Original

Cardiac Rehabilitation for Enhancing Functional Status and Physical Activity in Post-Stroke Patients: A Systematic Review of Strategies and Outcome Measures

Hana A S Abujarad [1,3], Siti Noraini Asmuri [1*], Mazatulfazura SF Salim [1], Thanalactchumy Chandrabose [1], Katijjahbe Md Ali [2], Sami S Elmahgoub [3], Waseem E M Elfantazy [3].

[1] *Department of Rehabilitation Medicine, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia*
[2] *Department of Medical Rehabilitation Services, Hospital Canselor Tuanku Muhriz, Universiti Kebangsaan Malaysia, 56000 Cheras, Kuala Lumpur*
[3] *Department of physiotherapy, Faculty of Medical Technology, University of Tripoli, Libya*

***Corresponding author:**

Dr. Siti Noraini Asmuri, Senior Lecturer, PhD Rehabilitation (Occupational Therapy), Department of Rehabilitation Medicine, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia, Email: ctnoraini@upm.edu.my, Phone:0060177917559 ,ORCID: https://orcid.org/0000-0001-6196-3909

Abstract

Stroke is a major global disability, causing impaired functional status and reduced physical activity. Cardiac rehabilitation (CR) programs have shown effectiveness in improving outcomes, but their application for post-stroke patients remains underexposed. This systematic review aims to identify the components of CR programs, how these components are implemented, progressed, and evaluated, and whether these strategies improve cardiorespiratory fitness, physical and functional recovery in stroke survivors. A comprehensive search was conducted using Web of Science, Scopus, PEDro, and EBSCOhost databases up to May 1st, 2023. Studies were identified using specific search keywords related to CR after stroke. A total of 2615 articles were initially retrieved, with 11 selected for final analysis. CR programs for post-stroke patients focused on reducing risk factors, improving health-related quality of life (HRQOL), aerobic capacity, walking ability, motor recovery, psychological outcomes, mortality, and other health impacts. Various types, durations, and intensities of exercise were utilized in these programs. Outcome measures included functional capacity, cardiovascular fitness, walking ability, psychological outcomes, and quality of life (QOL). Significant improvements were observed in cardiovascular fitness, 6-minute walk distance test (6MWDT), balance, mental health, cognitive function, and physical activity levels in the intervention groups. CR programs have the potential to improve functional status and increase physical activity levels in post-stroke patients. However, the limitations of the included studies underscore the need for standardized measures and more rigorous controlled trials. Future research should focus on developing evidence-based CR programs tailored to post-stroke patients to enhance their QOL and reduce disability.

Keywords: Cardiac Rehabilitation; Post-stroke recovery; Exercise interventions; Functional outcomes; Physical fitness training.

1. Introduction

Stroke survivors face numerous challenges in regaining physical abilities and achieving optimal recovery due to the complex nature of stroke and its impact on specific areas, such as the heart. Physical impairments, including muscle weakness, paralysis, balance issues, and coordination difficulties, can significantly hinder mobility and daily activities [1]. Stroke rehabilitation can be critical in maximizing functional status and promoting physical activity among stroke survivors [2-5]. Rehabilitation interventions have been shown to reduce disability, improve independence, and enhance the overall Quality of Life (QOL) for post-stroke patients [6,7]. Physical fitness training is essential in stroke rehabilitation, as stroke survivors often have low physical activity and fitness levels [8]. Engaging in fitness training after a stroke has been associated with decreased mortality rates, increased independence, and improved functional outcomes such as enhanced mobility, balance, and physical performance. Furthermore, regular exercise has been linked to better cognitive function and psychological well-being among stroke survivors [9]. Another essential aspect of stroke rehabilitation is functional recovery, which aims to improve motor skills, coordination, balance, and overall endurance [2,10].

Stroke survivors encounter various obstacles in regaining physical abilities and achieving optimal recovery due to the intricate nature of stroke and its impact on specific areas, such as the heart. Physical impairments, such as muscle weakness, paralysis, balance issues, and coordination difficulties, can significantly impede mobility and daily activities. Stroke rehabilitation plays a crucial role in maximizing functional status and encouraging physical activity among stroke survivors [1]. Research has demonstrated that rehabilitation interventions can reduce disability, enhance independence, and improve the overall QOL for individuals post-stroke. Physical fitness training is a key component of stroke rehabilitation, as stroke survivors often have low levels of physical activity and fitness. Engaging in fitness training post-stroke has been linked to reduced mortality rates, increased independence, and improved functional outcomes, including enhanced mobility, balance, and physical performance. Additionally, regular exercise has been associated with better cognitive function and psychological well-being among stroke survivors. Functional recovery is another vital aspect of stroke rehabilitation, focusing on improving motor skills, coordination, balance, and overall endurance.

The literature has shown that integrating stroke survivors into exercise-based CR programs can be highly beneficial. A study by Regan et al. [11] demonstrated that the frequency and intensity of exercise-based CR program can potentially improve cardiovascular endurance and health status in stroke survivors, with some improvements persisting even after six months. It was also highlighted that stroke patients often had reduced aerobic capacity, and structured exercise programs, such as CR, are needed to address this issue and enhance their physical fitness [12]. Furthermore, early CR programs have shown promise in stroke patients with cardiac disease. These programs involve inpatient and home-based interventions, including symptom-limited exercise tolerance tests and structured exercise programs. In one case report,a stroke patient with cardiac disease underwent early inpatient CR and subsequently participated in a home-based CR program, increasing exercise capacity [12]. Studies have also emphasised the positive impact of CR on cognition, mental health, and QOL in stroke survivors [13].

CR interventions rely on reliable tests and measures to evaluate their effectiveness. The American College of Cardiology (ACC) and the American Heart Association (AHA) have developed comprehensive performance measures to assess various aspects of CR programs [14]. These measures cover referrals from inpatient and outpatient settings, exercise training referrals, and other essential components. Different measures are employed to gauge physical activity levels during and after CR. For instance, the 6MWDT measures the distance a patient can walk in six minutes, providing insights into their physical capabilities [8,15,16]. Also, wearable activity trackers and self-report questionnaires like the Physical Activity Scale for the Elderly (PASE) are utilised to assess physical activity levels [16]. Functional capacity tests, such as cardiopulmonary exercise testing (CPET), are also employed to examine the physiological response to exercise [15,17]. These tests offer valuable information about exercise capacity, oxygen consumption, and cardiovascular function.

CR programs have demonstrated their ability to enhance functional status and increase physical activity levels among patients who have experienced a cardiac event. However, the effectiveness of these programs for patients who have suffered a stroke remains relatively unexplored. Given that stroke is a leading cause of disability, rehabilitation plays a pivotal role in the recovery process. Hence, gaining insights into the strategies and outcome measures employed in CR programs explicitly tailored for post-stroke patients is crucial. This review was developed based on the question “What are the components of CR programs, how these components are implemented, progressed, and evaluated, and do these strategies improve cardiorespiratory fitness, physical and functional recovery in stroke survivors?". This systematic review aims to identify the components of CR programs, how these components are implemented, progressed, and evaluated, and whether these strategies improve cardiorespiratory fitness, physical and functional recovery in stroke survivors. The findings of this review could inform the development of evidence-based rehabilitation programs tailored to this particular patient population, ultimately enhancing their QOL and decreasing disability.

2. Materials and Methods

This review was drafted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist [18].

2.1 Systematic Data Resource

The digital records of published articles were gathered from the databases Web of Science, Scopus, PEDro, and EBSCOhost (including MEDLINE Complete, Academic Search Complete, CINAHL Plus with full text, and Sport Discuss with full text). This review specifically examined articles published between 2000 and 2023, with a focus on English articles only. The search was restricted to articles published up to May 1st, 2023. The primary keywords used were "stroke survivors," "cardiac rehabilitation," "functional status," "physical activity," and "outcome measures," with the Boolean operator "AND/OR" utilized for further search refinement.

2.2 Eligibility and Exclusion Criteria

The eligibility criteria were established according to PICO strategy including patients, intervention, comparison, and outcome, as follows:

Patients (P): Patients with a stroke (except where a person without disabilities acts as a person with disabilities). Interventions (I): CR for stroke survivors. Comparisons (C): No rehabilitation or other intervention. Outcomes (O): The results after intervention regarding Functional Status and Physical Activity.

