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The relationship between levels of physical activity and participation in everyday life in stroke survivors: A systematic review and meta-analysis

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ABSTRACT

Background: Stroke survivors demonstrate decreased physical activity (PA) and take time to return to participation in everyday life, but the relationship between the two variables is unknown.
Objective: To investigate the correlation and trajectory over time between levels of PA and participation in everyday life in stroke survivors.
Methods: PubMed, Web of Science, Scopus, SPORTDiscus, Rehabilitation&Sport Medicine Source, and PEDro databases were searched from inception to January 2024.
Cross-sectional and prospective studies evaluating both levels of PA and participation in stroke survivors were included.
Two reviewers independently conducted the study selection, data extraction, and quality assessment. Meta-analyses of pooled correlation coefficients were calculated when at least two studies reported a correlation coefficient between the same PA and participation outcomes.
Results: Of 4962 studies identified, 49 were included in the systematic review. Studies were rated high (55%%) or fair (45%) quality. A wide range of monitoring methodologies for assessing PA and participation were found in the 23 prospective studies. Seven studies were included in the meta-analyses, showing a positive moderate correlation between PA time and participation in activities of daily living ($n = 148$; $r = 0.52$; $P < 0.01$; $I^2 = 81\%$) in participants <6 months post-stroke, and between PA time and the participation in all areas ($n = 126$; $r = 0.44$; $P < 0.01$; $I^2 = 0\%$) in participants ≥6 months post-stroke. Overall, while PA showed significant improvements over time, participation only showed a tendency.
Conclusions: Despite the heterogeneity, consistent positive associations were found between PA time and participation levels in some areas. Establishing consensus is crucial to reduce heterogeneity and facilitate data pooling.

1. Introduction

Stroke has a profound impact on an individual's life, increasing dependency and leading to significant health and socio-economic costs.[1,2] Stroke survivors often experience sequelae that result in impairments in bodily structures and functions, limiting their ability to perform daily activities and return to participation in everyday life.[1] Of particular importance is the extended time required for stroke survivors to return to full participation in everyday life,[3] participation is defined simply by the International Classification of Functioning, Disability and Health (ICF) as a person's involvement in life situations.[4] However, participation is a complex construct that implies not only performance but also subjective experience of meaning, autonomy, and self-determination.[4] It consists of a person's active involvement in carrying out daily life activities and finding them purposeful and meaningful.[5] It is a person-task-environment interaction that changes throughout life and responds to the demands of the environment and tasks.[6] The American Occupational Therapy Association grouped participation into activities of daily living, instrumental activities of daily living, sleep and rest, work, education, play, leisure and social participation.[7] Participation

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restrictions are influenced by multiple factors,[8–10] encompassing personal factors, stroke-related sequelae,[3,11] the physical and social environment, as well as available resources.[12]

Many stroke survivors lead sedentary lifestyles[13] (defined as energy expenditure of 1.5 METs or less during awake time), spending prolonged periods of inactivity sitting or lying[14] and failure to adhere to the recommendations of the World Health Organization[15] on physical activity (PA). Physical activity is defined as "any bodily movement produced by skeletal muscles that results in energy expenditure".[16] Stroke survivors are inactive during all phases of recovery.[13] Numerous factors[17–21] may contribute to such behavior[22,23] or encourage a more active lifestyle,[24,25] including the influence of early life experiences and the effects of rehabilitation.[26]

Inadequate PA increases the risk of future cardiovascular events in stroke survivors.[27,28] Conversely, engaging in recommended levels of PA has a positive impact on neuroplasticity[29] and improves physical fitness, reducing the effects of stroke sequelae[30,31] as well as risk factors of a recurrent stroke.[32] It is well-documented that adopting a healthy lifestyle, including participation in daily life activities, can significantly contribute to overall well-being and health.[33,34] Consequently, there is a pressing need for up-to-date information on the impact of these factors on secondary prevention,[35,36] the most effective methods for measuring PA levels,[14,37–39] and strategies for facilitating a return to full participation.[40,41]

Low PA levels are a problem not only for stroke survivors with a high level of disability; but also for stroke survivors who return to independent walking.[10,42–44] Recent research[24] suggests a relationship between participation in daily life activities and PA levels, echoing earlier studies that explored the relationship between participation in everyday life and PA intensity.[44] Consequently, further investigation is needed to provide an updated synthesis of the scientific evidence on the relationship between these variables among stroke survivors.[45] Importantly, it remains unknown whether changes in PA levels and participation after a stroke are interrelated and whether this relationship varies depending on the time elapsed since stroke onset.

This study primarily aimed to investigate the relationship between PA and participation levels in stroke survivors. Furthermore, a secondary aim was to quantify whether levels of PA and participation in everyday life follow a similar trajectory over time.

2. Methods

2.1. Study design and registration

This systematic review and meta-analysis, conducted under the Population-Exposure-Outcome framework,[46] was reported following the PRISMA statement[47] and registered in the International Prospective Register of Systematic Reviews database (PROSPERO: CRD42022360711). The full protocol, including any minor deviations from the initial PROSPERO protocol, is available elsewhere.[45]

2.2. Eligibility criteria

2.2.1. Study types

Studies with a cross-sectional or prospective design (i.e., cohort and randomized controlled trials (RCTs)) that evaluated PA levels and participation levels in stroke survivors were included. Only articles with full-text availability and publication in an English or Spanish peer-reviewed journal were included. The search was not limited by the date of publication, but case studies or case series with a sample size of fewer than 10 participants were excluded.[48]

2.2.2. Participants characteristics

Studies recruiting adult participants (≥18 years) with a diagnosis of stroke, irrespective of the time since stroke or severity of stroke sequelae, etiology, sex, or geographical location, were included. Studies that involved mixed populations with composite data were excluded unless stroke-specific data could be extracted separately. The results were categorized based on the time elapsed since the stroke. Consequently, two groups were formed: (1) participants who experienced a stroke within the last 6 months, and (2) those whose stroke occurred more than 6 months before the beginning of the study.

2.2.3. Characteristics of the outcome measures

Studies reporting PA data according to recent international consensus were classified in the following sub-variables (1) PA frequency, (2) intensity and duration, (3) intensity, and (4) duration.[38] Theses sub-variables included measures such as metabolic equivalent of task (METs), minutes of total, vigorous or moderate PA, walking time, daily step count, total time spent in sedentary behavior, measured using objective devices (e.g., pedometers, accelerometers, fitness trackers, smartwatches) or self-reported questionnaires (e.g., International Physical Activity Questionnaire, Physical Activity Scale for the Elderly). Additionally the studies had to report information about participation in at least one daily life activity according to the occupational therapy framework,[49] including activities of daily living and instrumental activities of daily living, sleep and rest, work, education, play, leisure, or social participation using self-reported questionnaires (e.g., Stroke Impact Scale, Barthel Index, Frenchay Activities Index, or Activity Card Sort) or direct observation assessment (e.g., behavioral mapping), were included. Studies that solely included physical performance tests or energy expenditure in short laboratory sessions or PA performed during leisure time only were excluded. Furthermore, studies reporting correlation findings between PA and participation outcomes were considered for the meta-analysis.

