among adults, stroke has a wide range of physical, cognitive, and emotional impacts, which are mostly seen to persist throughout the life of a patient (2). Rehabilitation after a stroke is an essential part of the recovery process, with a focus on restoring physical function to maximize independence and, when possible, returning individuals to their communities (3). These services are complex and multi-component, requiring coordinated and specialized approaches in the care of stroke survivors (4). In this context, physical activity has taken center stage owing to its widely acknowledged contribution to improving functional mobility and reducing secondary health complications, thereby assisting in recovery (5).

Rehabilitation after a stroke is intrinsically challenging due to the variety of interactions between different levels of impairments in the motor, sensory, and cognitive spheres that patients may face (6). Recovery is generally a long process, with each stage requiring specific interventions that are altered according to continuously changing patient needs (7). Early mobilization, regular physical exercise, and therapeutic activities all contribute to the enhancement of neuroplasticity and allow for optimal motor recovery (8). Physical activity contributes to strength, balance, and coordination development and supports the cardiovascular continuum a critical factor in recurrent stroke prevention (9). However, these patients are not able to keep themselves actively living even after a stroke due to various limitations, including physical limitations coupled with a lack of motivation and psychological barriers (10). Structured support and encouragement constitute an important part of any effective rehabilitation program in this context (11).

Nurse-led support programs have the potential to address the barriers to rehabilitation and physical activity potentially (12). This system allows nurses to provide services continuously, in a personalized manner, both clinically and psychosocially (13). Given that they are the healthcare professionals closest to the patients in hospitals, community health institutions, and rehabilitation centers, nurses are specially positioned to manage a wide range of stages in the recovery of stroke survivors throughout various phases (14). Their role is not confined only to carrying out therapeutic exercises but also includes the education, motivation, and encouragement of patients and their families regularly (1). Most nurse-led programs also cover individualized physical activity regimens tailored to the specific mobility, health condition, and goals of the patient (15). Moreover, it is highly helpful in stroke rehabilitation because each patient's path toward recovery often proves unique (16).

Nurse-led interventions may also involve holistic approaches that consider aspects of life after a stroke (17). While the exercises are central, they are only part of the rehabilitation program. These patients have many other health-related needs, such as managing their comorbid conditions, emotional stress, and preventing social isolation (18). This is where nurse-led programs could fill in-person-centered approaches to bridge the gap between physical rehabilitation and broader aspects of well-being toward more sustainable recovery outcomes (19). Furthermore, this may be informed by the evidence that patients are most likely to adhere to rehabilitation regimens if they receive consistent and empathetic support from healthcare providers (20). In addition, nurse-led programs empower patients through knowledge and skills to actively help themselves through the process, tending to build an atmosphere of independence and resilience (21).

In recent years, interest in physical activity has increased concerning its impact on neuroplasticity and functional outcomes (22). Research has also shown that regular, targeted physical activity stimulates neurogenesis, improves neural connectivity, and enhances cognitive function, which is vital in the recovery of lost abilities post-stroke (23). This means that it is a unique chance for stroke patients to manage their physical activity professionally because such an approach might help them rebuild their motor skills, make them more intensive, and improve coordination (24). Such activities can be appealing if specially trained nurses can design them, considering all the peculiarities of each patient's current condition and further dynamics most safely and effectively (25). Structured and closely monitored exercise routines provided by a nurse-led program will directly contribute to these important improvements in physical function and overall health (26).

Another critical feature of nurse-led support programs relates to the accessibility and adaptability inherent in such programs (24). Unlike other healthcare interventions, which require specific equipment or settings, nurse-led support can often be delivered within the confines of varied environmental contexts, including but not limited to hospitals, rehabilitation centers, and patients' homes (27). This attribute is highly relevant for stroke patients, many of whom have sizable logistical or financial obstacles to receiving traditional rehabilitation services (28). That is, exercises that are nurse-led can be made flexible and easily accessible to reach as many people as possible, including those living in hard-to-reach areas and those who, for one reason or another, have various forms of immobility (29). Such inclusiveness itself justifies the expectation of nurse-led support for positive changes in the wider level of rehabilitation outcomes (30).

In addition to physical aspects, there are psychological and social parts that play an important role in the process of recovery after a stroke. Feelings of frustration, helplessness, or social withdrawal are common among stroke survivors and may present further obstacles to engaging positively in rehabilitation (31). Through her extensive professional preparation and patient-centered orientation, the nurse is particularly prepared to provide emotional support and encouragement individualized to the needs of each client (32). In these cases, the environment can be made positive and enabling, whereby psychological obstacles are overcome to facilitate maximum adherence by patients to rehabilitation protocols, thereby ensuring better long-term outcomes (33).

Research studies have shown that the need for rehabilitation in post-stroke patient management cannot be underestimated. Even so, more studies need to be conducted on the implications of particular types of nursing support for this group. Adjunct physical fitness programs integrated into nursing-provided structured programs have enabled patients to gain more control over their actions and have promoted better outcomes in terms of muscle strength, mobility, and body composition. Considering the above potential benefits, this study investigated the effects of nurse-led interventions on rehabilitative and physical activity across stroke survivors in terms of how different types of support are manipulated for immediate recovery as well as how these effects are related to physical engagement in the long run. From this perspective, we also attempted to determine how using nurses would be possible and beneficial in stroke patient rehabilitation as a whole.

Materials and methods

Study Design and Context

This meta-analysis was written according to the recommended guidelines for abstracts of systematic reviews and meta-analyses (PRISMA), to investigate the effect of nurse-led support programs on the rehabilitation and physical activity of stroke patients, and this study has also been registered in the international prospective registered of systematic reviews (PROSPERO) with the code CRD42024612146 (34).

Eligibility criteria

The systematic search of the peer-reviewed manuscripts was performed up to November 2024, without limitation of the primary language. This study adopted the PICOS framework for study selection: P (Population)= Stroke included acute ischemic stroke and transient ischemic attack; I (Intervention)= Nurse-led Support Programs; C (Comparison)= Control group without intervention; O (Outcome)= Rehabilitation and physical activity; and S (Study design)= Randomized Clinical Trial.

Population

Studies that included people with stroke, including acute ischemic stroke (AIS) and transient ischemic attack (TIA), were included.

Outcomes

Rehabilitation and physical activity were the main outcomes. All the outcomes were measured with the help of self-report questionnaires, including the MBI (Modified Barthel Index), Activities of Daily Living (ADL), Motor Assessment Scale (MAS), and Stroke Rehabilitation Assessment of Movement Measure (range of motion and coordination), whose validation was performed for each outcome and language.

Research design

The review considered only those randomized clinical trials (RCTs) that evaluated the efficacy of the programs on nurse-led support in the rehabilitation and physical activity of patients who suffered a stroke.

Search strategy and study selection

The databases searched normally included the following: searches were performed without language restrictions from January 1, 2019, until November 6, 2024. The search terms used as a reference for this review were terms and medical subject headings

(MESH) via Boolean operators (AND, OR, and NOT): Nurse-Led, Nurse Led, Support Programs, Support Program, Recovery of Function, Functional Recovery, Function Recoveries, Function Recovery, Rehabilitation, Habilitation, Physical Activity, Activities, Physical, Physical, Physical, Physical Activities, Acute Exercise, Acute, Exercise, Exercise, Physical Exercise, Stroke, Cerebrovascular Accident, Cerebral Stroke, Stroke, Cerebral, Cerebrovascular Apoplexy, Apoplexy, Cerebrovascular, Vascular Accident, Brain, Vascular Accident, Vascular Accident, Brain, Cerebrovascular Stroke, Stroke, Cerebrovascular, Stroke, Acute, Acute Stroke, Cerebrovascular Accident, Acute, Acute Cerebrovascular Accident.