Meanwhile, the exclusion criteria included reviews, letters, and meta-analysis. Further, the articles that did not target stroke survivors were removed. In addition, publications where CR program, results, case report, or full text were unavailable were not included for review.

2.3 Screening, Selection, and Extraction Process

The reviewers conducted a comprehensive screening to identify relevant studies. Initially, they independently screened the titles and abstracts of all the records. The literature search, extraction and cross-checking were carried out independently with (Rayyan Systematic Review Software) by two reviewers, and any disagreements were discussed or negotiated with a third party. Subsequently, the reviewers proceeded to review the full text of the selected records to determine their eligibility for inclusion in the systematic review following the following inclusion criteria: (1) Studies that include post-stroke patients who are undergoing CR programs for secondary prevention and post-stroke recovery, (2) Studies with a sample size of at least 10 participants per group, and (3) Studies that include adult stroke patients (18 years and older). Studies falling under the following criteria were excluded: (1) Studies that include pediatric populations or adult populations with other neurological conditions, and (2) Studies that include patients who have not completed a rehabilitation program following a stroke. In cases where there were disagreements or uncertainties regarding the eligibility of a particular study, the reviewers engaged in discussions to reach a consensus. If consensus could not be reached, a third independent reviewer was brought in to offer input and assist in resolving any discrepancies. The extracted data included details such as author, year, country/region, study design, study population, type of exercise, and main findings.

2.4 Risk of bias (quality)assessment

The tools were used for both risk of bias assessment and quality assessment in this review. the Revised Cochrane risk-of-bias tool for randomized trials (RoB 2) tool for evaluated randomized control trials, the Newcastle-Ottawa Quality Assessment Form for assessed cohort studies, and the Mixed Methods Appraisal Tool (MMAT) for appraised mixed studies reviews. These three different tools:1) Revised Cochrane risk-of-bias tool for randomized trials (RoB 2) evaluated several key domains, such as random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective outcome reporting, and other sources of bias.2) Newcastle-Ottawa Quality Assessment Form for Cohort Studies assessed three main areas: selection of study groups, comparability of groups, and ascertainment of the exposure or outcome of interest. The tool assigns stars or points to different criteria within each area to determine the overall quality of the study.3) Mixed Methods Appraisal Tool (MMAT), version 2018 helped evaluate the quality of both qualitative and quantitative studies included in mixed methods reviews. The tool assessed various aspects, including the study design, data collection methods, data analysis, and integration of qualitative and quantitative data. This approach allows for a thorough evaluation of the strengths and limitations of the included studies, enhancing the reliability and validity of the overall findings.

2.5 Meta-Analysis

The results from some included studies were combined for physical and functional outcomes to give an overall estimate of CR wherever appropriate. A fixed-effect model meta-analysis was performed using SPSS software [19] to evaluate the statistical heterogeneity (I^2) and the mean difference following CR among rehabilitated participants compared to nonparticipants.

3. Results

3.1 Study Selection

Initially, the search resulted in 2615 identified articles selected for screening. A number of 5 articles were added after performing a cross-referencing and manual search. After titles and abstracts screening, 337 articles were excluded for being identified as a wrong population from PEDro, and another 2269 were excluded due to not meeting the inclusion criteria. The remaining 14 articles were full text, leaving 11 articles to be included in this systematic review. The PRISMA flow diagram of the search results with reasons for article exclusion are presented in (Fig. 1).

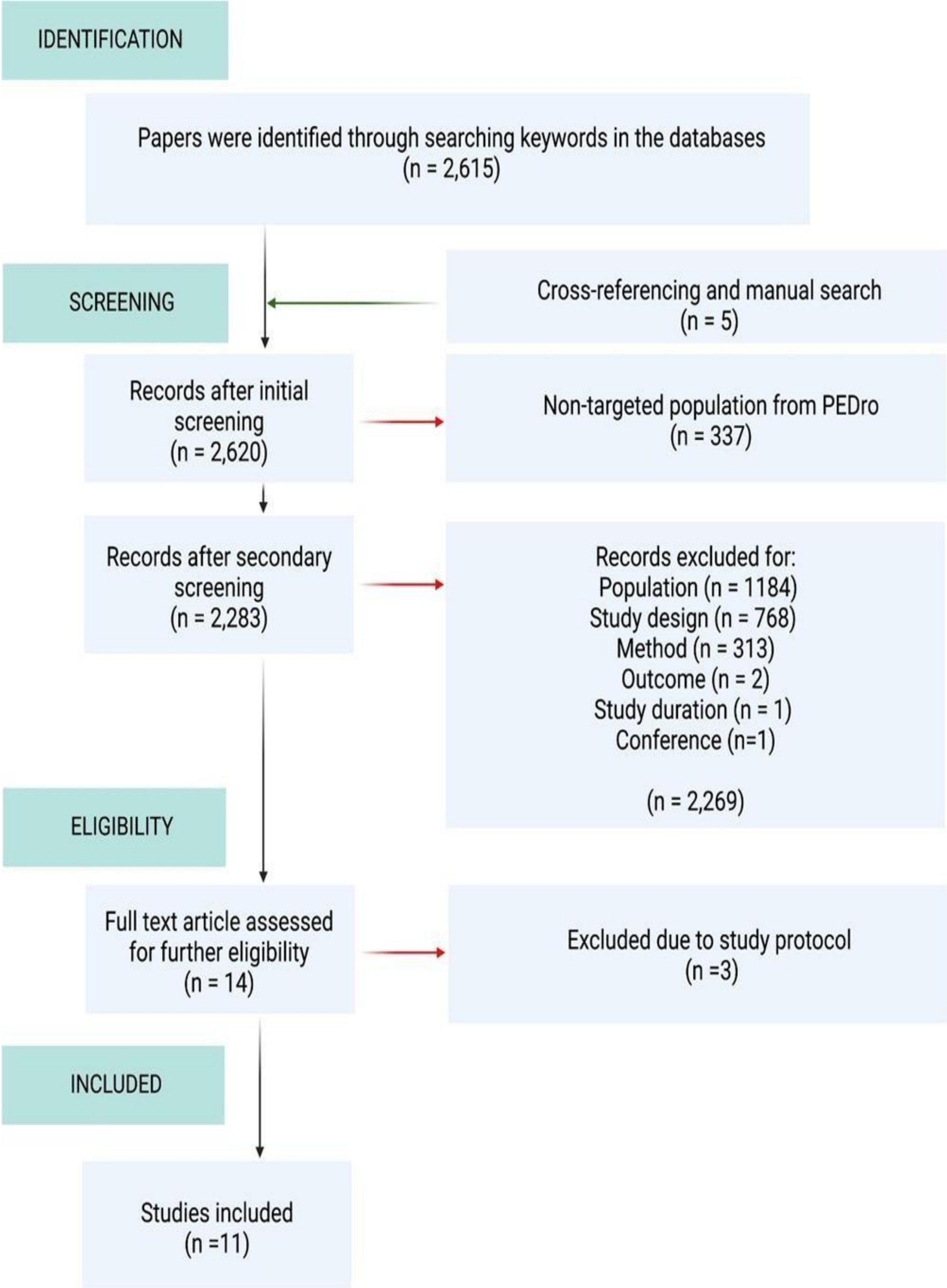

Fig. 1. PRISMA flow diagram of the systematic review

3.2 Risk of bias (quality)assessment

This review employed three distinct assessment tools to comprehensively evaluate the risk of bias and quality of the included studies. The Revised Cochrane risk-of-bias tool for randomized trials (RoB 2) was utilized to appraise the risk of bias in two randomized controlled trials (RCTs) [20,23]. The results indicated that both RCTs exhibited a low risk of bias, suggesting methodological robustness in terms of their design, implementation, and reporting (Fig. 2). This implies a reduced likelihood of systematic errors or biases that could undermine the validity and reliability of the findings. For the evaluation of cohort studies, the Newcastle- Ottawa Quality Assessment Form was employed. Among the seven cohort studies assessed, one study was classified as good quality, indicating a high level of methodological rigor and minimal risk of bias [22]. One study was deemed fair quality, implying the presence of certain limitations in the reporting [21]. However, the majority of the cohort studies (five out of seven) were appraised as poor quality, highlighting significant methodological flaws or limitations that could compromise the dependability and validity of their outcomes [24-28].