2.3. Data sources and searches

Six electronic databases (Medline via PubMed; Web of Science and Scopus via Web of Science, managed by the Spanish Foundation for Science and Technology; SPORTDiscus and Rehabilitation & Sport Medicine Source via EBSCOhost; and PEDro) were searched from inception to January 2024. The search terms were categorized into three groups: stroke-related terms, terms related to PA, and terms related to participation in daily life activities. The search strategy of each database is provided in *Appendix A*. Aiming to identify additional records, a comprehensive review of the references included in the reviewed full-text articles was conducted.

2.4. Study selection

All studies found in the databases were downloaded and organized using Endnote Software (*Clarivate Analytics Philadelphia, USA*). Once duplicate records were eliminated, title and abstract screening was completed following predefined eligibility criteria. The full texts of the included studies were then carefully reviewed and assessed, applying the same eligibility criteria. At each step, two independent researchers (CDA and ABE) selected the studies, and in the event of any disagreements, a consensus was reached with the assistance of a third researcher (PBL).

2.5. Evaluation of the risk of bias in the studies

Two researchers (CDA and PRP) independently assessed the risk of bias of the studies using the Newcastle-Ottawa scale for cohort studies[50] and its adapted version for cross-sectional studies,[51] while the PEDro scale was used for RCTs.[52] A third researcher (PBL), who verified the assessments, resolved any discrepancies.

The Newcastle-Ottawa scale evaluates seven to eight items, grouped into three criteria: selection, comparability, and exposure or outcome. The maximum score is 9 (or 10 for cross-sectional studies). Articles with a score of at least 7 were classified as "high quality," those with a score of

4–6 were considered "fair quality," and those with a score less than 4 were categorized as "poor quality".[50]

The PEDro scale consists of 11 items, where articles are awarded 1 point if they meet the criterion and 0 points if not. Item 1 assesses external validity, items 2–9 assess internal validity, and items 10 and 11 assess the interpretability of the results. The maximum achievable score is 10 points since item 1 is not counted in the final score. Articles that score at least 6 out of 10 are considered "high quality," those scoring 4 or 5 are deemed "fair quality," and those with a score of less than 4 are labeled as "poor quality.[53]

2.6. Data collection

Two researchers (CDA and RGN) independently extracted data from the selected studies using a standardized data extraction sheet (*Appendix B*). Concurrently, a third and fourth researcher (PBL & AMR) cross-verified the extracted data and resolved any discrepancies.

The following data were collected: general study information, sample and subgroup characteristics, study characteristics, outcome measures, and outcome data related to PA and participation. Finally, the main results, including correlation coefficients between PA and participation outcomes, were extracted when available. The results were categorized based on the time elapsed since the stroke (i.e., <6 months or ≥6 months).

Whenever possible, patterns of PA and participation outcomes over time were extracted from prospective studies to identify significant changes. Significant improvements or deterioration in PA and participation outcomes were considered when there were statistically significant differences between the baseline and follow-up assessments. Conversely, if no significant changes were observed over time, it was categorized as "no change". As this review and meta-analysis do not intend to assess intervention effectiveness, it is essential to clarify that for RCTs, the treatment arms were considered as independent cohorts. This approach was intended to allow for a comprehensive understanding of how PA and participation may change over time and provide a comprehensive analysis of the data.[54]

2.7. Meta-analysis

When at least two studies reported a correlation coefficient between the same PA and participation outcomes, the weighted summary of correlation coefficients under the random effects model was calculated using the Hunter-Schmidt method, based on a weighted mean of the raw correlation coefficients.[55] Heterogeneity between the results of the included studies was investigated using I^2 statistics, with values > 50% indicating substantial heterogeneity across studies.[56] Correlations were considered as '*strong*' ($\rho \geq 0.70$), '*moderate*' ($0.40 > \rho < 0.69$), '*weak*' ($0.10 > \rho < 0.39$), or '*negligible*' ($\rho < 0.10$).[57] Subgroup analyses were conducted based on whether PA variables were measured by objective devices or self-reported questionnaires. Selection bias was examined by using funnel plots and Egger's tests. All analyses were conducted using STATA v.16.1 (*StataCorp, College Station, Texas 77845, USA*), and alpha was set at $P < 0.05$. Results from meta-analysis were also displayed in form of forest plots.

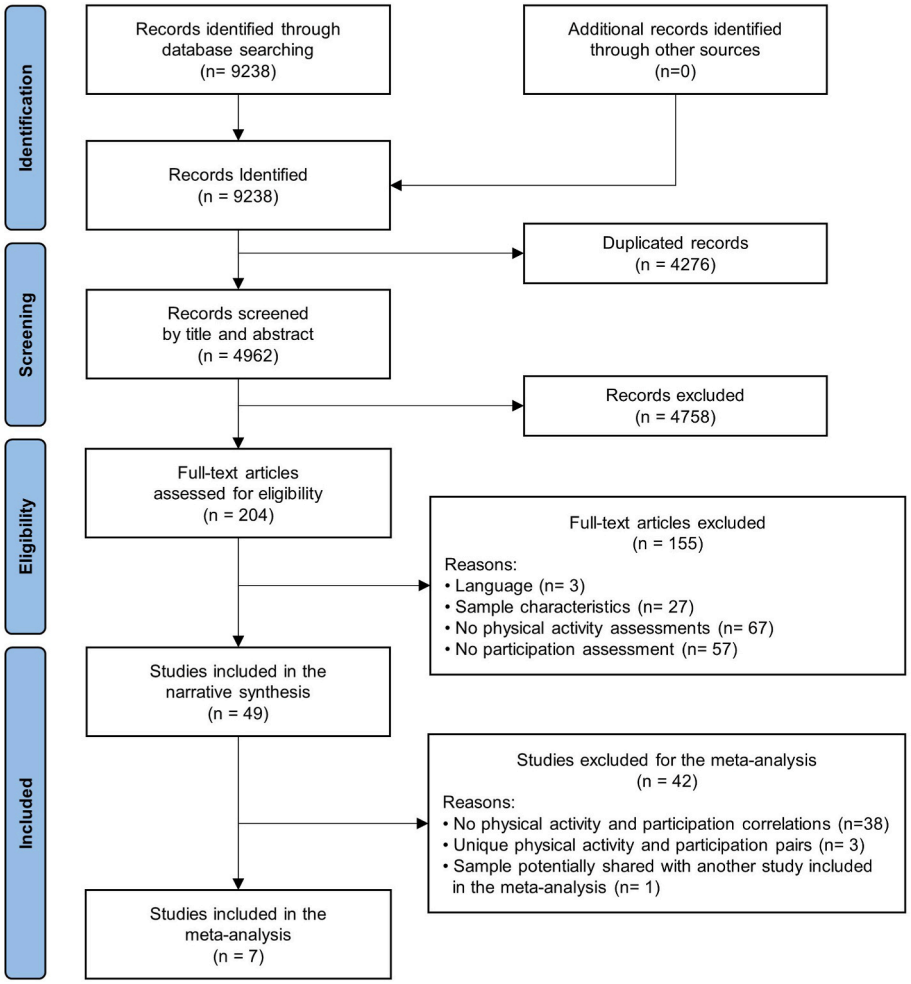

Fig. 1. Study flow-chart according to the PRISMA statement.