Selection process

All included studies were reviewed for potential literature references in their reference lists. Using predefined inclusion and exclusion criteria, two independent authors performed title and abstract screening and then full-text screening. Whenever there was a disagreement between them, the authors could reach a consensus through a discussion involving two reviewers or alternately invite a third reviewer on the research team to resolve the conflict.

Data extraction

Characteristics of the study (first author, year of publication, country, duration of the study, type of study), characteristics of the participants (the study population that included patients with AIS and TIA), and outcome data (sample size of the intervention and control groups, sample size of the male and female, mean and standard deviation rehabilitation and mean and standard deviation of physical activity) were among the information that was extracted.

Quality Assessment

The risk of bias for the methodology was assessed by us via the Standard Cochrane Collaboration risk of bias tool in RevMan 5.4 software for the included RCTs (35). In 2019, Stern (36) developed five critical domains useful for assessing the risk of bias for randomized controlled trials. These include (1) bias due to the randomization process, (2) bias due to deviation from intended interventions, (3) bias due to missing outcome data, (4) bias in outcome measurement, and (5) bias in the selection of reported results, which were all investigated and observed in this study.

Statistical analysis

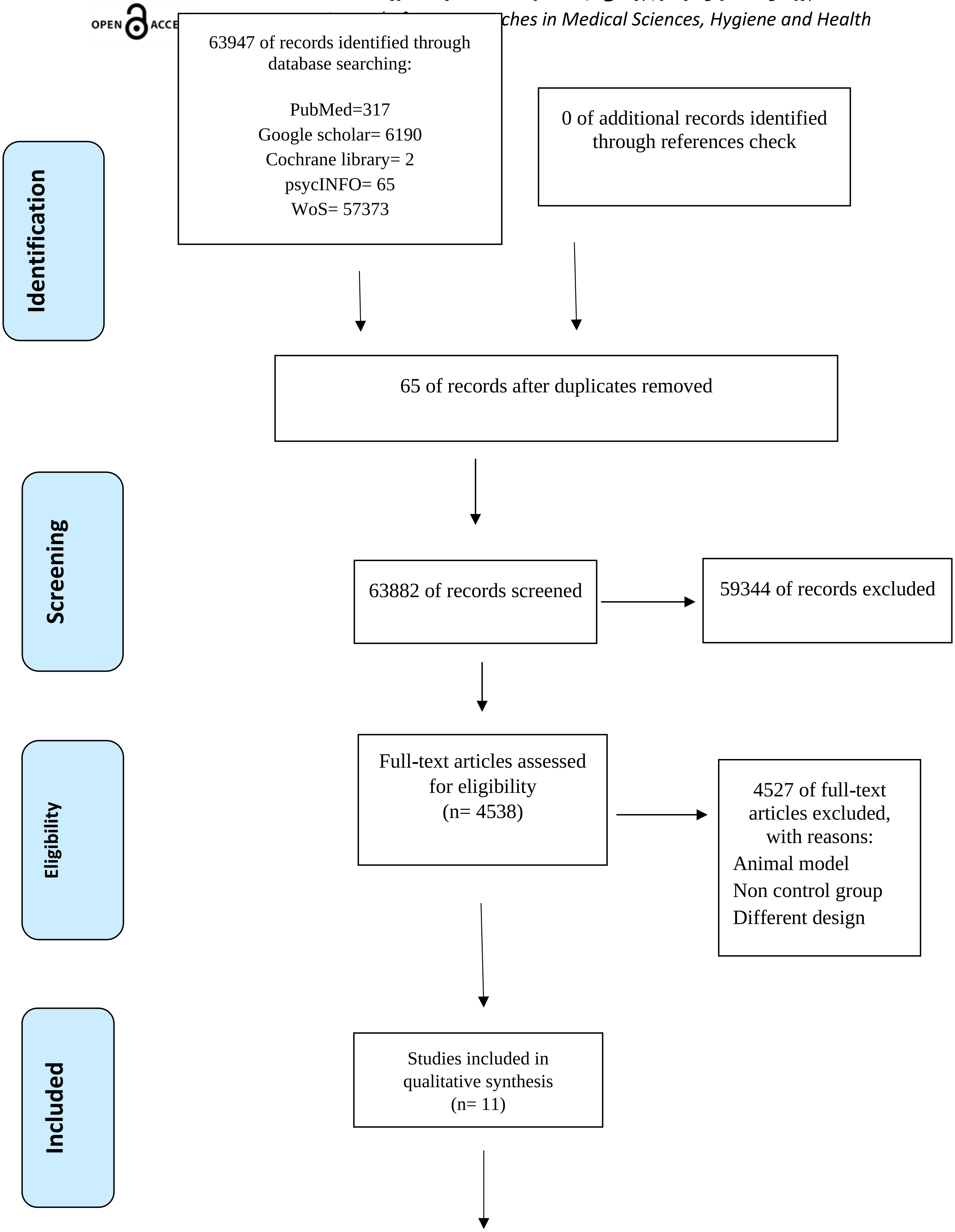
The means and SDs of the mentioned criteria were collected from the intervention and control groups. The mean differences were defined as the effect size, and the mean differences were compared after intervention in the control and intervention groups. The mean differences were pooled among the subgroups. A fixed effects inverse variance model was used to pool the results of studies when heterogeneity between studies was low; when heterogeneity between studies was significant, random effects models were used. I^2 and H^2 statistics were used to determine heterogeneity. The significance of the

H^2 statistic was checked via a Z test. An I^2 less than 25% is usually regarded as low heterogeneity, an I2 between 25% and 50% is moderate, and an I2 greater than 50% is considered high heterogeneity. The results are graphically represented in such a format that enables us to visualize the results. Data analysis was performed with STATA V.17 and SPSS V.16 software. P values less than 0.05 were considered significant.

Results

Sudies selection

The sample size for this review was 906 patients with stroke (AIS and TIA); 452 participants were assigned to the intervention group, whereas the remaining 454 participants fell into the control group in 8 studies. A total of 63947 relevant articles were found: 317 in PubMed, 6190 in Google Scholar, 2 in the Cochrane Library, 57373 in the Web of Sciences, and 65 in PsycINFO. After 65 duplicate articles were removed, 63882 articles were screened and then reviewed. A total of 59344 out of 63882 articles were excluded after the irrelevant title determination was established. The review included 4538 articles, 4527 of which were excluded based on the lack of a control group, studies that included animal participants, or a statistical population unrelated to the study. Eleven studies reached the quality assessment stage, among which 3 studies could not obtain the necessary and sufficient quality to be included in the study; these studies were classified as high-risk studies and excluded from the study. Finally, the total number of articles included in this study was 8, of which 5 reported the variable of rehabilitation and 3 reported the variable of physical activity. Figure 1 presents a PRISMA flow diagram of the selection of studies. The general characteristics of the studies included in this meta-analysis are described in Table 1.


Identification
63947 of records identified through database searching:
PubMed=317
Google scholar= 6190
Cochrane library= 2
psycINFO= 65
WoS= 57373
0 of additional records identified through references check
65 of records after duplicates removed
Screening
63882 of records screened
59344 of records excluded
Eligibility
Full-text articles assessed for eligibility (n= 4538)
4527 of full-text articles excluded, with reasons:
Animal model
Non control group
Different design
Included
Studies included in qualitative synthesis (n= 11)

Studies included in quantitative synthesis (meta-analysis)
(n= 8)

Fig 1 The P[...]led studies

Study and participant characteristics

A total of two studies were published in 2024. Of the total of 8 studies, 5 were conducted in China, and the remaining 3 were performed in the United States, Netherlands, and India. The intervention and control groups consisted of 452 and 454 patients, respectively. Among the 906 participants, 624 were male, and 281 were female. The duration of the intervention ranged from 7 days to 6 months (Table 1).