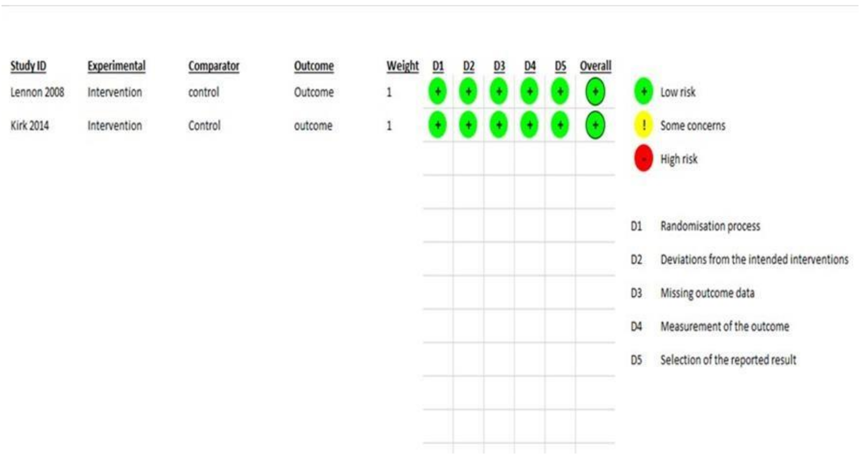

Fig.2. Risk of bias graph: review authors for each risk of bias item presented as percentages across RCTs studies.

In addition, the Mixed Methods Appraisal Tool (MMAT) was utilized to assess the quality of two mixed methods studies [11,29]. The findings revealed that both studies demonstrated a high level of quality, indicating robust methodological approaches in integrating qualitative and quantitative components. This ensured a rigorous and comprehensive exploration of the research questions under investigation. The utilization of these assessment tools facilitated a thorough evaluation of the risk of bias and quality of the included studies within the systematic review. The results demonstrated a low risk of bias in the randomized controlled trials, indicating methodological robustness and minimizing potential systematic errors or biases. Conversely, the cohort studies exhibited varying levels of quality, with a minority categorized as good or fair quality, and a majority classified as poor quality due to significant methodological flaws. On the other hand, the mixed methods studies were appraised as possessing a high level of quality, emphasizing their reliability and valuable contribution to the systematic review's findings.

3.3 Study Characteristics

This review comprises a compilation of 11 studies related to CR in stroke survivors, involving a collective participant count of 1,823 individuals (Table 1). In this compilation, four studies were conducted in the United Kingdom [23,25, 28,29], three in Canada [21,22,24], two in the United States [26,27], and one each in Cambodia [11] and Ireland [20]. The majority of studies included in this systematic review were cohort studies [21,22,24,28], with two studies being randomized controlled trials (RCTs) [20,23], and an additional two studies using a mixed methods approach [11,29]. The studies varied in quality, with the RCTs demonstrating high quality, robust methodology, and minimal bias. In contrast, the cohort studies showed differing levels of quality, with one considered good, another fair, and the majority poor. This diversity highlights methodological differences among the cohort studies. However, the two mixed methods studies consistently exhibited high quality, indicating a strong and consistent approach in integrating qualitative and quantitative components. This lack of heterogeneity suggests methodological consistency in the design and implementation of the mixed methods studies.

3.4 Description of included studies

All included studies aim to evaluate the impact, feasibility, effectiveness, or benefits of a CR program for stroke patients [11,20,27] (Table 2 & Table 3). The objectives include assessing risk factor reduction, HRQOL, aerobic capacity, walking capacity, stroke risk factors, motor recovery, physiological outcomes, psychological outcomes, mortality, functional outcomes, physical function, and other health impacts [11,20–28]. Most studies performed controlled trials, repeated measures design, or cohort trials to assess the effects of the CR programs [20,22,28], including control or comparison groups or a single group. The exercise types employed in the included studies include aerobic training (AT), resistance training (RT), walking, stretching, and relaxation exercises [11,20–29]. Some studies also incorporate psychosocial and dietary counselling [24,25]. The duration of the CR programs varies, ranging from 6 weeks to 24 weeks. The frequency of sessions ranges from 2 to 5 times per week [21–24,27,29]. The exercise intensity is measured using parameters such as heart rate (HR), rating of perceived exertion (RPE) [11,20,21,26,27], or metabolic equivalents (METs) [26–28]. The intensity levels aimed to achieve a moderate level of exertion. Various outcome measures are used across the studies, including assessments of risk factors (blood pressure (BP), cholesterol), functional capacity, cardiovascular fitness (VO2peak, 6MWDT), walking ability, motor recovery, psychological outcomes, QOL, balance, depression, cognition, adherence indicators, and subjective health status.

Significant improvements in cardiovascular fitness measures, specifically VO2, in the intervention groups were observed compared to controls ($p < 0.05$) [20,25]. No significant changes were observed in the cardiovascular-metabolic risk factors such as total cholesterol, LDL, HDL, triglycerides, systolic BP, and diastolic BP ($p > 0.05$) [21,22]. Similarly, no significant differences were found in the Frenchay Activity Index or Health Anxiety and Depression Scale (HADS) change scores between groups ($p > 0.05$) [20,21]. Some trials observed significant improvements in the 6MWDT after the CR program ($p < 0.01$) [22,26] and ($p < 0.001$) [11].

The impact of CR on secondary outcomes was also investigated. CR was reported to improve balance significantly, affected-side range of motion, grip strength, and participation [22,26]. Moreover, Kirk et al. [23] and Prior et al. [28] reported significant improvements ($p < 0.001$) in activity levels and physical functioning domains of the SF-36 questionnaire in the intervention groups. Furthermore, advances in mental health status and cognitive function measures were also observed [25,27]. Similarly, Cuccurullo et al. [27] and Clague- Baker et al. [29] demonstrated positive changes in outcome measures such as exercise capacity, fatigue, anxiety, depression, and physical activity levels ($p < 0.01$).

3.4 Meta-Analysis

Seven studies were eligible for meta-analysis of CR outcome post-stroke; 4 studies performed the 6MWDT per meter for 147 participants to measure the cardiac physical activity [11,21,22,24]. Three studies performed VO2peak (mL.kg-1.min-1) for 69 participants to measure cardiac functional activity [20,21,24]. An overall significant enhancement of cardiac activity was scored for participants undergoing CR program (MD=0.30, 95% CI: 0.07 to 0.53, $p<0.01$ for 6MWDT and MD=0.31, 95% CI: 0.02 to 0.59, $p<0.04$) in comparison with nonparticipant control (Fig. 3 & Fig. 4). The heterogeneity index was low (I2 = 0%), reflecting a standardised measure of cardiac recovery post-rehabilitation. The funnel plots for both meta-analyses showed no evidence of publication bias (Fig. 5).

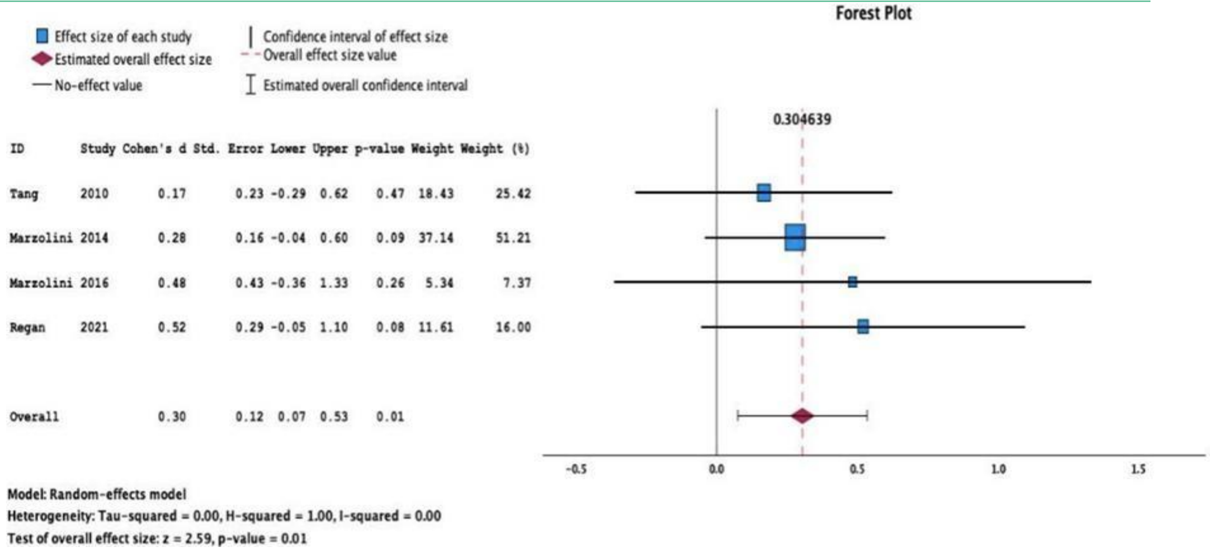

Fig. 3. Forest plot of mean difference of post-stroke physical cardiac function recovery of 4 studies following CR among rehabilitated participants compared to nonparticipants. The diamond represents the overall MD. CR effectively promoted physical cardiac function (MD = 0.30, 95% CI: 0.07 to 0.53 m, $p < 0.01$).