3. Results

3.1. Study selection

The article selection process of the articles is summarized in Fig. 1. After removing duplicates, 4962 records were identified. Two hundred and four full-text articles were screened as potential eligible studies, resulting in the inclusion of 49 studies in the review. The list of records excluded after full-text screening is presented in *Appendix C*. No additional records were identified within the bibliographic references of the reviewed full-text articles.

3.2. Study characteristics

The main characteristics of the articles included in this systematic review are presented in Table 1 for those including stroke survivors within 6 months post-stroke and in Table 2 after 6 months. The 49 articles comprising a total of 4554 stroke survivors (39% female). Twenty-four studies included stroke survivors within the first 6 months after stroke,[13,58–80] and 24 studies included stroke survivors recruited at least 6 months after stroke.[34,81–103] Only one study included both subgroups of stroke survivors as independent groups.[104]

3.3. Risk of bias assessment

The total Newcastle-Ottawa and PEDro scores for each study are integrated into Tables 1 and 2. Detailed tables showing the methodological quality assessment results of the retrieved studies are presented in *Appendix D*.

From the 26 cross-sectional studies, 14 studies (54%) were considered to be of high quality[67,68,70,76,80,84–86,91,93,94,97,102,103] and 12 studies (46%) of fair quality.[34,71,74,75,82,83,87,89,90,95,98,104]

From the 19 cohort studies, nine studies (47%) were considered to be of high quality[13,62–66,79,81,99] and 10 studies (53%) of fair quality.[58–60,69,72,73,77,78,92,96]

All four RCT's (100%) were considered to be of high quality.[61,88,100,101]

3.4. Physical activity

Of the articles included in the systematic review, 14 studies (29%) included self-reported questionnaires (e.g., International Physical Activity Questionnaire, Physical Activity Scale for the Elderly),[62,64,69,74,76,78,80,82,89,90,94,95,98,104] 27 studies (55%) included objective devices (e.g., ActiGraph, ActivPal),[13,34,58–60,65–68,70,72,73,75,81,83–86,88,91,92,96,97,99,100,102,103] of which only an article[102] includes Fitbit activity trackers, and eight studies (16%) included both subjective and objective measurement tools.[61,63,71,77,79,87,93,101]

Variables collected by self-reported questionnaires variables included: (1) intensity and duration (time spent in moderate to vigorous PA, light intensity PA), and/or (2) duration (total time spent in sedentary behavior, walking time, habitual weekly minutes of PA). Outcomes collected via objective devices included: (1) PA frequency (daily step count, number of activity counts), (2) intensity and duration (time spent in moderate to vigorous or light intensity PA), (3) intensity (energy expenditure by METs per day), and/or (4) duration (habitual weekly minutes of PA, total time spent in sedentary behavior and walking time).

3.5. Participation

Twelve studies (25%) recorded only activities of daily living (e.g., Barthel Index, Modified Barthel Index),[58,67,70,71,74–76,88–91,94] 21 studies (43%) used only a tool to assess the impact of stroke on all participation areas (e.g., Stroke Impact Scale-16, Stroke Impact Scale 3.0)[60,62,64,65,68,73,79,80,82-87,92,95-102], while only one study (2%) assessed both.[60] Seven studies (14%) used different assessment tools for other participation aspects (e.g., The Assessment of Life Habits, Activity Card Sort)[13,61,63,66,69,77,93] six studies (12%) used more than one participation assessment tool (e.g., Barthel Index and The Frenchay Activities Index).[34,60,72,81,104]

Only two studies (4%)[69,72] included direct observation assessment by using a behavior mapping protocol.

3.6. Meta-analysis

From the initial 49 studies, only 11 studies (22%) reported correlations between PA and participation outcomes within the first 6 months post-stroke[59,70,71,77,105] or greater than 6 months post-stroke.[85,87,95,97,99,103] Three of these studies were excluded from the meta-analysis due to investigating unique pairs of PA and participation outcomes (daily steps & Activity Card Sort, vs International Physical Activity Questionnaire & Activity Card Sort,[77] vs increase in daily steps & Stroke Impact Scale,[99] vs daily steps & Instrumental Activities of Daily Living[103]). Additionally, one study[70] was excluded due to likely inclusion of the same sample as another study.[71] We attempted to contact the authors but did not receive a reply.

Fig. 2 (<6 months since stroke) and Fig. 3 (≥6 months since stroke) show the forest plots for the pooled correlation coefficients between PA outcomes and participation from the included studies. No selection bias was detected after examining funnel plots and Egger's tests (Fig. 4).

Three studies, accounting for 148 individuals within 6 months post-stroke, investigated correlations between PA measures recorded by objective devices and participation in activities of daily living assessed through the Barthel Index, with the pooled coefficient showing a moderate correlation ($r = 0.52$; $P < 0.01$; $I^2 = 81\%$) (Fig. 2).

Four studies, accounting for 126 individuals greater than 6 months post-stroke, investigated correlations between PA time and participation in all areas by the Stroke Impact Scale, with the pooled coefficient showing a moderate correlation ($r = 0.44$; $P < 0.01$; $I^2 = 0\%$) (Fig. 3). Subgroup analyses also showed a moderate correlation between PA and participation when PA measures were recorded by self-reported questionnaires ($n = 50$; $r = 0.41$; $P < 0.01$; $I^2 = 28\%$) or objective devices ($n = 76$; $r = 0.45$; $P < 0.01$; $I^2 = 0\%$) (*Appendix E*).

The studies excluded from the meta-analysis due to analyzing unique pairs of outcomes[77,99,103] indicated a positive correlation between PA levels and participation levels. Specifically, for participants within 6 months since stroke, Thilarajah et al.[77] found a correlation between participation, recorded through the Activity Card Sort, and PA registered by using the International Physical Activity Questionnaire ($n = 55$; $r = 0.43$, $P < 0.05$) and a pedometer ($n = 55$; $r = 0.40$, $P < 0.05$). Meanwhile, Sullivan et al.[99] found that in people who had a stroke more than 6 months ago, the greater increase in the number of steps recorded with a pedometer, the greater the level of participation recorded by Stroke Impact Scale ($n = 11$; $r = 0.74$, $P < 0.05$). However, Levin et al.[103] only found a positive correlation between daily steps and the Instrumental Activities of Daily Living in a subsample of stroke survivors using a support device for walking ($n = 22$; $r = 0.51$, $P < 0.05$) but not in those who were able to walk independently ($n = 15$; $r = -0.18$, $P > 0.05$).