Table 1 Characteristics of the included studies

ID	**Author**	**Year**	**Country**	**Intervention Time**	**Population**	**SEX**		**Outcome Measured**	**Study Type**
						Male	**Female**		
1	*Li*	*2023*	*China*	*3 months*	*Patients with acute ischemic stroke (AIS)*	*113*	*47*	*1. Myodynamia 2. MBI 3. SS-QOL*	*RCT*
2	*Devi*	*2022*	*India*	*6 months*	*Patients with stroke and their caregivers*	*119*	*51*	*1. ADL 2. QOL 3. SS-QOL 4. Caregiver Burden*	*RCT*

3	*Wang*	*2022*	*China*	*7 days*	*Diagnosed with acute ischemic stroke*	*88*	*0*	*1. MAS* *2. MBI* *3. NIHSS*	*RCT*
4	*Ding*	*2024*	*China*	*4 weeks*	*Patients diagnosed with ischemic stroke and caregivers (18 years or older) who are physically and cognitively healthy, and are the primary caregivers for the stroke patients*	*31*	*27*	*1. MAS* *2. MBI* *3. SS-QOL* *4. NIHSS* *5. C-M-CSI*	*RCT*

5	*Wang*	*2024*	*China*	*3 months*	*People with all kinds of fractures, including hip fractures, knee fractures, and types of cerebrovascular accidents, including cerebral hemorrhage and cerebral infarction*	*43*	*37*	*1. Nursing satisfaction 2. FIM 3. SAS 4. SDS 5. LOTCA 6. Fracture healing time 7. Length of hospital stay 8. Hospitalization expenses*	*RCT*

6	*Brouwer Goossensen*	*2022*	*Netherlands*	*3 months*	*People with TIA, a Moderately healthy lifestyle, with mild overweight on average, used more alcohol than advised and were smokers.*	*85*	*51*	*1. Clinical features of TIA or ischemic stroke 2. Demographic data 3. NIHSS score 4. Vascular history and risk factors 5. Body mass index 6. Waist circumference 7. Medication use 8. Cholesterol levels 9. Glucose levels 10. Blood pressure*	*RCT*

7	*Swank*	*2020*	*United States*	*28 days*	*Patients admitted to an inpatient rehabilitation facility after a stroke*	*39*	*34*	*1. Stroke Rehabilitation Assessment of Movement Measure 2. Functional Independence Measure 3. Balance (assessed by NeuroCom Balance Master) 4. Physical activity 5. Stroke Impact Scale*	*RCT*
8	*Lin*	*2022*	*China*	*3 months*	*Couples suffering from stroke*	*106*	*34*	*1. SSEQ 2. SSQoL-12 3. SPKQ 4. CSI*	*RCT*

****ID:*** *Identification,* ***MBI:*** *Modified Barthel Index,* ***ADL:*** *Activities of Daily Living,* ***MAS:*** *Motor Assessment Scale,* ***SS-QOL:*** *Stroke-Specific Quality of Life,* ***NIHSS:*** *National Institutes of Health Stroke Scale,* ***C-M-CSI:*** *Chinese Modified Caregiver Strain Index,* ***FIM:*** *Functional Independence Measure,* ***SAS:*** *Self-Rating Anxiety Scale,* ***SDS:*** *Self-Rating Depression Scale,* ***LOTCA:*** *Lowenstein Occupational Therapy Cognitive Assessment,* ***QOL:*** *Quality of Life,* ***SSQoL-12:*** *Stroke-Specific Quality of Life - 12 Items,* ***SPKQ:*** *Stroke Prevention Knowledge Questionnaire,* ***SSEQ:*** *Stroke Self-Efficacy Questionnaire, and* ***RCT:*** *Randomized Controlled Trial.*

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Quality Assessment

Of the 11 identified studies whose full-text articles were assessed, 3 were of low quality. The results of the quality assessment are presented in Table 2 and Figs. 2 and 3, respectively. Overall, the risk of bias in studies with a low risk of bias was labeled "low risk" in all studies.

Table 2 The methodological quality of the included studies

	Random Sequence (selection bias)	Allocation Concealment	Blinding of Particle	Blinding Out Come	Incomplete Outcome	Selective Reporting	Other Bias	RISK
1. Urcan	*Y*	*PY*	*N*	*N*	*N*	*N*	*Y*	*High*
2. Lasheen	*N*	*N*	*N*	*N*	*N*	*N*	*Y*	*High*
3. Ali	*N*	*N*	*N*	*NI*	*N*	*N*	*Y*	*High*
4. Li	*Y*	*Y*	*Y*	*NI*	*Y*	*N*	*Y*	*Low*
5. Devi	*Y*	*Y*	*N*	*Y*	*N*	*Y*	*Y*	*Low*
6. Wang 2022	*Y*	*Y*	*Y*	*Y*	*Y*	*N*	*Y*	*Low*
7. Ding	*Y*	*Y*	*Y*	*Y*	*Y*	*N*	*Y*	*Low*
8. Wang 2024	*Y*	*Y*	*Y*	*N*	*Y*	*Y*	*Y*	*Low*
9. Brouwer Goossensen	*Y*	*Y*	*N*	*Y*	*Y*	*Y*	*Y*	*Low*
10. Swank	*Y*	*Y*	*N*	*N*	*Y*	*Y*	*Y*	*Low*
11. Lin	*Y*	*Y*	*N*	*Y*	*Y*	*Y*	*Y*	*Low*