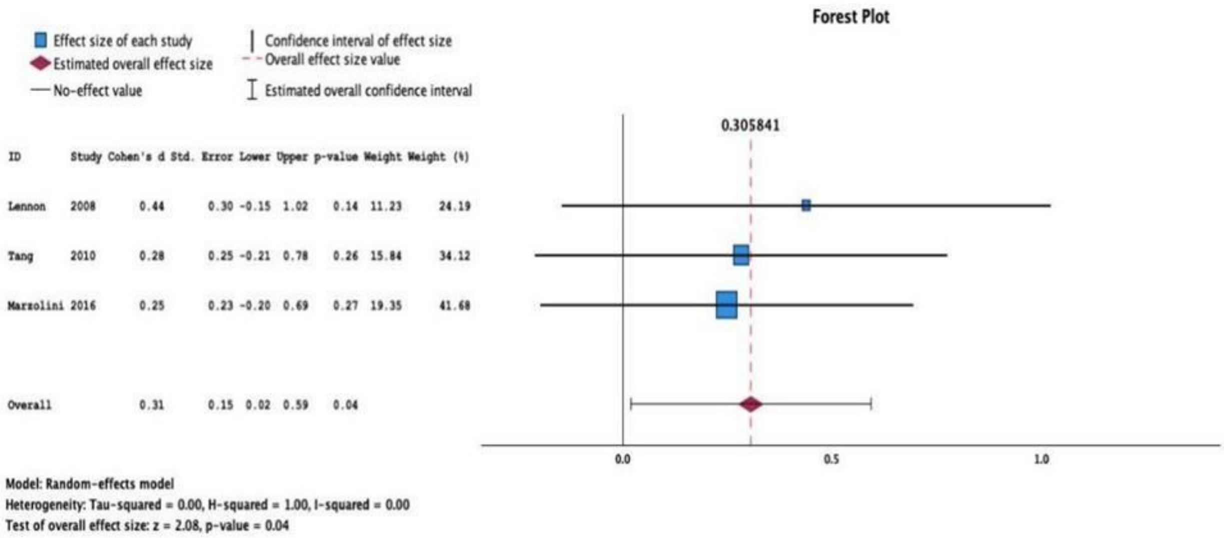

Fig. 4. Forest plot of mean difference of post-stroke cardiac functional recovery of 3 studies following CR among rehabilitated participants compared to nonparticipants. The diamond represents the overall MD. CR effectively promoted cardiac functional recovery (MD = 0.31, 95% CI: 0.02 to 0.59 mL.kg-1.min-1, $p < 0.04$).

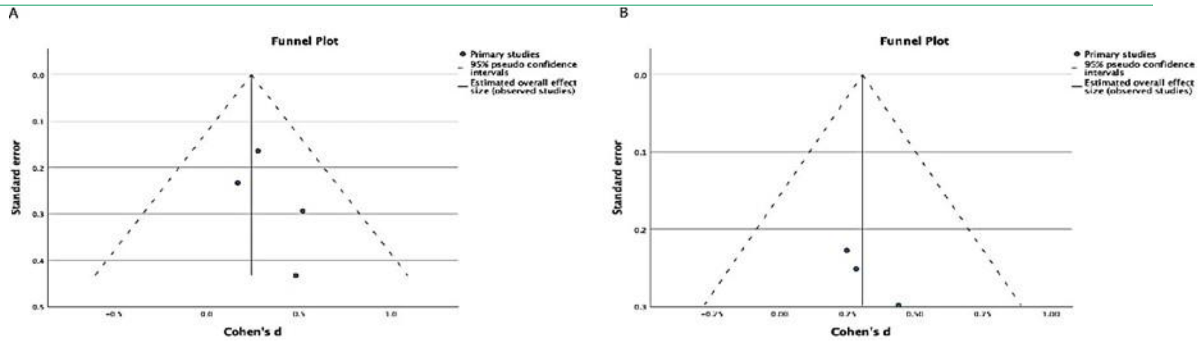

Fig. 5. Funnel plot for the assessment of publication bias. A) Funnel plot of the studies included for physical cardiac function in the meta-analysis. B) Funnel plot of the studies included in cardiac functional recovery in the meta-analysis. The funnel plots for the seven meta-analyses performed showed no evidence of publication bias.

4. Discussion

This systematic review aimed to summarize the current research on the components of cardiac rehabilitation (CR) programs, strategies, and outcome measures utilized in CR programs for individuals who have had a stroke, with a focus on improving functional status and physical activity. The review included 11 relevant studies that examined the impact, feasibility, and effectiveness of CR programs for stroke survivors. Various assessments were used to measure functional and physical activity outcomes, such as aerobic capacity, cardiovascular fitness, functional scores, walking capacity, mobility, and physical functioning. However, the lack of consistency in outcome measures among the studies hinders direct comparisons and definitive conclusions. Future studies should establish standardized outcome measures in stroke rehabilitation to facilitate better comparisons and meta-analyses.

Younger participants show more significant improvements in functional and physical activity than older participants, indicating that age plays a role in CR intervention effectiveness, potentially due to physiological resilience and response to rehabilitation [30,31]. The time since stroke onset also influenced outcomes, and earlier rehabilitation induced better improvements [22]. Early intervention following a stroke may positively impact recovery and rehabilitation outcomes [32,33]. Baseline functional status can influence CR outcomes as well [34]. Participants with lower initial functional status showed greater improvements. This suggests that individuals with more severe impairments at the start of rehabilitation have more room for improvement and exhibit larger gains.

Including exercise interventions is essential in CR programs for improving physical function, psychological recovery, dietary and lifestyle behaviors, mobility parameters, and health-related quality of life (HRQOL) among stroke survivors [30,31]. Aerobic exercise, resistance training (RT), and combined aerobic and resistance exercise are commonly utilized in CR programs [22]. Aerobic exercise enhances cardiovascular fitness and functional capacity, leading to improved functional status post-stroke, while RT focuses on muscle strength and endurance, benefiting muscle function and physical performance, ultimately contributing to better physical activity post-stroke. Combined aerobic and resistance exercises have favorable effects on aerobic capacity, muscle strength, and functional ability [32,33]. Higher levels of exercise frequency and intensity result in greater improvements in functional and physical activity outcomes. However, individualizing or personalizing exercise prescriptions is crucial to tailor them to patients' abilities and preferences [39,40]. Therefore, a comprehensive exercise program that includes a mix of aerobic and resistance exercises with appropriate frequency and intensity can maximize the benefits for individuals [34]. Finally, significant improvements in cardiovascular fitness measures, specifically, can be achieved through a well-rounded exercise program.

Exercise interventions are crucial in cardiac rehabilitation for stroke survivors, as they improve physical function, psychological recovery, dietary and lifestyle behaviors, mobility parameters, and HRQOL. Commonly used in cardiac rehabilitation programs are aerobic exercise, resistance training, and a combination of both. Aerobic exercise enhances cardiovascular fitness and functional capacity, leading to improved functional status post-stroke [35,36]. Resistance training targets muscle strength and endurance, improving muscle function and physical performance, ultimately enhancing physical activity post-stroke. Combined aerobic and resistance exercises have positive effects on aerobic capacity, muscle strength, and functional ability. Higher frequency and intensity of exercise result in greater improvements in functional and physical activity outcomes [37, 38]. It is essential to personalize exercise prescriptions to accommodate individual abilities and preferences. A well-rounded exercise program that includes a mix of aerobic and resistance exercises with appropriate frequency and intensity can maximize benefits for stroke survivors [39,40]. As a result, significant improvements in cardiovascular fitness measures are observed with such exercise programs.