Furthermore, in participants within 6 months since stroke Barrett et al.[59] also found that lower participation in activities of daily living (Barthel Index) was associated with higher levels of sedentary behavior both during weekdays ($n = 19$; $r = -0.54$, $P = 0.02$) and weekends ($n = 19$; $r = -0.55$, $P < 0.05$).

3.7. Relationship between levels of physical activity and participation over time

The 23 prospective studies included in the systematic review[13,58–66,69,72,73,77–79,81,88,92,96,99–101] displayed high variability in the time points for measuring PA and participation.

Of the 16 prospective studies involving participants ($n = 1508$)

Table 1
Main characteristics of the included articles with **stroke survivors within 6 months post-stroke.**

Study	Design & Country	Participants (N, age, sex)	Stroke severity	PA measures	Participation measures	Results: changes over time and correlations	Quality assessment
Askim, 2013[54]	Cohort; Assessments at baseline,1, 3, & 6 months; Norway	N = 28; 78.7 ± 8.7 years; 46.4% female	SSS 41.2 ± 14.8	▪PAL 2® (right leg): time spent upright, sitting, and lying; number of transitions. -Duration of monitoring: between 1 and 3 complete days.	▪BI	PAL 2 ↑ BI N/A Correlations: N/A	6 Fair quality
Barrett, 2018[55]	Cohort; Assessments at baseline & 7 days before discharge; Canada	N = 19; 68.2 ± 9.8 years; 36.8% female	NIHSS 4.7 ± 3.3	▪Actiheart monitor® (chest): SB and PA time. -Duration of monitoring: 7 complete days	▪Activity log ▪BI	Actiheart monitor ≈ Activity Log ≈ BI N/A Correlations: PA time & BI: r = 0.37 Sedentary & BI: r = −0.54	6 Fair quality
Blaszcz, 2022[56]	Cohort; Assessment at baseline & 6 weeks; Poland	N = 31; 72.3 ± 6.5 years; 58.1% female	–	▪Caltrac® (affected hip): (over hip on the paresis side) -Duration of monitoring: 8.30 to 17.30 for 6 weeks	▪BI ▪SIS	Caltrac ↑ BI ≈ SIS ≈ Correlations: N/A	4 Fair quality
Brauer, 2022[57]	RCT; Assessment at baseline, 8 & 26 weeks; Australia	N = 119; - EG 62 ± 11 years; 20% female - CG 64 ± 9 years; 22% female	mRS - EG 2.8 ± 0.6 - CG 2.9 ± 0.6	▪activPAL3™ (anterior non-paretic thigh): Steps/day. ▪PASIPD -Duration of monitoring: 4 days	▪IPAQ	PASIPD ≈ activPAL3 ≈ IPAQ ≈ Correlations: N/A	8 High quality
Brounds, 2021[58]	Cohort; Assessment at baseline, 3 & 6 months; The Netherlands	N = 318; 60.4 ± 11.5 years; 36.4% female	–	▪IPAQ-SF	▪SIS ▪USER-P	IPAQ-SF ≈ SIS ↑ USER-P ↑ Correlations: N/A	7 High quality
Caetano, 2021[59]	Cohort; Assessment at baseline, 3 & 6 months; Brazil	N = 20; 64 ± 11 years; 20% female	–	▪Actigragh Wgt3X-BT® (waist non-paretic side): average step counts. Duration of monitoring: 7 days ▪IPAQ	▪LIFE-H	IPAQ ≈ Actigragh ≈ LIFE-H ≈ Correlations: N/A	8 High quality
Cook, 2020[60]	Cohort; Assessment at baseline & ≤3months; Sweden	N = 117; 68.4 ± 10.1 years; 41% female	mRS: 3(2–4)	▪SGPALS	▪SIS 3.9	SGPALS N/ASIS (ITEM 8) N/A Correlations: N/A	8 High quality
de Graaf, 2022[61]	Cohort; Assessment at baseline, 6 &12 months; The Netherlands	N = 200; 67.8 ± 11.2 years; 68% female	NIHSS 4.4 ± 4.4 -Sedentary exercisers:3.8 ± 3.9 -Sedentary movers:3.6 ± 3.5 -Sedentary prolongers:4.7 ± 4.7	▪Activ8® (thigh): SB, LPA, and MVPA time. -Duration of monitoring: 2 weeks during waking hours	▪SIS–P	Activ8 N/A SIS–P ↑ Correlations: N/A	9 High quality
de Rooji, 2021[62]	Cohort; Assessment at baseline & 6 weeks; The Netherlands	N = 52; 61.6 ± 10.5 years; 30.8% female	–	▪DynaPort MM® (middle of the lower back): walking activity. -Duration of monitoring: 5 days	▪USER-P	DynaPort ≈ USER-P ↑ Correlations: N/A	7 High quality
Egerton, 2006[63]	Cross-sectional; Assessment at baseline; UK	N = 41; 68.2 ± 11.3 years; 46.3% female	–	Pressure transducer (unaffected leg): upright activity time, number of transitions from nonupright to upright. -Duration of monitoring: one therapeutic day from 7 to 8am until 4.30pm	▪BI	Correlations: Upright activity time & BI: r = 0.79	7 High quality
Ezeugwu, 2017[64]	Cross-sectional; Assessment at baseline; Canada	N = 30; 63.8 ± 12.39 years; 43.3% female	–	▪actiPAL3 Micro® (thigh of non-hemiparetic leg): sleep duration, SB time, PA time, transitions to upright. -Duration of monitoring: 7 days	▪SIS	Correlations: N/A	8 High quality
Honado, 2023[100]	Cross-sectional; Assessment at baseline; Benín	N = 60; 56.7 ± 10.4 years; 26.7% female	–	▪IPAQ-SF	▪BI ▪RNLI	Correlations: N/A	5 Fair quality

(*continued on next page*)

Table 1 (*continued*)