**Y= Yes, PY= Most likely, Yes, N= No, and NI= No Information*

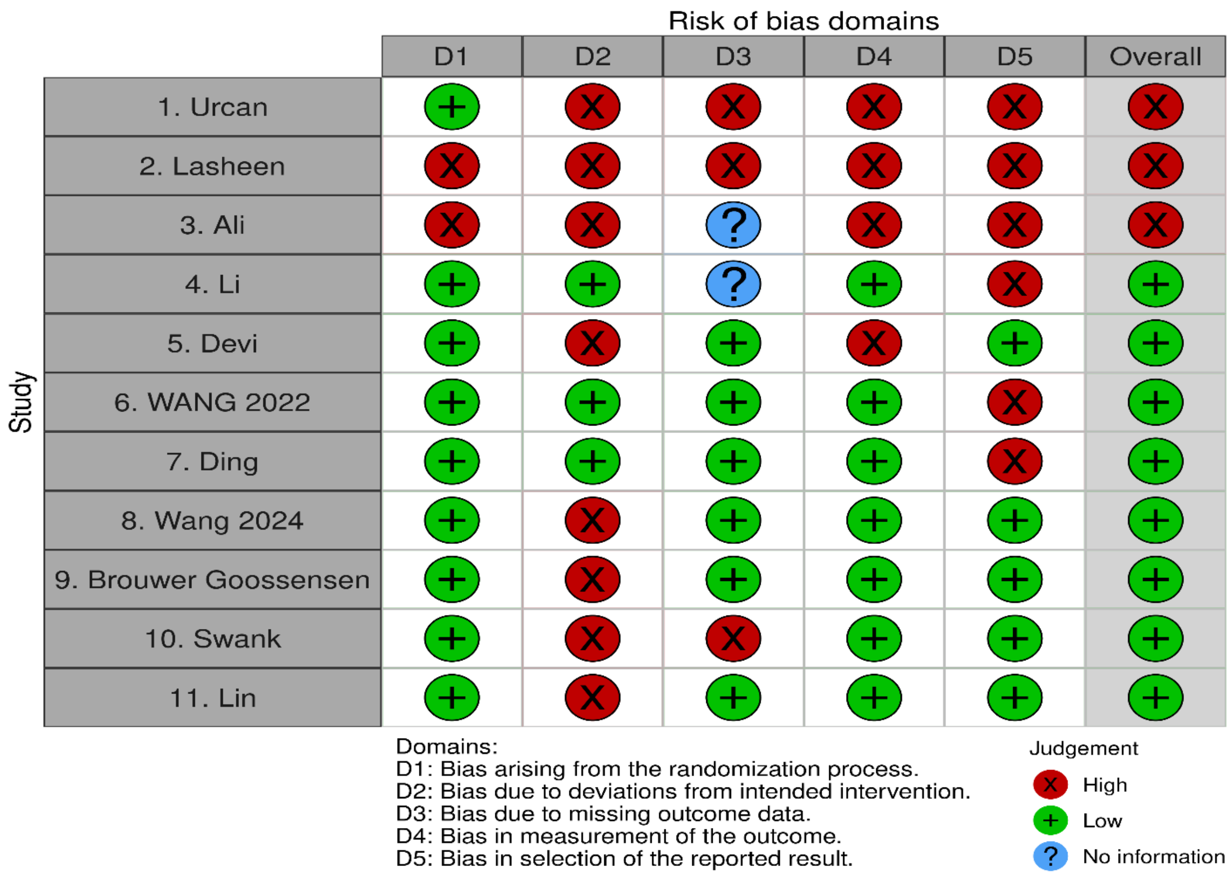

Fig 2 Risk of bias summary

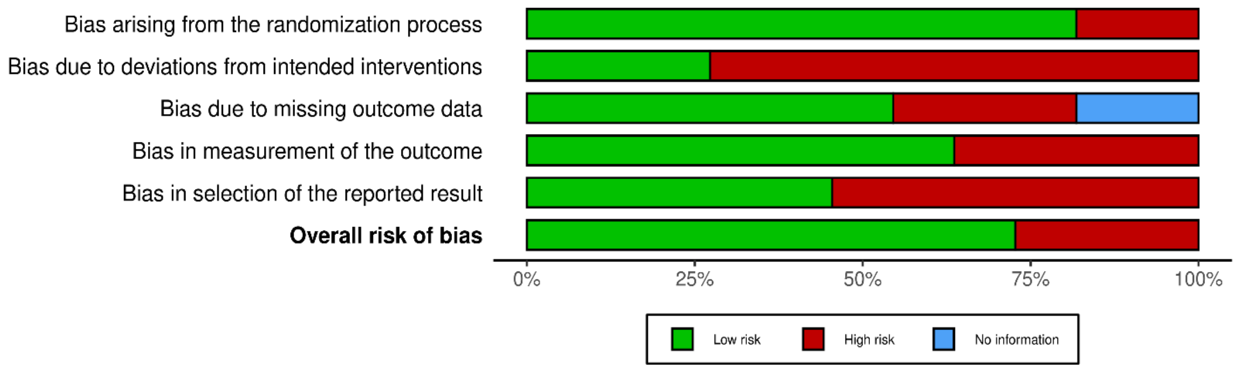

Fig 3 Risk of bias graph

Efficacy Outcomes

Rehabilitation

Analysis of the intervention duration

The studies with intervention periods of less than 3 months had considerable heterogeneity, represented by Q(1) = 13.86 and I^2 = 92.78%, P = 0.000, reflecting large variability in the outcomes of these studies. Interventions that lasted for 3 months had moderate heterogeneity since Q(1) = 10.56, I^2 = 90.53%, and P = 0.000, indicating a fair consistency of the effect size within this group. The mean differences between these windows of intervention show an outcome that progressively improves with increasing intervention periods. While the studies with an intervention period of less than 3 months reported an MD of 5.75 (95% CI: [1.17, 10.32]), those studies with exactly 3 months of intervention had an MD of 10.02 (95% CI: [0.05, 19.99]). The MD was highest for interventions over 3 months, with an MD value of 1.13, 95% CI: [-1.98, 4.24], indicating that extended rehabilitation programs are more efficacious in enhancing recovery. Overall, the heterogeneity for all studies concerning intervention duration was high [I^2 = 95.49%, τ^2 = 20.30, H^2 = 22.15], indicative of a large variability in the results of the studies. The high heterogeneity can be explained by different intervention protocols, different rehabilitation settings, and different adherence to treatment regimens.

Population-based analysis with a focus on AIS classification

The analysis also stratifies studies according to population characteristics, specifically those with AIS classifications. Concerning AIS populations, studies reported an MD of 6.23 (95% CI: [2.05, 10.40]), indicating significant positive rehabilitation outcomes for this category. Pooling the studies in which AIS participants were involved and considering heterogeneity resulted in high variability: Q(4) = 36.10, I^2 = 95.49%, P = 0.000. Such heterogeneity may pertain to different AIS classification levels for various sample populations, such as the severity level of spinal cord injury, and, in turn, to a diverse range of rehabilitation techniques that were employed in these studies.

Intervention Duration and Population Characteristics

When combined effects are analyzed within a multifactorial framework, detailed analyses of both intervention duration and population-specific characteristics yield nuanced insights. Prolonged rehabilitation durations tend to be more effective in AIS patients, with reduced heterogeneity, indicating that longer interventions would produce more consistent and clinically significant effects in this population. On the other hand, AIS populations with less than 3 months of intervention presented smaller mean differences, with increased heterogeneity, perhaps owing to insufficient duration of intervention to meet the demands for optimal rehabilitation (Figures 4 and 5 and Tables 3 and 4).

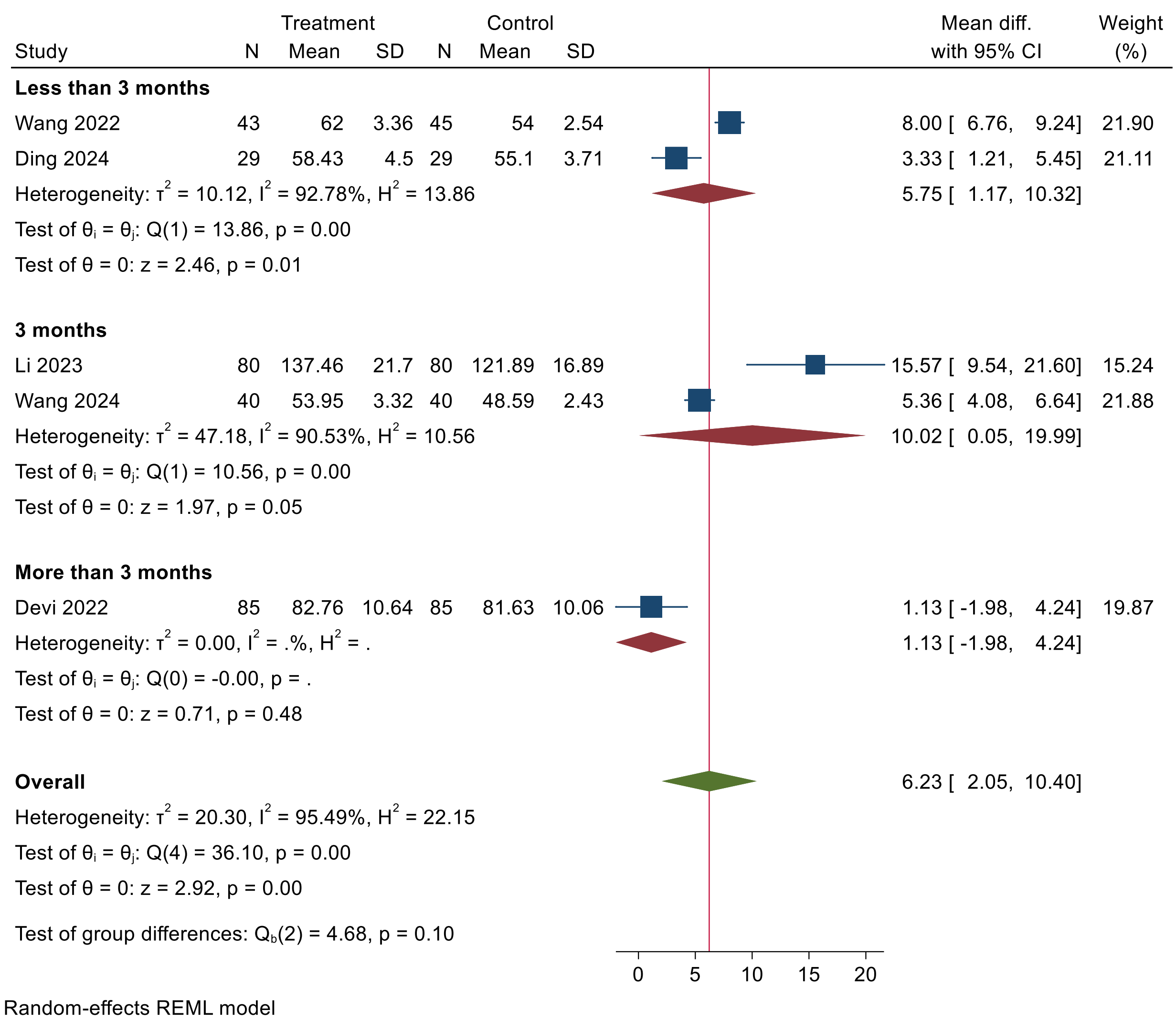

Fig 4 Forest plot of the effect of interventions on the rehabilitation variable based on the duration of the intervention