The intervention groups showed significant improvements in VO2 compared to controls. Similarly, the CR program led to significant enhancements in the 6MWDT, indicating improved physical performance and mobility. The Meta-analysis also demonstrated positive trends in physical function (6MWDT) and functional status (VO2) outcomes. Along with improvements in cardiovascular fitness, CR programs had positive effects on secondary outcomes like psychological recovery and HR QOL [9,41].

These findings enhance our understanding of the effectiveness of CR programs for post-stroke patients in improving functional status and physical activity. They support previous research showing the benefits of CR on cardiovascular fitness, physical performance, mobility, balance, mental health, and cognitive function in stroke survivors. However, it is important to acknowledge the limitations of the included studies, such as small sample sizes, lack of control groups, and language restrictions to English publications. These limitations, along with potential biases and variations in study design and outcome measurements, should be considered when interpreting the results. The focus on specific subsets of stroke survivors with moderate to severe deficits may also limit the generalizability of the findings.

Further research is needed to determine the optimal characteristics of CR programs and assess their long-term benefits for post-stroke patients. Future studies should address these limitations by conducting more extensive randomized controlled trials with diverse stroke populations, incorporating appropriate control groups and consistent outcome measures. Long-term follow-up assessments would also provide valuable insights into the sustainability of improvements and their impact on long-term functional status and quality of life.

5. Conclusion

This systematic review emphasizes the potential of cardiac rehabilitation (CR) programs to significantly improve the functional status and physical activity levels of post-stroke patients. The evidence indicates that CR programs, especially those incorporating a mix of aerobic exercise, resistance training, and combined modalities, can result in substantial enhancements in cardiovascular fitness, physical performance, mobility, balance, mental health, and cognitive function. These findings underscore the importance of integrating CR as a crucial element of comprehensive rehabilitation strategies for stroke survivors.

While the results are promising, the review also points out the necessity for further research to refine CR program characteristics and evaluate their long-term advantages. Overcoming the limitations of current studies, such as small sample sizes, absence of control groups, and variability in outcome measures, will be essential. Future research should also explore the applicability of CR benefits across diverse stroke populations, with extended follow-ups to assess the sustainability of improvements in functional status and quality of life. In this systematic review results showed CR programs offer a transformative intervention that can enhance the rehabilitation journey for stroke survivors, providing them with a pathway to better health and well-being.

Declaration of Competing Interest

The authors declare that they have no known competing financial

Credit authorship contribution statement

Hana A S Abujarad: Writing – original draft, Validation, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Siti Noraini Asmuri**: Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Conceptualization**. Mazatulfazura SF Salim**: Writing – review & editing, Methodology, Investigation, Conceptualization. **Katijjahbe Md Ali**: Writing – review & editing. **Thanalactchumy Chandrabose**: Writing – review & editing. **Sami S Elmahgoub**: Writing – review & editing. **Waseem E M Elfantazy**; Investigation.

References

[1] C. Grefkes, G. R. Fink, Recovery from stroke: current concepts and future perspectives. Neurol. Res. Prac. 2 (2020) 17. https://doi.org/10.1186/s42466-020-00060-6

[2] R. S. Taylor, H. M. Dalal, S. T. J. McDonagh, The role of cardiac rehabilitation in improving cardiovascular outcomes, Nat. Rev. Cardiol. 19 (2022) 180–94. https://doi.org/10.1038/s41569-021-00611-7

[3] Han, Peipei, Zhang. Wen, Kang. Li, Ma. Yixuan, Fu. Liyuan, Jia. Liye, et al. "Clinical Evidence of Exercise Benefits for Stroke." Advances in experimental medicine and biology vol. 1000 (2017): 131-151. https://doi.org/10.1007/978-981-10-4304-8_9

[4] G. O. Dibben et al., Exercise-based cardiac rehabilitation for coronary heart disease: a meta-analysis, Eur. Heart J. 44 (2023) 452–69. https://doi.org/10.1093/eurheartj/ehac747

[5] S. A. Billinger, R. Arena , J. Bernhardt, JJ. Eng, BA. Franklin, CM. Johnson, et al., Physical activity and exercise recommendations for stroke survivors: A statement for healthcare professionals from the American Heart Association/American Stroke Association, Stroke, 45 (2014) 2532–2553. https://doi.org/10.1161/STR.0000000000000022

[6] P. Langhorne, J. Bernhardt, G. Kwakkel, Stroke rehabilitation, Lancet. 377 (2011) 1693–702. https://doi.org/10.1016/S0140-6736(11)60325-5

[7] C. Graven, K. Brock, K. Hill, L. Joubert, Are rehabilitation and/or care co-ordination interventions delivered in the community effective in reducing depression, facilitating participation and

improving quality of life after stroke? Disabil. Rehabil. 33 (2011) 1501–20. https://doi.org/10.3109/09638288.2010.542874

[8] D. H. Saunders, M. Sanderson, S. Hayes, L. Johnson, S. Kramer, DD. Carter, et al., Physical fitness training for stroke patients, Cochrane Database Syst. Rev. 2020 (2020) 1–3. https://doi.org/10.1002/14651858.CD003316.pub7

[9] D. H. Saunders, C. A. Greig, G. E. Mead, Physical activity and exercise after stroke: Review of multiple meaningful benefits, Stroke. 45 (2014) 3742–7. https://doi.org/10.1161/STROKEAHA.114.004311

[10] C. M. Stinear, C. E. Lang, S. Zeiler, W. D. Byblow, Advances and challenges in stroke rehabilitation, Lancet. Neurol. 19 (2020) 348–60. https://doi.org/10.1016/S1474-4422(19)30415-6

[11] E. W. Regan, R. Handlery, J. C. Stewart, J. L. Pearson, S. Wilcox, S. Fritz, integrating survivors of stroke into exercise-based cardiac rehabilitation improves endurance and functional strength, J. Am. Heart. Assoc. 10 (2021) 1–12. https://doi.org/10.1161/JAHA.120.017907

[12] S. Marzolini, Including Patients with Stroke in Cardiac Rehabilitation: Barriers and Facilitators, J. Cardiopulm. Rehabil. Prev. 40 (2020) 294–301. https://doi.org/10.1097/HCR.0000000000000540

[13] S.C. Lee, E. J. Ko, J. Y. Lee, A. L. Hong. Safety and effectiveness of early cardiac rehabilitation in a stroke patient with heart failure and atrial fibrillation: a case report, Yeungnam Univ. J. Med. 38 (2021) 361–365. https://doi.org/10.12701/yujm.2020.00885

[14] R. J. Thomas, G Balady., G. Banka, TM. Beckie, J. Chiu, S. Gokak, et al., 2018 ACC/AHA clinical performance and quality measures for cardiac rehabilitation: A report of the American College of Cardiology/American Heart Association Task Force on Performance Measures, Circ. Cardiovasc Qual. Outcomes. 11 (2018) 1–29. https://doi.org/10.1161/HCQ.0000000000000037

[15] G. R. Reeves, S. Gupta, D. E. Forman, Evolving role of exercise testing in contemporary cardiac rehabilitation, J. Cardiopulm. Rehabil. Prev. 36 (2016) 309–19. https://doi.org/10.1097/HCR.0000000000000176

[16] M. Alharbi, A. Bauman, M. Alabdulaali, L. Neubeck, S. Smith, S. Naismith, et al., Comparison of Different physical activity measures in a cardiac rehabilitation program: A prospective study, Sensors. 22 (2022) 1–11. https://doi.org/10.3390/s22041639

[17] S. Nichols, DO. Gleadall-Siddall, R. Antony, AL. Clark, JGF. Cleland, S. Carroll, et al., Estimated peak functional capacity: an accurate method for assessing change in peak oxygen consumption after cardiac rehabilitation? Clin. Physiol. Funct. Imaging. 38 (2018) 681–8. https://doi.org/10.1111/cpf.12468