Study	Design & Country	Participants (N, age, sex)	Stroke severity	PA measures	Participation measures	Results: changes over time and correlations	Quality assessment
Janssen, 2014[65]	Cohort; Assessment at baseline & 2 week; Australia	N = 14; 78 [68–81] years; 36% female	NIHSS 3(2–8)	▪Behavioral mapping checklists (48h direct observation)	▪Behavioral mapping checklists	Behavioral mapping checklists N/A Correlations: N/A	4 Fair quality
Lacroix, 2016[66]	Cross-sectional; Assessment at baseline; France	N = 21; 63 ± 20 years; 43% female	–	▪SenseWear armband® (unaffected arm): PA time. -Duration of monitoring: 1 day (from 9am to 4.30pm)	▪BI	Correlations: PA time & BI: r = 0.34	5 High quality
Lacroix, 2016[67]	Cross-sectional; Assessment at baseline; France	N = 88; 66 ± 17 years; 41% female	–	▪SenseWear armband® (unaffected arm): PA time. -Duration of monitoring: 2 days from 9am to 4.30pm	▪BI	Correlations: PA time & BI: r = 0.34	7 Fair quality
Rosbergen, 2017[68]	Cohort; Assessment at baseline & 3 months; Australia	N = 90; 76.0 ± 12.8 years; 37.7% female -Usual care N = 30; 76.0 ± 12.8 years; -Enriched N = 30; 76.7 ± 12.1 years; -Sustainability N = 30; 73.8 ± 17.4 years	NIHSS Usual care 8.5 ± 6.4 Enriched 7.8 ± 5.8 Sustainability 7.0 ± 4.8	▪Behavioral mapping	▪MBI ▪Behaviour mapping protocol	Behavioral mapping↑ MBI N/A Correlations: N/A	6 Fair quality
Shaughnessy, 2005[69]	Cohort; Assessment at baseline & 3 months; USA	N = 19; 68 ± 12.8 years; 47.3% female	–	▪SAM® (n/a): daily steps count.	▪SIS	SAM ↑ SIS ≈ Correlations: N/A	4 Fair quality
Skarin, 2013[70]	Cross-sectional; Assessment at baseline; Sweden	N = 104; 70.3 ± 14.4 years; 47.1% female	NIHSS 8(4–18)	▪Behavioural mapping ▪ACs	▪BI	Correlations: N/A	6 Fair quality
Strommen, 2014[71]	Cross-sectional; Assessment at baseline; Denmark	N = 57; 70.2 ± 13.4 years; 49% female	NIHSS 3(1–7) mRS 2 (1–3)	▪Actical Accelerometer® x5 (both wrists, both ankles, right anterior superior iliac spine): activity counts -Duration of monitoring: 7 days	▪BI	Correlations: N/A	6 Fair quality
Stroud, 2009[72]	Cross-sectional; Assessment at baseline; USA	N = 673; – 43.4% female	–	▪Self-reported PA questions	▪BI	Correlations: N/A	7 High quality
Thilarajah, 2020[73]	Cohort; Assessment at baseline & 3 months; Singapore	N = 55; 59(49–67) years; 36% female	NIHSS: 6 (4–10)	▪BMA250 triaxial accelerometer® (ankle): steps/day ▪IPAQ-S7 -Duration of monitoring: 4 days daytime	▪ACS-HDL	BMA250 N/ AIPAQ-S7 N/A ACS-HDL N/A Correlations: BMA250 & ACS: r = 0.40 IPAQ-S7 & ACS: r = 0.43	6 Fair quality
Tieges, 2015[10]	Cohort; Assessment at baseline, 1, 6 & 12months; UK	N = 96; 72.2 [64–80] years; 33.3% female	mRS: 2(1–3)	▪activPAL activity monitor® (unaffected thigh): SB time (bouts of time spent in sitting-lying). -Duration of monitoring: 7 days	▪NEADL	activPAL ≈ NEADL≈ Correlations: N/A	7 High quality
Tse, 2017[74]	Cohort; Assessment at baseline, 3 & 12 months; Australia	N = 185; 67 ± 13 years; 34% female	mRS: 1(1–2)	▪RAPA	▪WSAS ▪SIS 3.0	RAPA N/A WSAS N/ASIS 3.0 N/A Correlations: N/A	6 Fair quality
Wondergem, 2022[75]	Cohort; Assessment at baseline, 6, 12 & 24 months; The Netherlands	N = 200; 67.8 ± 11.2 years; 36% female	NIHSS: No symptoms: 13.0; Minor symptoms: 55.5; Moderate to severe symptoms: 31.5	▪Activ8® (thigh): SB time, LPA, MVPA. ▪SIS-PHYSICAL -Duration of monitoring: 14 days	▪SIS	SIS-PHYSICAL N/ AActiv8 N/A SIS N/A Correlations: N/A	8 High quality
Zirnsak, 2022[76]	Cross-sectional; Assessment at baseline; Germany	N = 481; 69.6 ± 12.5 years; 41.2% female	mRS: 2 ± 3.0 NIHSS: 2.8 ± 3.9	▪IPAQ	▪SIS	Correlations: N/A	9 High quality

General abbreviations: G: Group; N: simple size; N/A: not available; r: correlation coefficient; LPA: light physical activity; mRS: modified Rankin Scale; MVPA: moderate to vigorous physical activities; NIHSS: National Institute of Health Stroke Scale; RCT: randomized controlled trial; SB: sedentary behaviour (sitting or lying position during waking hours); SSS: Scandinavian Stroke Scale. TCMSA-AI: The telephone interview version of the Chedoke-McMaster Stroke Assessment–Activity

Inventory.

Symbols: ≈: non-significant change over time; ↑: significant increase/improvement over time; ↓: significant decrease/deterioration over time.

Physical Activity assessments: ACs: activity categories; ACS-HDL: high-demand leisure activity section of the Activity Card Sort; IADL: Instrumental Activities of Daily Living; IPAQ: International Physical Activity Questionnaire; IPAQ-AF: the Africa francophone version of the International Physical Activity Questionnaire; IPAQ-LF: International Physical Activity Questionnaire Long Form; IPAQ-SF: International Physical Activity Questionnaire Short Form; IPAQ-S7: International Physical Activity Questionnaire-Short 7 Days; PASE: Physical Activity Scale for the Elderly; PASIPD: The physical activity scale for individuals with physical disabilities; PIEL: Participation in Everyday Life; RAPA: The Rapid Assessment of Physical Activity; SGPALS: Saltin Grimby 6-Level Physical Scale; SIS-PHYSICAL: Physical domain of the Stroke Impact Scale.

Participation assessments: EMA: Ecological Momentary Assessment; BI: Barthel Index; FAI: Frenchay Activities Index; IPAQ: Impact on Participation and Autonomy Questionnaire; LIFE-H: The Assessment of Life Habits Questionnaire; MBI: modified Barthel Index; NEADL: The Nottingham Extended Activities of Daily Living Questionnaire; RNLI: Reintegration to Normal Living Index; SIS: Stroke Impact Scale; SIS–P: Stroke Impact Scale participation subscale; USER-P: Utrecht Scale for Evaluation of Rehabilitation-Participation; SAM: Step-watch Activity Monitoring; WSAS: Work and Social Adjustment Scale.

within 6 months post-stroke,[13,58–66,69,72,73,77–79] 14 collected data within the first 3 months of the study,[13,58–64,66,69,72,73,77,78] showing significant increases in PA levels and a trend of change in the level of participation during this short period, where only one study confirmed a significant increase.[72] Only one study[62] showed a significant increase in participation levels. Among the eight studies recording data beyond 3 months of study commencement,[13,58,61–63,65,78,79] a tendency to increase PA levels was also observed, with only one study[65] demonstrating significant increases in participation levels.

From the seven studies conducted in participants (n = 732) greater than 6 months post-stroke,[81,88,92,96,99–101] four studies indicated an increasing trend, of which only two found significant increases both in PA levels and participation levels.[88,100] One showed no significant changes over time,[96] and the rest did not provide data or the results were not significant, even though they showed a tendency of improvement over time.