Table 3 Summary of heterogeneity in the effect of the rehabilitation variable on the duration of the intervention

Groups	Df	Q	P > Q	Tau2	I^2 %	H^2
Less than 3 months	*1*	*13.86*	*0.000*	*10.118*	*92.78*	*13.86*
3 months	*1*	*10.56*	*0.001*	*47.185*	*90.53*	*10.56*
More than 3 months	*0*	*-0.00*	.	*0.000*	.	.
Overall	*4*	*36.10*	*0.000*	*20.301*	*95.49*	*22.15*

***Df**: Degrees of Freedom, **Q**: Cochran's Q (a statistic used to test for heterogeneity in meta-analyses), **P > Q**: P-value for Cochran's Q (indicates the statistical significance of heterogeneity), **Tau²**: Between-Study Variance (an estimate of the variance among study effects in a meta-analysis), **I² %**: Percentage of Total Variation Due to Heterogeneity (measures inconsistency across studies in a meta-analysis), and **H²**: Relative Excess Heterogeneity (another measure of heterogeneity indicating the ratio of total variance to sampling variance).*

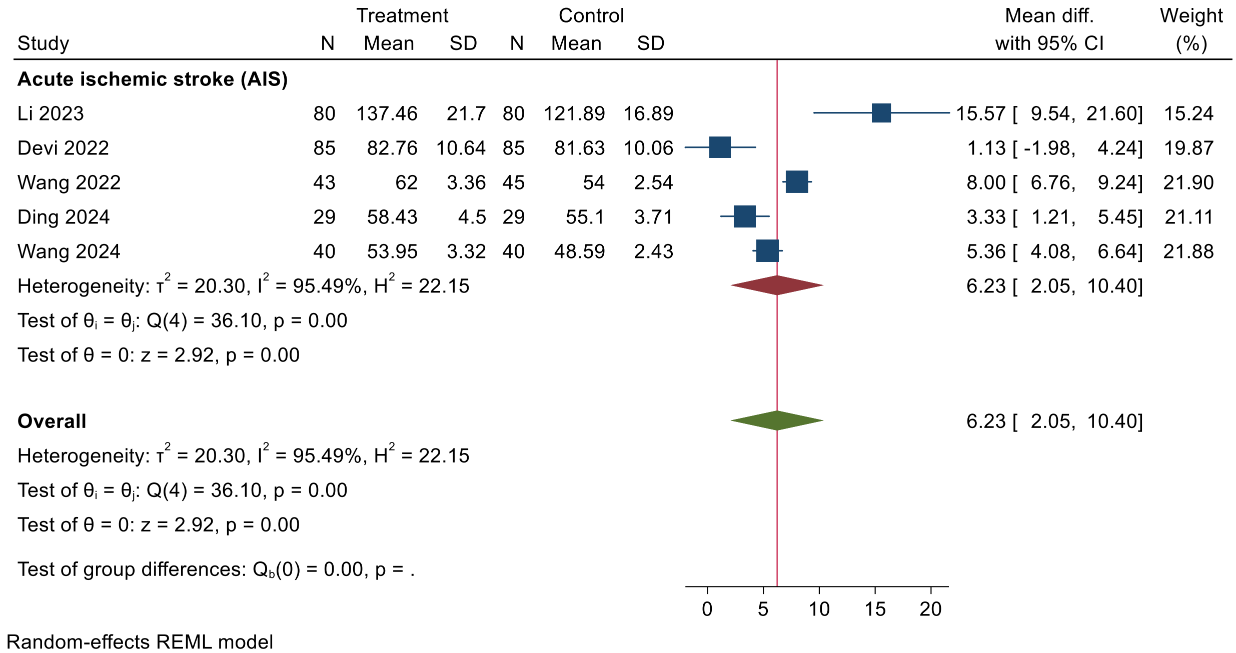

Fig 5 Forest plot of the effects of interventions on the rehabilitation variable based on the population

Table 4 Heterogeneity summary for the rehabilitation variables based on the population

Groups	Df	Q	P > Q	Tau2	I^2 %	H^2
Acute ischemic stroke	*4*	*36.10*	*0.000*	*20.301*	*95.49*	*22.15*
Overall	*4*	*36.10*	*0.000*	*20.301*	*95.49*	*22.15*

****Df**: Degrees of Freedom, **Q**: Cochran's Q (a statistic used to test for heterogeneity in meta-analyses), **P > Q**: P-value for Cochran's Q (indicates the statistical significance of heterogeneity), **Tau²**: Between-Study Variance (an estimate of the variance among study effects in a meta-analysis), **I² %**: Percentage of Total Variation Due to Heterogeneity (measures inconsistency across studies in a meta-analysis), and **H²**: Relative Excess Heterogeneity (another measure of heterogeneity indicating the ratio of total variance to sampling variance).*

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Physical activity

Analysis of Intervention Duration

Those studies with durations of less than 3 months were significantly heterogeneous: Q(0) = -0.00, I^2 = .%, P = ., indicating substantial variability in study outcomes across this stratum. For the interventions lasting exactly 3 months, the heterogeneity was moderate: Q(1) = 10741.93, I^2 = 99.99%, P = 0.000, indicating relatively consistent effect sizes within this particular duration. The mean difference (MD) showed that progressive improvement was associated with longer intervention periods: those studies that had a duration of less than 3 months had an MD of 6.40 (95% CI: [-1.98, 14.78]), and the studies lasting exactly 3 months had an MD of 7.84 (95% CI: [1.95, 13.73]). For more than 3 months, the highest MD was 13.15 (95% CI: [-12.62, 38.92]), which again shows that extended interventions in physical activity contributed to better outcomes. In aggregate, the heterogeneity across all studies by intervention duration was notably high, with I^2 = 99.97%, τ^2 = 192.03, and H^2 = 2991.82. This high variability could be due to differences in the physical activity protocols, varying levels of adherence, and the different contexts in which these interventions were given.

Population-based analysis with a focus on specific demographics

The results of stratification analyses by population characteristics showed promising results for certain demographics. For studies in participants with AIS, the analysis indicated that there was a significant positive effect for the physical activity intervention. The MD for this group was 16.81 (95% CI: [-2.67, 36.29]), showing a very large improvement among AIS participants receiving a physical activity intervention. However, heterogeneity within this group was substantial, with Q(1) = 21.60 and I^2 = 95.37%, P = 0.000. Such high variability might have been caused by the difference in AIS severity among the participants and differences in the intensity, duration, and compliance with physical activity protocols among the studies. These differences suggest that physical activity generally has healthful effects on AIS patients but might vary widely based on individual- and protocol-specific factors.