[18] A. Liberati, DG. Altman, J. Tetzlaff, C. Mulrow, PC. Gøtzsche, JPA. Ioannidis et al., The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration, J. Clin. Epidemiol. 62 (2009) e1–34. http://dx.doi.org/10.1016/j.jclinepi.2009.06.006

[19] S. Sen, I. Yildirim, A Tutorial on How to Conduct Meta-Analysis with IBM SPSS Statistics. Psych. 4 (2022) 640–667. https://doi.org/10.3390/psych4040049

[20] Lennon, Olive O. Lennon, A. Carey, N. Gaffney, J. Stephenson, C.Blake. "A pilot randomized controlled trial to evaluate the benefit of the cardiac rehabilitation paradigm for the non-acute ischaemic stroke population." *Clinical rehabilitation* vol. 22,2 (2008): 125-33. https://doi.org/10.1177/0269215507081580

[21] A. Tang, S. Marzolini, P. Oh, W. E. McIlroy, D. Brooks, Feasibility and effects of adapted cardiac rehabilitation after stroke: A prospective trial, BMC Neurol. 10 (2010) 40. https://doi.org/10.1186/1471-2377-10-40

[22] S. Marzolini, A. Tang, W. McIlroy, P. I. Oh, D. Brooks, Outcomes in people after stroke attending an adapted cardiac rehabilitation exercise program: Does time from stroke make a difference? J. Stroke Cerebrovasc. Dis. 23 (2014) 1648–56. https://doi.org/10.1016/j.jstrokecerebrovasdis.2014.01.008

[23] H. Kirk, P. Kersten, P. Crawford, A. Keens, A. Ashburn, J. Conway, The cardiac model of rehabilitation for reducing cardiovascular risk factors post transient ischaemic attack and stroke: A randomized controlled trial, Clin. Rehabil. 28 (2014) 339–49. https://doi.org/10.1177/0269215513502211

[24] S. Marzolini, C. Danells, P. I. Oh, D. Jagroop, D. Brooks, Feasibility and Effects of Cardiac Rehabilitation for Individuals after Transient Ischemic Attack, J. Stroke. Cerebrovasc. Dis. 25 (2016)2453–63. https://doi.org/10.1016/j.jstrokecerebrovasdis.2016.06.018

[25] P. L. Prior, V. Hachinski, R. Chan, K. Unsworth, S. Mytka, M. Harnadek, et al. Comprehensive Cardiac Rehabilitation for Secondary Prevention after Transient Ischemic Attack or Mild Stroke, J. Cardiopulm. Rehabil. Prev. 37 (2017)428–36. https://doi.org/10.1161/STROKEAHA.111.620187

[26] S. J. Cuccurullo, TK. Fleming, WJ. Kostis, C. Greiss, MS. Gizzi, A. Eckert, et al., Impact of a Stroke Recovery Program Integrating Modified Cardiac Rehabilitation on All-Cause Mortality, Cardiovascular Performance and Functional Performance, Am. J. Phys. Med. Rehabil. 98 (2019) 953–63. https://doi.org/10.1097/PHM.0000000000001214

[27] S. J. Cuccurullo, TK. Fleming, S. Zinonos, NM. Cosgrove, J. Cabrera, JB. Kostis, et al., Stroke Recovery Program with Modified Cardiac Rehabilitation Improves Mortality, Functional & Cardiovascular Performance, J. Stroke. Cerebrovasc. Dis. 31 (2022) 106322. https://doi.org/10.1016/j.jstrokecerebrovasdis.2022.106322

[28] P. L. Prior, V. Hachinski, K. Unsworth, R. Chan, S. Mytka, C. O'Callaghan, et al., Comprehensive cardiac rehabilitation for secondary prevention after transient ischemic attack or mild stroke: I: Feasibility and risk factors, Stroke. 42 (2011) 3207–13. https://doi.org/10.1161/STROKEAHA.111.620187

[29] N. Clague-Baker, T. Robinson, C. L. Gillies, S. Drewry, A. Hagenberg, S. Singh, Adapted cardiac rehabilitation for people with sub-acute, mild-to-moderate stroke: a mixed methods feasibility study, Physiother. 115 (2022) 93–101. https://doi.org/10.1016/j.physio.2021.11.002

[30] G. Sandercock, V. Hurtado, F. Cardoso, Changes in cardiorespiratory fitness in cardiac rehabilitation patients: A meta-analysis, Int. J. Cardiol. 167 (2013) 894–902. https://doi.org/10.1016/j.ijcard.2011.11.068

[31] M. A. Alfaraidhy, C. Regan, D. E. Forman, Cardiac rehabilitation for older adults: current evidence and future potential, Expert. Rev. Cardiovasc. Ther. 20 (2022) 13–34. https://doi.org/10.1080/14779072.2022.2035722

[32] B. Janus-Laszuk, D. Mirowska-Guzel, I. Sarzynska-Dlugosz, A. Czlonkowska, Effect of medical complications on the after-stroke rehabilitation outcome, Neuro. Rehabilitation. 40 (2017) 223–32. https://doi.org/10.3233/NRE-161407

[33] C. I. Dohle, M. L. Reding, Management of medical complications, Neurorehabilitation. 17 (2011) 510–29. https://doi.org/10.1212/01.CON.0000399070.54320.0c

[34] W. R. Harlan, S. A. Sandier, K. L. Lee, L. Choi Lam, D. B. Mark, Importance of Baseline Functional and Socioeconomic Factors for Participation in Cardiac Rehabilitation, Am. J Cardiol. 76 (1995) 36–9. https://doi.org/10.1016/S0002-9149(99)80797-8

[35] G. Caminiti, F. Iellamo, A. Mancuso, A.Cerrito, M. Montano, V. Manzi ,et al, Effects of 12 weeks of aerobic versus combined aerobic plus resistance exercise training on short-term blood pressure variability in patients with hypertension, J. Appl. Physiol. 130 (2021) 1085–92. https://doi.org/10.1152/japplphysiol.00910.2020

[36] H. Dor-Haim, S. Barak, M. Horowitz, E. Yaakobi, S. Katzburg, M. Swissa, C. Lotan. Correction: Improvement in cardiac dysfunction with a novel circuit training method combining simultaneous aerobic-resistance exercises. A randomized trial, PLos ONE. 13 (2018) e0204198. https://doi.org/10.1371/journal.pone.0188551

[37] M. Gomes-Neto, AR. Duraes, LS. Conceição, L. Roever, CM. Silva,IG. Alves, et al., Effect of combined aerobic and resistance training on peak oxygen consumption, muscle strength and health-related quality of life in patients with heart failure with reduced left ventricular ejection fraction: a systematic review and meta-analysis, Int. J. Cardiol. 293 (2019) 165–75. https://doi.org/10.1016/j.ijcard.2019.02.050

[38] Z. Wang, X. Peng, K. Li, C. J. Wu. Effects of combined aerobic and resistance training in patients with heart failure: A meta-analysis of randomized, controlled trials, Nurs. Health. Sci. 21 (2019) 148–156. https://doi.org/10.1111/nhs.12593

[39] S. Chindhy, P. R. Taub, C. J. Lavie, J. Shen, Current challenges in cardiac rehabilitation: strategies to overcome social factors and attendance barriers, Expert. Rev. Cardiovasc. Ther. 18 (2020) 777–89. https://doi.org/10.1080/14779072.2020.1816464

[40] A. B. Gevaert, V. Adams, M. Bahls, TS. Bowen, V. Cornelissen, M. Dörr, et al., Towards a personalised approach in exercise-based cardiovascular rehabilitation: How can translational

research help? A ‘call to action’ from the Section on Secondary Prevention and Cardiac Rehabilitation of the European Association of Preventive Cardiology, Eur. J. Prev. Cardiol. 27 (2020) 1369–85. https://doi.org/10.1177/2047487319877716

[41] K. E. Laver, B. Lange, S. George, J. E. Deutsch, G. Saposnik, M. Crotty, Virtual reality for stroke rehabilitation, Cochrane Database Syst. Rev. Issue 11. (2017)Art. No.: CD008349. https://doi.org/10.1002/14651858.CD008349.pub4

Figure legends

Fig. 1. PRISMA flow diagram of the systematic review.

Fig. 2. Risk of bias graph: review authors for each risk of bias item presented as percentages across RCTs studies.