4. Discussion

This systematic review with meta-analysis is the first to comprehensively collate scientific evidence on PA and participation in stroke survivors. The review encompasses 49 studies comprising 1491 stroke survivors within the first 6 months after a stroke and 3063 stroke survivors recruited at least 6 months after a stroke. The meta-analysis of seven studies revealed positive correlations between PA and participation levels in stroke survivors both within and greater than 6 months post-stroke. The levels of PA appeared to increase in the first weeks or months compared to participation levels, which needed more time to show significative improvements. The results were influenced by various factors, including study design, research objectives, and the psychometric properties of the assessment tools. This review serves as a preliminary exploration, highlighting the necessity for further research with studies specifically designed to investigate the correlation between PA and participation both cross-sectionally and longitudinally.

The studies included in this review primarily utilized the Barthel Index within the first 6 months or the Stroke Impact Scale after 6 months to document significant changes in participation. While there is a discernible trend toward a change in the level of participation, it has been significantly demonstrated in only 2 studies. Further research is needed to thoroughly investigate these changes. Despite the limited number of studies included, this review validates the previously hypothesized assumption that returning to participation in everyday life after a stroke requires more than 6 months, challenging the prior belief that no significant change is possible after this period.[106] Previous studies specifically indicate that it may take up to 4 years to regain pre-stroke participation in daily life activities,[10] and 6 years to return to community participation.[8,107] This suggests that it may be necessary to monitor stroke survivors over a longer period to identify significant improvements in participation, as indicated by previous studies.[8,10,107]

It is noteworthy that among the 25 articles that included individuals who had a stroke more than 6 months ago, only 12 articles[81,82,86,90,93,95–97,99,102–104] included people who had a stroke more than 4 years ago, and only 8 articles[81,82,86,90,99,102–104] included individuals who had a stroke more than 6 years ago. It is evident that there is a need to investigate whether the changes that occur in the reorganization of the nervous system[108] after 6 months are transferred to the return to both participation[109] and active lifestyle, and how this process evolves over time and with aging.[3,110]

This systematic review reveals a high degree of heterogeneity in the tools used to record PA variables through objective devices or self-reported questionnaires and the participation variable through self-reported questionnaires. While most of the studies included in this research adhere to the recommendations of a recent consensus on PA variables and tools,[38] the same cannot be said for the measures of participation. The tools primarily used (do not provide comprehensive information (e.g., level of participation in different daily life activities,[7,111] restriction or dependence in participation or changes in participation due to disease[40,41]). The Barthel Index only covers the level of participation in the performance of activities of daily living, while the Stroke Impact Scale is the most widely used tool to measure participation in stroke survivors[41]; however, it does not uniformly cover the 9 activity and participation domains of the ICF[12] and do not include other aspects of the participation construct such as the meaningful subjective experience of participation or perceived autonomy[4,7] Therefore, the information provided in this review about the correlation between PA and participation (measured with Barthel Index and Stroke Impact Scale) may be incomplete. Further efforts are required to identify a comprehensive outcome measure for participation, given the current lack of consensus.[112]

4.1. Research implications

This systematic review with meta-analysis emphasizes the need to enhance scientific research not only within the initial months following a stroke but also beyond 6 months. In such studies, it is crucial to utilize recommended assessment tools for measuring PA and establish a standardized participation measure that cover the different aspects of the participation domain apart from performance. Additionally, establishing a consensus on the optimal timing of measurements to capture significant changes for each variable is imperative. Furthermore, future scientific publications should include all necessary data and information, including supplementary materials. This will facilitate the analysis of data in subsequent meta-analyses and contribute to the translation of findings into clinical care.

4.2. Clinical implications

This systematic review has demonstrated a progressive increase in participation associated with the increase in PA. This interrelationship underscores the importance of inter-disciplinary collaboration in rehabilitation clinical practice when striving for PA and participation goals, along with the careful selection of validated tools and optimal clinical assessment timepoints to capture changes.

Table 2
Main characteristics of the included articles with **stroke survivors greater than 6 months post-stroke.**

Study	Design & Country	Participants (N, age, sex)	Stroke severity	PA measures	Participation measures	Results: changes over time and correlations	Quality assessment
Aguiar, 2020[97]	RCT; Assessment at baseline, 12 & 16 weeks; Brazil	N = 22; -EG: 52 ± 11 years; 27.2% female -CG: 48 ± 10 years; 27.2% female	–	▪SenseWear Mini® (unaffected arm): PA time. ▪Human Activity Profile -Duration of monitoring: 7 days	▪SIS 3.0	SenseWear Mini ≈ Human Activity Profile ≈ SIS 3.0 N/A Correlations: N/A	8 High quality
Barclay, 2021[77]	Cohort; Assessment at baseline, 6 & 12 months; Canada	N = 13; 61.5 ± 15.5 years; 61.5% female	–	▪ActiGraph GT3X+® (unaffected ankle): steps/day. -Duration of monitoring: waking hours/1week	▪RNL ▪SIS ▪TCMSAAI	ActiGraph GT3X+ ≈ RNL ≈ SIS N/A TCMSA-AI N/A Correlations: N/A	7 High quality
Danielsson, 2011[78]	Cross-sectional; Assessment at baseline; Norway	N = 31; 59.7 ± 8.1 years; 29% female	mRS: 3 ± 1	▪PASE	▪SIS	Correlations: N/A	5 Fair quality
English, 2016[79]	Cross-sectional; Assessment at baseline; Australia	N = 50; 67.2 ± 11.6 years; 34% female	NIHSS n(%) No symptoms: 8 (16%) Mild: 25 (50%) Moderate: 16 (32%) Severe: 1 (2%)	▪activPAL3® (anterior thigh): sitting/lying, standing and stepping- Duration of monitoring: 14 days ▪Actigraph GT3X+® (non-paretic hip): MVPA -Duration of monitoring: 7 days	▪SIS	Correlations: N/A	6 Fair quality
Espernberger, 2022[30]	Cross-sectional; Assessment at baseline; Australia	N = 19; 74 ± 11 years; 52% female	–	▪ActivPAL3® (unaffected thigh): Steps/day, transitions, walking time and SB time. -Duration of monitoring: 7 days	▪BI ▪FAI	Correlations: N/A	4 Fair quality
French, 2016[80]	Cross-sectional; Assessment at baseline; USA	N = 59; 59 ± 11.2 years –	–	▪SAM®(ankle non-paretic lower extremity): steps/day -Duration of monitoring:3 days	▪SIS	Correlations: N/A	7 High quality
Fulk, 2010[81]	Cross-sectional; Assessment at baseline; USA	N = 19; 65.7 ± 11.9 years –	–	▪SAM® (ankle non-paretic lower extremity): steps/day -Duration of monitoring: 1 week	▪SIS	Correlations: PA time & SIS: r = 0.18	7 High quality
Fulk, 2017[82]	Cross-sectional; Assessment at baseline; USA	N = 441; 61.4 ± 12.4 years; 41% female	–	▪SAM® (ankle non-paretic lower extremity): steps/day -Duration of monitoring: between 2 and 7 days	▪SIS–P	Correlations: N/A	8 High quality
Giray, 2022[83]	Cross-sectional; Assessment at baseline; Turkey	N = 25; 55.0 ± 10.8 years; 32% female	–	▪Actical® (nonparetic hip): SB and PA time total activity counts, energy expenditure, and step/day. ▪PASE -Duration of monitoring: 3 weekdays	▪SIS 3.0	Correlations: PASE & SIS: r = 0.49 PA time & SIS: r = 0.50 Sedentary & SIS: r = 0.34	6 Fair quality
Grau-Pellicer, 2019[84]	RCT; Assessment at baseline & 3 months; Spain	-EG: N = 24; 63.0 ± 11.9 years; 45.8% female -CG: N = 17; 68.5 ± 11.5 years; 52.9% female	–	▪APP monitoring + Pedometer UW100, UW101 A&D® (positioning N/A): step/day, activity/sedentary behavior, walking distance and walking speed. -Duration of monitoring: 8 weeks	▪BI	APP & Pedometer ↑ BI ↑ Correlations: N/A	6 High quality
Hoang, 2012[85]	Cross-sectional; Assessment at baseline; France	N = 32; 64.6 ± 11.2 years; 34% female	–	▪Dijon Physical Activity Score	▪BI	Correlations: N/A	6 Fair quality
Honado, 2023[100]	Cross-sectional; Assessment at baseline; Benín	N = 60; 56.7 ± 10.4 years; 26.7% female	–	▪IPAQ-AF	▪BI ▪RNLI	Correlations: N/A	5 Fair quality
Jönsson, 2014[86]	Cross-sectional; Assessment at baseline; Sweden	N = 145; 74.4/78.1 (28–97); 41%female	mRS no symptoms: n = 39(27%) mRS no significant disability or slight: n = 64 (34%) mRS moderate or severe	▪Self-reported PA questions	▪BI	Correlations: N/A	5 Fair quality