Joint analysis of the AIS and TIA populations when the AIS and TIA populations were analyzed together revealed that physical activity interventions had a pooled MD of 11.03 (95% CI: [-4.88, 26.95]). However, heterogeneity was still high at I^2 = 99.97%, τ^2 = 192.03, and H^2 = 2991.82, which indicated large variability between the studies. Such variability likely reflects that while physical activity is beneficial for both AIS and TIA populations, the effectiveness of these interventions depends largely on population characteristics, physical activity protocol, and length of intervention (Figures 6 and 7 and Tables 5 and 6).

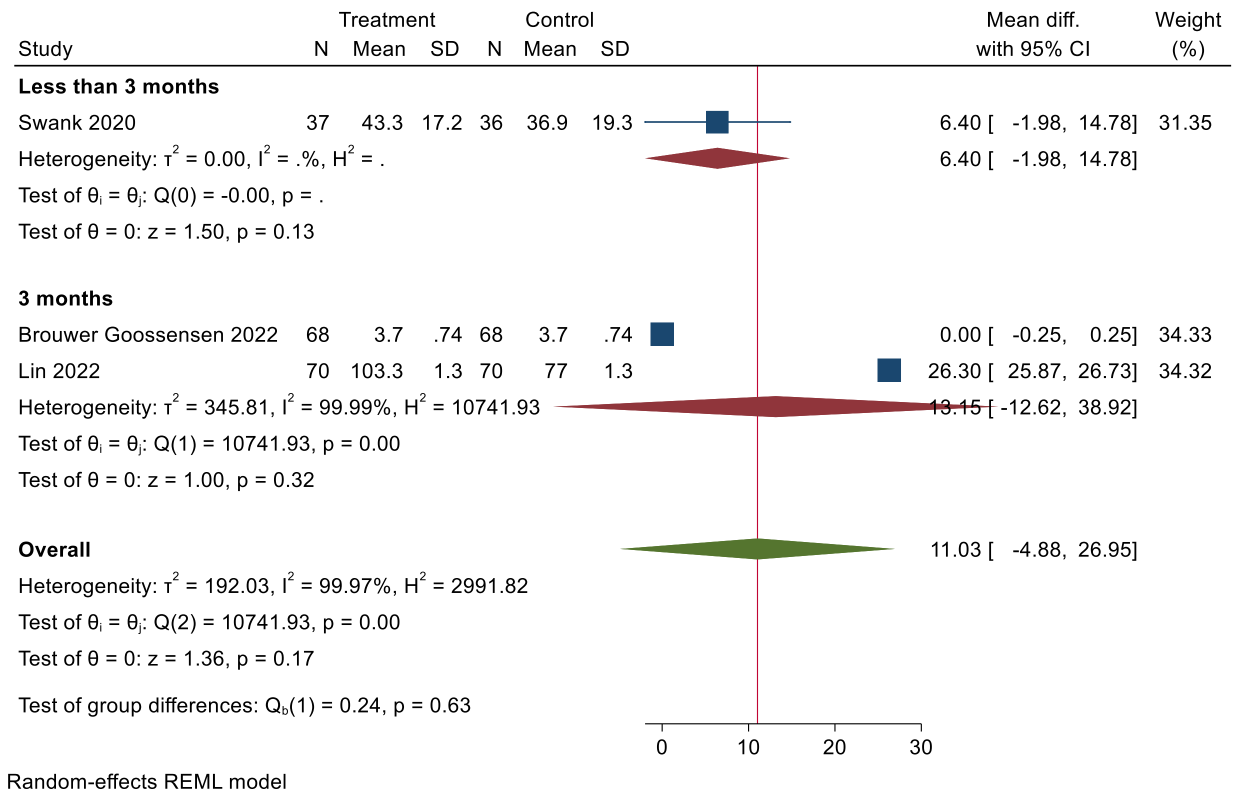


Fig 6 Forest plot of the effect of interventions on the physical activity variable based on the duration of the intervention

Table 5 Heterogeneity summary for the effect of the physical activity variable on the duration of the intervention

Groups	Df	Q	P > Q	Tau2	I^2 %	H^2
Less than 3 months	*0*	*-0.00*	.	*0.000*	.	.
3 months	*1*	*10741.93*	*0.000*	*345.813*	*99.99*	*10741.93*
Overall	*2*	*10741.93*	*0.000*	*192.035*	*99.97*	*2991.82*

****Df*: Degrees of Freedom, **Q**: Cochran's Q (a statistic used to test for heterogeneity in meta-analyses), **P > Q**: P-value for Cochran's Q (indicates the statistical significance of heterogeneity), **Tau²**: Between-Study Variance (an estimate of the variance among study effects in a meta-analysis), **I² %**: Percentage of Total Variation Due to Heterogeneity (measures inconsistency across studies in a meta-analysis), and **H²**:*

Relative Excess Heterogeneity (another measure of heterogeneity indicating the ratio of total variance to sampling variance).

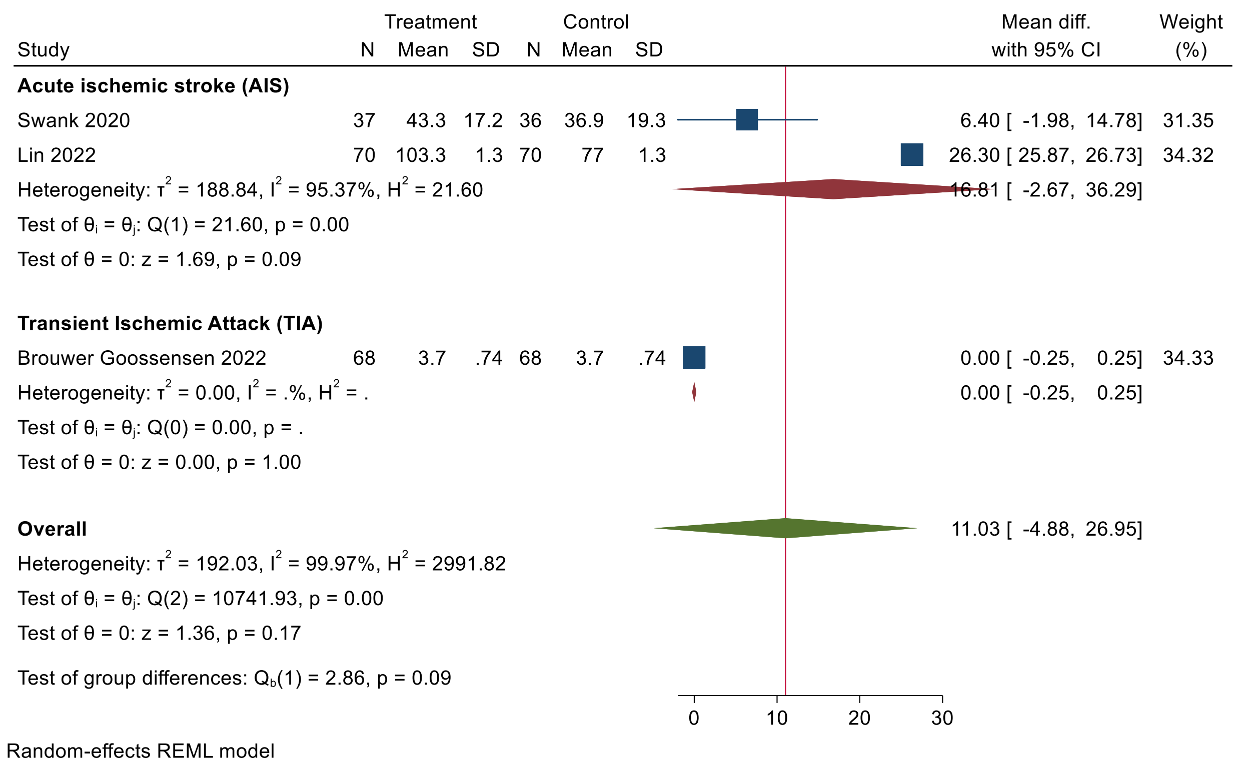


Fig 7 Forest plot of the effects of interventions on the physical activity variable based on the population