Fig. 3. Forest plot of mean difference of post-stroke physical cardiac function recovery of 4 studies following CR among rehabilitated participants compared to nonparticipants. The diamond represents the overall MD. CR effectively promoted physical cardiac function (MD = 0.30, 95% CI: 0.07 to 0.53 m, $p < 0.01$).

Fig. 4. Forest plot of mean difference of post-stroke cardiac functional recovery of 3 studies following CR among rehabilitated participants compared to nonparticipants. The diamond represents the overall MD. CR effectively promoted cardiac functional recovery (MD = 0.31, 95% CI: 0.02 to 0.59 mL.kg-1.min-1, $p < 0.04$).

Fig. 5. Funnel plot for the assessment of publication bias. A) Funnel plot of the studies included for physical cardiac function in the meta-analysis. B) Funnel plot of the studies included in cardiac functional recovery in the meta-analysis. The funnel plots for the seven meta-analyses performed showed no evidence of publication bias.

Table legends

Table 1. Data extraction of the studies' characteristics.

Table 2. Data extraction of the studies' characteristics.

Table 3. Key findings of the included studies investigating the effectiveness of CR programs.

Table 1. Data extraction of the studies' characteristics.

Study ID	Country	Participants	Design of the study	Study objective(s)	Intervention/Control	Results
Regan et al. (2021) [11]	Columbia	29 participants (24 completed) Age: 68 years Time since stroke : 12 months	Mixed methods design combineda a single group, pre-program-post-program design, with a pragmatic qualitative inquiry of participant perception.	To study the impact of an existing CR program through pilot measures for physical function and for other health impacts and to evaluate participant perception of program impact on physical function, health,and future exercise plans.	Warm-up, cardiovascular endurance activities(treadmill, recumbent step machine, recumbent bike, and over ground walking), cool down. Duration: 31 to 50 Min. Frequency: 3 times/week (36 sessions)	the 6MWDT on average by 61.92 m (95% CI, 33.99–89.84 m), and maximum METs improved by a medianof 3.6 (interquartile range, 2.35). Five times sit to stand (functional strength) improved programmer to post program by a median of 2.85 s (interquartile range, 4.03 s). Qualitative findings highlight additional health improvements.
Lennon et al. (2006) [20]	Ireland	48 participants (24, 24) Age: >18 years Time since stroke: >12months	Single-blind randomized controlled trial	To evaluate risk factor reduction and HR QOL following a 10-week CR programme in non-acute ischemic stroke subjects.	usual care (excluding aerobic exercise) attended 16 cycle geometry sessions of aerobic-training intensity + two stress-management classes. Duration: 30 min Frequency: twice week (10weeks)/ (usual care Functional Activities, balance and gait (excluding aerobic exercise)	Cardiac risk; CRS; ($p = 0.015$); Fitness and function; VO2: ($p < 0.001$), (RPE= 0.043), Self-reported function and HRQOl;(HADS; Anxiety, median(rang), ($p = 0.938$) and Depression median(range), ($p = 0.222$)); Frenchay Activity Index, median ($p = 0.724$)
Tang et al. (2010) [21]	Canada	43 participants (20, 10) Age: 64.5± 12.2 years Time since stroke : 0-3 months	Repeated measures design	To determine the feasibility of modifying aCR model for individualswith mild to moderate disability following a stroke, and to evaluatethe program's impact on aerobic capacity, walking capacity, and stroke risk factors.	adapted of CR education (1-2 times/ monthly) and supervised, individually-aerobic and resistance exercise and 1-2additionalRT sessions conducted at home Duration: 90 min Frequency: 1 times/week (16sessions)	CR is feasible, VO2peak improved relative to the stable baseline period (P= 0.046) and the increase in ventilatory threshold approached significance (P = 0.062).

Table 1. (Continued)

Study ID	Country	Participants	Design of the study	Study objective(s)	Intervention/Control	Results
Marzolini et al. (2014) [22]	Canada	120 participants Age:63.8±12.7 years (range 27-88) Time since stroke: 101.5±169.3 days	Prospective cohort study	To assess the effects of a CRP on individuals with motor impairment and to investigates the impact of time elapsed since a stroke onphysiological and quality-of-life outcomes	The TRI-REPS program complete 4 additional AT in class and 1-2 RT sessions at home Duration: 90 min Frequency: 1times/week (24 sessions)	significant improvements (all P<, .001)in 6MWDT (283.2 ± 126.6 to 320.7 ± 141.8 m), sit-to-stand performance (16.3 ±9.5 to 13.3 ± 7.1 seconds), affected-side IKES (25.9 6 10.1 to 30.2 6 11 kg as a percentage of body mass), and VO2peak (15.2 ± 4.5 to 17.2 ±4.9 mL.kg.min-1). improvements in anaerobic threshold, balance, affected-side hip/shoulder ROM, grip and isometric elbow flexorstrength, participation, walking speed,cadence (all P <,.001), and bilateral step lengths (P<,.04). there was a negative association between the change in 6MWDT and time from stroke (β= -242.1; P= 5.002) independent of baseline factors.
Kirk et al. (2014) [23]	United Kingdom	24 participants (12, 12) Age: 47-84 years Time since stroke: 1 years	Single-blind randomized controlled trial	To assess the feasibility and effectiveness of implementing a standard National Health Service CR program for reducing risk factors in patients following a minor stroke and transient ischemicattack	Standard care and CR (Circuit exercise +education classes) Duration:60 min. Frequency: 1times/week (8weeks)	CVD risk score: (p =0.042) HsCRP: (p = 0. 342) Physical functioning: (p =0.012) General health: (p = 0.284) HADS anxiety: (p = 0.127) HADS depression: (p =0.285)

Table 1

Study ID	Country	Participants	Design of the study	Study objective(s)	Intervention/Control	Results
Marzolini et al. (2016) [24]	Canada	85 participants (65 in Retro-TIA cohort, 20 Pro-TIA cohort) Age:43-88years Time since stroke: 6-8 weeks	Prospective and respectively TIA cohort	To evaluate the impact of CR on cardiovascular fitness, precisely VO2peak and 6MWDT, following a transient ischemic attack (TIA), while also considering secondary outcomes related to clinical and process indicators.	5Aerobic + 2-3 RT session in home or community Duration: 90min, Frequency: once per week (24 sessions), no control group	improvements in VO2peak for both cohorts, and these improvements were statistically significant (both, P < .02). In the pro-TIA cohort, significant improvement in depression scores when compared to the stable baseline period (1.1 ± 4.3 and −3.3 ± 3.9, respectively;P = .04), no significant improvement inthe 6MWDT (4.8 ± 42 m and 61.0 ± 73.5 m, respectively; P = .06).
Prior et al. (2017) [25]	United Kingdom	100 participants Age: ≥20 years. Timesince stroke : >24 hours	prospective cohort trial	To examine the psychological outcomes during the sub acute phase after a TIA or MNDS and to test the hypothesis that CCR, combined with risk factor reduction, would be independently associated with improvements in anxiety, depression, QoL, and cognition.	CCR, Mean Duration: 7-6months. (No Controlgroup)	Psychological service recipientsimproved significantly more than non-recipients in depression (P = .049), NAART score predicted exercise attendance (P = .044), NYHA class and depression score predicted exit physicalhealth status (P < .001) and Depression score predicted exit mental health status(P < .001).
Cuccurullo et al. (2019) [26]	United States	783 participants (136,473) Age: 62.2 years Time since stroke : at least 4 months	Prospective cohort study (Non-randomised sub-group analysis)	To investigate the effects of a SRP integrating modified CR on mortality and functional outcomes for stroke survivors	modified CR Sessions included a warm- up, interval cardiovascular training, + cool down. Duration: 30 min, Frequency:2–3 times/week (36 sessions)/ (no control group)	excellent safety, cardiovascular performance over 36 sessions (103% increase in metabolic equivalent of tasks times minutes), Activity Measure of Post-Acute Care domains (P <0.001), positively impact mortality, and nonparticipants had 9.09 times higher hazard of mortality (P = 0.039).