(*continued on next page*)

Table 2 (*continued*)

Study	Design & Country	Participants (N, age, sex)	Stroke severity	PA measures	Participation measures	Results: changes over time and correlations	Quality assessment
			disability: n = 27 (19%)				
Joseph, 2017[87]	Cross-sectional; Assessment at baseline; South Africa	N = 45; 58.4 ± 13.7 years; 48.8% female	NIHSS: 4.4 ± 5.0	▪Actigraph GT3X® (unaffected hip): PA time, steps/day, activity count -Duration of monitoring: 5 days during waking hours	▪BI	Correlations: N/A	8 High quality
Kringle, 2020[88]	Cohort; Assessment at baseline, 6, 11 & 18 months; USA	N = 21; 70.8 ± 10.9 years; 61.9% female	–	▪ActivPAL micro3® (unaffected thigh): sitting time. -Duration of monitoring: 7 days	▪SIS–P	ActivPAL N/A SIS–P N/A Correlations: N/A	5 Fair quality
Koffman, 2023[98]	Cross-sectional; Assessment at baseline; USA	N = 70; 61 ± 13 years; 45.7% female	–	▪Fitbit Inspire 2 (unaffected wrist): step/day -Duration of monitoring: 2 weeks	▪SIS-16	Correlations: N/A	8 High quality
Lau, 2022[89]	Cross-sectional; Assessment at baseline; USA	N = 40; 52.8 ± 7.5 years; 42.5% female	–	▪ActivPAL® (anterior unaffected thigh): METs. -Duration of monitoring:7 days ▪IPAQ-LF	▪PIEL Survey App (8 EMA surveys every 2h/7 days, 8am10pm)	Correlations: N/A	8 High quality
Levin, 2023[99]	Cross-sectional; Assessment at baseline; Israel	N = 37; 59.0 [54.0–64.5] years; 37.8% female	–	▪Acticial Minimitter Co. (affected hip): Step/day -Duration of monitoring: 3 days	▪IADL questionnaire	Correlations: Steps/day & IADL: r = −0.18 (independent walkers: n = 12); r = 0.51 (device-users n = 22)	8 High quality
Nuñez Filha, 2020[90]	Cross-sectional; Assessment at baseline; Brazil	N = 53; 55.0 ± 13.4 years; 49%female	–	▪IPAQ	▪MBI	Correlations: N/A	8 High quality
Plow, 2017[91]	Cross-sectional; Assessment at baseline; USA	N = 25; 64.1 [46–89] years; 48% female	–	▪Godin Leisure Time Exercise Questionnaire	▪SIS16	Correlations: PA time & SIS: r = 0.41	4 Fair quality
Rowland, 2022[92]	Cohort; Assessment at baseline & 6 weeks; USA	N = 40; 58 ± 11 years; 35.4% female	–	▪SAM® (positioning N/A): Step/day -Duration of monitoring: N/A	▪SIS	StepWatch Activity Monitor (Average daily step count) = SIS–P = Correlations: N/A	5 Fair quality
Sánchez-Sánchez, 2021[93]	Cross-sectional; Assessment at baseline; Spain	N = 57; 58.2 ± 11.1 years; 35% female	mRS no significant disability or slight: n = 36 (63.2%) mRS moderate or severe disability: n = 21 (36.8%)	▪Actigraph wGT3XBT® (nonparetic hip): SB time, LPA time, MVPA time. -Duration of monitoring: ≥7 days over daytime	▪SIS-16	Correlations: PA time & SIS: r = 0.50	9 High quality
Sheng, 2021[94]	Cross-sectional; Assessment at baseline; China	N = 122; 65.5 ± 10 years; 40.16% female	–	▪SGPALS	▪SIS	Correlations: N/A	5 Fair quality
Sullivan, 2014[95]	Cohort; Assessment at baseline & during 6 weeks; USA	N = 11; 60.4 ± 12.1 years; 45.45% female	–	▪330 Step Pedometer® (unaffected hip): daily steps -Duration of monitoring: 7 days over 6 weeks	▪SIS-16	330 Step Pedometer ≈ SIS-16 ≈ Correlations: Steps increase & SIS: r = 0.74	8 High quality
Swank, 2020[96]	RCT; Assessment at baseline, 1 & 3 months; USA	N = 73; -G1:61.2 ± 16.9 years; 51.4% female -G2:61.3 ± 15.2 years; 41.7% female	NIHSS G1: 6.2 ± 3.5 NIHSS G2: 10.2 ± 6.6	▪Actigraph GTX3® (unaffected waist): SB and PA times. -Duration of monitoring: 3 consecutive days	▪SIS	Actigraph GTX3↑ SIS↑ Correlations: N/A	6 High quality

General abbreviations: G: Group; N: simple size; N/A: not available; r: correlation coefficient; LPA: light physical activity; mRS: modified Rankin Scale; MVPA: moderate to vigorous physical activities; NIHSS: National Institute of Health Stroke Scale; RCT: randomized controlled trial; SB: sedentary behaviour (sitting or lying position during waking hours); SSS: Scandinavian Stroke Scale. TCMSA-AI: The telephone interview version of the Chedoke-McMaster Stroke Assessment–Activity Inventory.