Table 6 Heterogeneity summary for the physical activity variable based on the population

Groups	Df	Q	P > Q	Tau2	I^2 %	H^2

Acute ischemic stroke	*1*	*21.60*	*0.000*	*188.839*	*95.37*	*21.60*
Transient ischemic attack	*0*	*0.00*	*.*	*0.000*	*.*	*.*
Overall	*2*	*10741.93*	*0.000*	*192.035*	*99.97*	*2991.82*

****Df**: Degrees of Freedom, **Q**: Cochran's Q (a statistic used to test for heterogeneity in meta-analyses), **P > Q**: P-value for Cochran's Q (indicates the statistical significance of heterogeneity), **Tau²**: Between-Study Variance (an estimate of the variance among study effects in a meta-analysis), **I² %**: Percentage of Total Variation Due to Heterogeneity (measures inconsistency across studies in a meta-analysis), and **H²**: Relative Excess Heterogeneity (another measure of heterogeneity indicating the ratio of total variance to sampling variance).*

Publication Bias

The funnel plot in Figure 8A is a visual assessment of publication bias in this meta-analysis. The standard error is plotted on the y-axis, and the mean difference is plotted on the x-axis for each study included in the analysis. Theoretically, this would imply that in an unbiased meta-analysis, studies should be symmetrically distributed around the estimated effect size, with the bottom having smaller studies (higher standard error) and larger studies (lower standard error) toward the top. In this graph, we see a little asymmetry, and we have a prominent outlier way over on the right-hand side of the graph. The existence of this outlier away from the general clustering of other studies could indicate that this particular study deviates substantially from the pooled effect size, possibly owing to unique characteristics or greater sampling variability. Moreover, some points lie close to the edges of the pseudo 95% confidence interval (CI), which indicates some variability in effect size among the studies. Nevertheless, most of the studies fall inside the pseudo-CI, which provides a reasonable level of homogeneity across the studies included in this analysis. The asymmetry here would suggest a mild to moderate degree of publication bias, where the smaller studies reported larger mean differences than did the larger studies. This may indicate the selective publication of studies showing significant or large effects and, hence, might affect the pooled effect size estimate. Finally, whereas most of the studies are contained within the pseudo 95% CI and exhibit homogeneity, the asymmetry of the plot and the presence of an outlier suggest some publication bias.

The funnel plot in Figure 8B also shows the relationship between the standard error (y-axis) and the mean difference (x-axis) for the studies included in this meta-analysis and visual assessment of publication bias. If there is no publication bias, the studies should be symmetrically distributed around the estimated effect size (shown by a vertical red line). Larger studies (with smaller standard errors) are clustered toward the top, whereas smaller studies (with higher standard errors) are spread toward the bottom. This funnel plot clearly shows asymmetry, with two outliers located at opposite ends of the plot. One has a mean difference close to 0, whereas another study has a high mean difference of approximately 25. This unequal distribution suggests the possibility of publication bias, as studies with larger effect sizes are disproportionately represented on one side of the funnel, away from the pooled estimate. In the final analysis, this funnel plot is asymmetric, and the outlier positioning indicates a bias toward the average release.

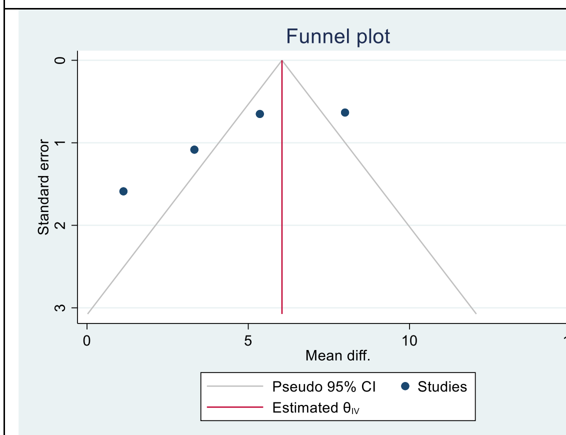
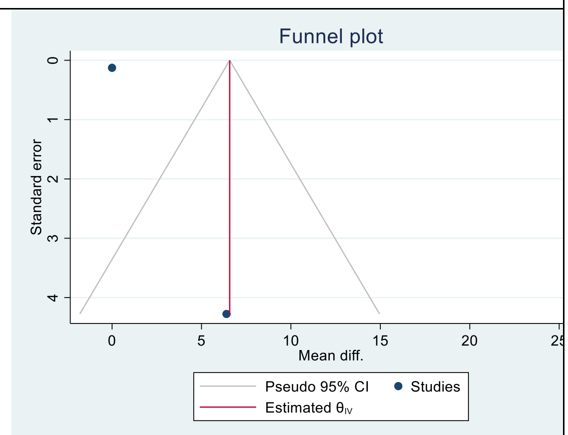
Fig 8A - Rehabilitation	**Fig 8B - Physical activity**
	

Fig 8A-B Funnel plot for publication bias

Data from two variables, "rehabilitation" and "physical activity," are presented for two conditions: "observed" and "observed + imputed." The effect size "Theta," for each condition is shown with 95% CIs, which provide the range within which the true effect is likely to fall. The estimated effect size Theta for the variable "rehabilitation" in the observed condition was 6.045, with a 95% CI ranging from 5.259--6.832. This narrow confidence interval is rather a narrow estimate with relatively low variability, reflecting a high level of consistency among the observed studies of this variable. This effect size is positive and statistically significant because the CI does not cross zero. Adding unpublished and imputed data for the "Observed + Imputed" condition increases the effect size to 6.225 but substantially increases the 95% CI from 2.052--10.399. This widening of the CI reflects less certainty in the estimate of effects with the imputation of data, perhaps owing to increased heterogeneity or variability contributed by these additional data points. However, the effect size remains positive and continues to suggest a possibly meaningful impact, though less precisely. The observed condition physical activity variable, the effect size theta, was 6.400, with a wide 95% CI from -1.981--14.781. This wide interval, crossing zero, suggests high uncertainty and indicates that the effect of physical activity may be positive, negligible, or even negative; hence, it cannot reach statistical significance. In the "Observed + Imputed" condition, after adding the imputed studies, the size of the effect increased to 13.149; however, the 95% CI was wider, ranging from -12.624--38.923. The extremely wide CI, crossing over zero, suggests very high variability and a lack of precision, likely owing to large heterogeneity among studies or the effect of imputed data. A wide CI reduces the interpretability of the effect size; a CI ranging from negative to highly positive suggests just how inconclusive the findings for physical activity are.

Overall, for the variable "rehabilitation", a statistically significant positive effect with a precise estimate is obtained with the observed data, whereas the inclusion of imputed data yields positive estimates with reduced precision, which may indicate potential variability introduced by the imputed studies. The results for the variable "Physical Activity" indicate that the observed data are not significant with high variability; adding the imputed data increases the effect size estimate and uncertainty and is hence inconclusive. These findings suggest that estimates might be influenced by publication bias or heterogeneity and could reduce the precision and reliability of these estimates for physical activity.

Table 7 Effect Size Estimates and Confidence Intervals for Rehabilitation and Physical Activity Variables Under Observed and Imputed Conditions

Imputation unpublished study	**Studies**	**Theta**	**95% CI**	
			Lower	**Upper**
Rehabilitation	Observed	*6.045*	*5.259*	*6.832*
	Observed+ imputed	*6.225*	*2.052*	*10.399*

Physical activity	Observed	*6.400*	*-1.981*	*14.781*
	Observed+ imputed	*13.149*	*-12.624*	*38.923*

*__Theta__: Effect Size (a measure of the strength of an intervention's impact in meta-analyses), and **95% CI**: 95% Confidence Interval (a range of values that is believed to encompass the true effect size with 95% certainty).

Discussion

Key results

The key conclusion of this review is that the role of nurse-led support programs enhances physical activities and rehabilitation outcomes of stroke patients significantly. In fact, through such organized programs that ensure close supervision, encouragement, and targeted interventions, the patients can show measurable improvements both in mobility and physical independence. This is supported by an emerging body of evidence on the efficacy of nurse-led interventions in stroke rehabilitation. This study has identified how nurse-led programs improve adherence to the rehabilitation regimen and make sustained progress by patients. The fact that this finding, and other leads, has been consistently supported by multiple studies of various types of outcome measures consolidates the importance of a potential nurse-led model as an essential element for effective stroke recovery programs.

The review of the related studies depicted a similar trend, thus giving validity to our findings. For instance, the findings of Aljohani and colleagues (2024) (1) showed significant disparities in patients' disability scores and quality of life within groups receiving the nurse-led interventions compared to those who received the standard rehabilitation programs. This study explains the findings on the basis that the nurses continued their presence and individualized care planning to help them lose their fears and increase motivation toward recovery. The same effect was presented in the case of Muniyandi and colleagues (2024) (2) fewer post-acute complications, and improved quality of life, were recorded after the implementation of a nurse-led bundle of care. Such findings are taken even further by Urcan and Kolcu (2022) (3) structured education/support programs provided by nurses brought significant improvements in both physical functioning and anxiety in patients with a disability due to stroke. The similarity of findings across these studies points to the general effectiveness of nurse-led interventions in improving patient outcomes in stroke rehabilitation, as observed from our analysis.

However, a study by Bahgat (2022) (4) observed that while nurse-led interventions were effective in improving physical aspects such as gait and balance, it was unhelpful in improving patients' emotional well-being and overall psychological recovery. This might be because the physical recovery of patients alone is not complete with all the psycho-social challenges that come with stroke rehabilitation. In like manner, Abd-Elkhalik and colleagues, (2023) (5) explain that while there are functional gains from nurse-led programs, the improvement in quality-of-life measures is not up to the rates one would imagine. This may be an indication that while nurse-led programs address the physical rehabilitation needs of the patients, there is an unmet need for psychological or emotional support. The diverging findings that are foundational to this current study call for an integrated approach, combining both physical and psychosocial interventions in offering comprehensive assistance for stroke survivors.

The different findings may be due to some methodological and demographic reasons. Another important factor involves the duration and intensity of such interventions, which tend to be quite variable from one study to another. For example, short-term interventions of less than three months may demonstrate rapid improvements but without the long-term benefits that longer interventions might achieve. Thus, studies included in this review that had an intervention period of three months or longer reported progressively greater benefits, with the patients having more time to follow through with the rehabilitation regimen and incorporate physical activity into daily life. These findings are in line with those presented by Li and colleagues (2023) (7), who showed that longer-term interventions had a stable and steadily improving physical activity and independence since such guidance by nursing staff was sustained. In addition to that, the effectiveness of this intervention can also heavily rely on certain patient demographics, including age and initial severity of the stroke. For instance, physical activity programs may be most effective for younger patients with less severe strokes, while outcomes may be poorer in older patients or those with higher levels of disability.

Second, the heterogeneity of the intervention protocols across the studies themselves can be another reason for inconsistent results. While some programs emphasize physical exercises, others include cognitive exercises, motivational interviewing, and family support. According to Fuller and colleagues (2024), interventions that address physical, cognitive, and psychosocial support would, therefore, be more likely to realize holistic benefits on account of their multifaceted nature in addressing the wide needs that stroke survivors have. This also corresponds to modern concepts of rehabilitation, which are orientated toward the patient, and hence could imply that the programs led by a nurse may be optimized by including a wider variety of therapeutic components. However, to what extent each of these components is incorporated will be a factor of institutional resources, expertise of nurses, and patients, further explaining variabilities observed between studies.

Clinically, the findings have important implications that reinforce the potential for nurse-led programs to facilitate improved physical and emotional recovery among patients with stroke. This model of care enables short-term gains in physical functionality and encourages long-term compliance with rehabilitative behaviors through ongoing motivation and support. The physical and mental presence of a nurse also tends to reduce feelings of isolation in clients, not least because the incidence of depression and anxiety among stroke survivors is extremely high. The research underlined that with the support of a nurse-led program, patients are most likely to actively participate in their recovery process for higher levels of satisfaction and self-efficacy. Such findings have important implications for healthcare systems seeking less costly ways of improving patient outcomes, as most nurse-led programs - compared with physician-led care - require less input into the resources while managing to achieve quality outcomes. Swank and colleagues (2020) (25) reported similar clinical significance in a study where patients who enrolled in a nurse-led physical activity program demonstrated higher functional mobility and overall well-being, which in the long term might promote health and reduce the chances of stroke recurrence.

This study confirms that nurse-led interventions are effective in improving physical recovery and overall well-being among survivors of a stroke. Such findings indicate that these types of interventions can be adopted into routine care in stroke rehabilitation, with possible extension to various healthcare settings. More work needs to be done regarding the development of comprehensive nurse-led models, which include mental health support, as this may provide some of the gaps in the current model. Longitudinal studies that would further determine the sustainability of physical and psychological improvements over time would contribute significantly to understanding the long-term benefits of such programs. Such optimization of nurse-led interventions would ensure they're being patient-centered yet adaptable to various needs. Other developments that could be furthered include expanding the availability of nurse-led rehabilitation programs by offering remote or telehealth options for those patients who reside in rural or otherwise underserved areas and may enjoy less access to direct, in-person rehabilitation services.

Conclusion

The study further revealed that nurse-led support programs are effective in enhancing physical rehabilitation and improving activity level outcomes for stroke patients. This personalized guidance and encouragement not only addresses physical but also motivational problems, leading to better rehabilitation adherence and overall improvement. Nurse-led programs have clinical value in that they permit tailored interventions to meet the many needs of stroke patients and have been cost-effective additions to health care. In conclusion, nurse-led interventions provide a promising framework for improving stroke recovery. Thus, future studies need to explore combined physical and psychological approaches, considering remote options to enhance access to such programmers, enabling more stroke survivors to achieve their fullest sustainable recovery.

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Author's Contribution

FR and AV prepared the material, collected data from scientific databases for use in statistical software, and performed the analysis. MS performed the literature search in scientific databases and drafted the first version of the manuscript, and FR, AV, and MS participated in the screening process. All authors (FR, AV, and MS) read and approved the final version of the manuscript.

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Availability of data and materials

Not applicable, since systematic reviews and meta-analyses rely on data extracted from other studies, the data summarizing the findings of this study in the studies mentioned in the article is publicly available. For this reason, this study, because the original data was not collected; In the data availability section, the word "not applicable" is mentioned because no new data has been collected and only published studies have been used.

Declarations

Ethics approval and consent to participate

Not applicable, the need for ethics approval and consent to participate was waived for this systematic review and meta-analysis as it did not involve direct human subjects.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Figures

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Abbreviations

AIS: Acute Ischemic Stroke
TIA: Transient Ischemic Attack
MBI: Modified Barthel Index
ADL: Activities of Daily Living
MAS: Motor Assessment Scale
SS-QOL: Stroke-Specific Quality of Life
NIHSS: National Institutes of Health Stroke Scale
C-M-CSI: Chinese Modified Caregiver Strain Index
FIM: Functional Independence Measure
SAS: Self-Rating Anxiety Scale
SDS: Self-Rating Depression Scale

LOTCA: Lowenstein Occupational Therapy Cognitive Assessment
SPSS: Statistical Package for the Social Sciences
STATA: Software for Statistics and Data Science
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RCT: Randomized Controlled Trial
CRD: Centre for Reviews and Dissemination
QOL: Quality of Life
SSQoL-12: Stroke-Specific Quality of Life - 12 Items
SPKQ: Stroke Prevention Knowledge Questionnaire
SSEQ: Stroke Self-Efficacy Questionnaire

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