Symbols: ≈: non-significant change over time; ↑: significant increase/improvement over time; ↓: significant decrease/deterioration over time.

Physical Activity assessments: ACs: activity categories; ACS-HDL: high-demand leisure activity section of the Activity Card Sort; IADL: Instrumental Activities of Daily Living; IPAQ: International Physical Activity Questionnaire; IPAQ-AF: the Africa francophone version of the International Physical Activity Questionnaire; IPAQ-LF: International Physical Activity Questionnaire Long Form; IPAQ-SF: International Physical Activity Questionnaire Short Form; IPAQ-S7: International Physical Activity Questionnaire-Short 7 Days; PASE: Physical Activity Scale for the Elderly; PASIPD: The physical activity scale for individuals with physical disabilities; PIEL: Participation in Everyday Life; RAPA: The Rapid Assessment of Physical Activity; SGPALS: Saltin Grimby 6-Level Physical Scale; SIS-PHYSICAL: Physical domain of the

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Participation assessments: EMA: Ecological Momentary Assessment; BI: Barthel Index; FAI: Frenchay Activities Index; IPAQ: Impact on Participation and Autonomy Questionnaire; LIFE-H: The Assessment of Life Habits Questionnaire; MBI: modified Barthel Index; NEADL: The Nottingham Extended Activities of Daily Living Questionnaire; RNLI: Reintegration to Normal Living Index; SIS: Stroke Impact Scale; SIS–P: Stroke Impact Scale participation subscale; USER-P: Utrecht Scale for Evaluation of Rehabilitation-Participation; SAM: Step-watch Activity Monitoring; WSAS: Work and Social Adjustment Scale.

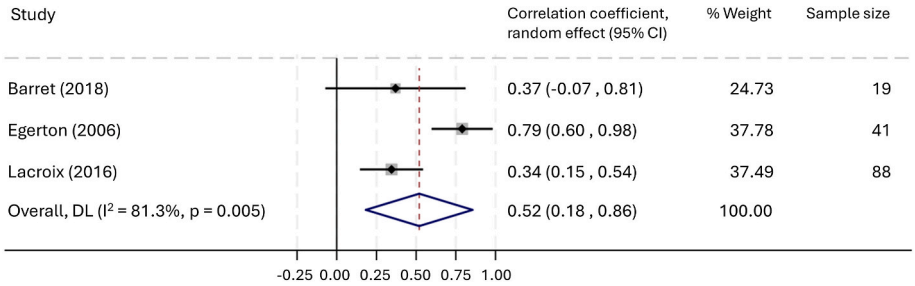

Fig. 2. Pooled correlations between PA (objective devices) and self-reported questionnaires on participation in daily life activities (Barthel Index) in participants within 6 months post-stroke.

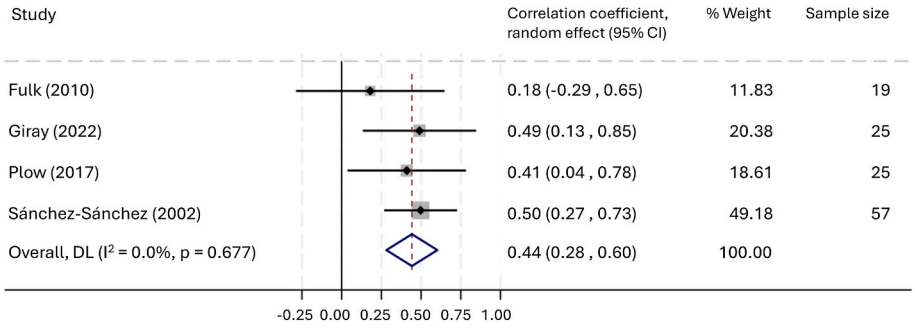

Fig. 3. Pooled correlations between PA (self-reported questionnaires & objective devices) and participation in all areas (Stroke Impact Scale) in participants greater than 6 months post-stroke.

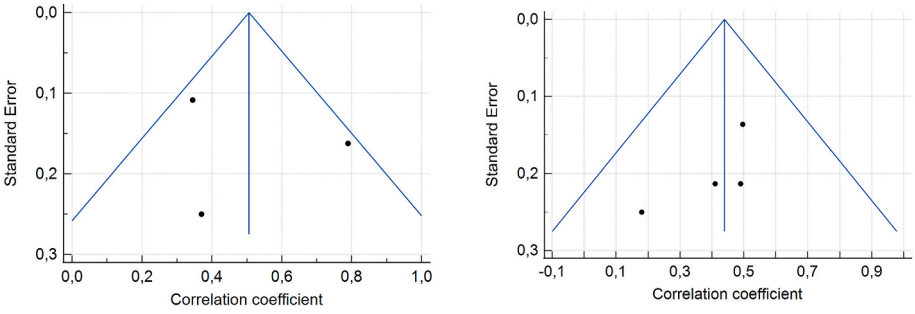

Fig. 4. Funnel plots and Egger's test assessing selection bias in (A) participants within 6 months post-stroke and (B) participants greater than 6 months post-stroke.

4.3. Study limitations

Despite incorporating the available scientific evidence to date, this study could only conduct a meta-analysis with seven studies due to the extensive heterogeneity in variables and assessment across articles, coupled with limited data provided in them. The correlations observed between the variables PA and participation depend directly on the assessment tools used and the impact of the intervention, and it is essential to interpret these findings with caution. Additionally, potential collinearity between variables due to the energy expenditure involved in carrying out any activities of daily living[74] may lead to an overestimation of the correlation[113] and the reader should interpret the results with appropriate caution.

5. Conclusions

This review demonstrated a moderate correlation between PA and participation levels within the first 6 months after stroke, which appears

to persist beyond 6 months. Improvements in PA and participation may require more than 6 months to manifest. Subsequent research is essential to validate these findings and establish a standardized framework for assessment methodology and follow-up times in stroke survivors.

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CRediT authorship contribution statement

Cristina de Diego-Alonso: Writing – review & editing, Writing – original draft, Visualization, Resources, Methodology, Investigation, Data curation, Conceptualization. **Pablo Bellosta-López:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Software, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Julia Blasco-Abadía:** Writing – review & editing, Resources, Methodology, Investigation. **Almudena Buesa-Estéllez:** Writing – review & editing, Resources, Methodology, Formal analysis. **Patricia Roldán-Pérez:** Writing – review & editing, Resources, Methodology, Formal analysis. **Almudena Medina-Rincón:** Writing – review & editing, Resources, Data curation. **María Pilar López-Royo:** Writing – review & editing, Resources, Data curation. **Rafael Giner-Nicolás:** Writing – review & editing, Resources, Investigation, Data curation. **Víctor Doménech-García:** Writing – review & editing, Validation, Resources, Funding acquisition. **Natalie A. Fini:** Writing – review & editing, Validation, Supervision, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.dhjo.2024.101640.

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