Study ID	Country	Participants	Design of the study	Study objective(s)	Intervention/Control	Results
Cuccurullo et al. (2022) [27]	United States	449 participants (246,203) Age: 68.5 years Time since stroke : 365 days	Retrospective analysis of prospectively collected data	To explore the benefits ofan integrated modified CR protocol into an enhanced SRP for stroke survivors.	SRP- modified CR a warm-up, interval cardiovascular conditioning, a cooldown period. (2-3 times/week) Duration: 30 min (36 sessions) (matchedcohort).	Activity Measure of Post-Acute Care domains (P < 0.001 for all, 95% CI for differences in AM-PAC scores compared to the matched cohort and an improvement in cardiovascular performance with an increase of 78% metabolic equivalent of tasks times minutes (P < 0.001, 95% CI) compared to baseline.
Prior et al. (2011) [28]	United Kingdom	110 participants (80 completed) Age: > 20 years Time sincestroke : 12 months	Prospective cohort study	To study the feasibility and effectiveness of 6- month outpatient CCR forsecondary prevention after a transient ischemic attack or mild, non-disabling stroke	Standardised, physician- supervised, symptom- limited, exercise stress testing 2 to 3 weeks, Twice-weekly, 50-session option, with supplementary home-based training at least twiceper week.	CCR is feasible, and significant intake-to-exit changes in aerobic capacity(+31.4%; P<0.001), total cholesterol (-0.30 mmol/L; P=0.008), in the lowest- mortality risk category of the Duke Treadmill (P<0.001
Clague- Baker et al. (2022) [29]	United Kingdom	32 participants Mean age: 64.4 years Time since stroke : 1 to 6 months. were recruited a mean of 88 (SD =30.9) days following stroke onset	Mixed methods feasibility study.	To assess the recruitment strategy, acceptability, adherence, outcome measures, and occurrence of adverse events related to a definitive investigation of adapted CR for stroke patients during the subacute stage of recovery.	adapted CR program. Education1st half (stroke participants)2nd half (cardiac patients) Duration: 3 hours. Health check, warm up (Duration: 15 min), circuit training (Duration: 30 min), Cool down Duration: 30 min Frequency:2times/week (6 months) 10- min discussion each week.	a significant increase from baseline to six weeks of 200 (standard deviation (SD) 191.2) to 234 m (193.1) (95% confidence intervals (CI) 21.19 to 46.96)., SF36 - Physical function 0.1 (−16.3 to 15.9), MAS 0.4 (−0.2 to 1.1),MFIS −7.1 (−1.35 to −12.8), HADS – overall score −2.6 (−0.30 to −4.8)

Table 2. Data extraction of the studies' characteristics.

Study ID	Study group	Exercise type	Frequency	Intensity	Follow-up Measures (baseline measures before CR)	Significant Measures (post measures after CR)
Regan et al. [11]	Subacute and chronic survivors of stroke	6 MWDT (RPE: on a scale 6 to 20),5 times sit to stand, 10m walk **Optional activities:** -Strengthening -Stretching, and/or relaxation, and warm-up. -Cardiovascular endurance activities (treadmill, recumbent stepmachine, recumbent bike,and over-ground walking).	12 weeks, 3 sessions per week,30-50 minutes.	RPE levelswere set from 11 to 14 (somewhat hard to hard)on a scale of6 to 20	HR, BP, heart rhythms ,and bloodglucose	**Cardiac endurance:** -SIS-Mobility and MET maximum -6/5/10 MWD **Physical function:** FTSS test, SSWS m/s ABC scale score SIS Physical **QOL:** SIS- (Mood, Memory, Communication, ADL, Hand, Participation and recovery) **Self-efficacy:** -SSEE and SOEE scale. -Stroke Impact Scale -Activities-Specific -Balance -Confidence Scale
Lennon et al. [20]	community-dwelling ischemic stroke patients	16 cycle geometry sessions of aerobic-training intensity and two stress- management classes comparison group:excluding aerobic exercise.	10 weeks	Not to exceed 60%max HR	-submaximal exercise test (a cycle ergometer), CRS, smoking status, glucose, total cholesterol and HDL scores, resting HR and SaO2, Resting BP, BMI	- CRS - VO2 (mL O2/kg per minute) - RPE - HADS -Frenchay Activity Index; -Fasting Lipid Profiles -Resting BP

Study ID	Study group	Exercise type	Frequency	Intensity	Follow-up Measures (baseline measures before CR)	Significant Measures (post measures after CR)
Tang et al. [21]	-3 months post-stroke, were recruited from stroke rehabilitation programs, -Outpatient follow-up clinicsand from the community.	Prescribed aerobic and resistance exercise training, walking, RT was prescribed 2-3 sessions per week for 7-10 upper and lower bodyexercises	-6 months. -Aerobic: 5 days per week (30-60min). -RT: prescribed 2-3 weekly sessions for 7-10 upper and lower bodyexercises.	Intensity of exercise to Achieve an 11-14 RPE	Aerobic capacity Five-meter Walk Six-Minute Walk Test Stroke Impact Scale	Aerobic capacity 6MWDT Cardiovascular disease risk factor profiles Measurement of waist and hip circumference, percent body fat by bioelectrical impedance analysis Fasting blood glucose Glycated haemoglobin High- (HDL) and low-density lipoprotein (LDL) cholesterol and triglyceride.
Marzolini et al. [22]	Patients had to be 12 weeks or more after the stroke with a stroke-related motor impairment score of less than 7 on the CMSA scale ofarm, hand, leg, or foot.	Semi-recumbent ergometer, 4 additional AT and 1- 2 RT sessions at home; Resistance was provided by handheld dumbbells, exercise bands (wrist/ankle attachments), or participants' body weight.	Twenty-four weeks of resistance and AT, 90-minute exercise class once weekly for 6 months.	Intensity considering a combinationof 40%-70% of HR reserve or VO2-peak, Borg 6-20 Scale.	The motor recovery stage of the arm, hand, leg, and foot of the stroke-affected side was classified on the 7-point CMSA scale Depressive symptoms were assessed using the CESD Scale, BP,Diabetes, Atrial fibrillation,	6MWDT Breath-by-breath Affected-side maximal IKES VO2peak Timed repeated sit-to-stand performance Gait characteristics (cadence, steplengths, and symmetry) Walking speed, Balance (Berg Balance Scale) Affected-side range of motion (ROM)Elbow flexor and grip strength Anaerobic threshold Perceptions of participation/social reintegration.

Study ID	Study group	Exercise type	Frequency	Intensity	Follow-up Measures (baseline measures before CR)	Significant Measures (post measures after CR)
Kirk et al. [23]	Clinical diagnosis (within 1 month of the incident) of a minor stroke or TIA(not Suspected patentforamen vale);independently mobile (can use astick but no falls within past two months); cognitive capacity sufficient to undertake group exercises(Mini-Mental Test score >7/10);considered medically fit for exercise; able to give verbal and written consent.	8weeks with weekly classes	10 minutes. paced walking, standingon the spotexercises , upperlimb and lower limbstretches. **Circuit:** 40 minutes. HR checks were carried out twice during the activities. **Intense exercises:** stepups, walking /runnin g, heel rises with theleg, step backs witharm raises, sidesteps. **Recovery exercises:** bicepcurls, lateral raises,and shoulder press.	Maintain HR at 50–70% of their maximal HR, calculated using the Karvonen formula: tar resting HR Intensity is also monitored by the Borg Scale with patients aiming to achieve a level too hard.	BP, HR, Changes in medication, Subjective health	Cardiovascular disease risk scoreLipid profiles Resting BP C-reactive protein [measured with a highly sensitive assay] and fibrinogen levels Blood glucose Obesity Physical activity levelsSubjective health status HADS
Marzolini et al. [24]	Retro-TIA: a cohort including 65 consecutively enrolled individuals. Pro-TIA: a cohort including 20 participants who were followed prospectively using a repeated measures design with a 3-month monitoring period without intervention (−3 to 0 months) followed by 6 months of CR.	AT, education sessions, and Psychosocial and dietary counselling	90-minute exercise classesonce per week for 6 months, 5 aerobic and 2-3 RT sessions per week	Increasing intensity to a maximum of 80%	Cardiopulmonary assessments, anthropometric measures,depression scores, and adherence indicators.	Percent of BMI bioelectrical impedance Stress test on either an upright cycle ergometer or 12-lead electrocardiogram Depressive symptoms:assessed using the validated CES-D FIM score (self-care, sphincter control, mobility, locomotion, communication, and social Cognition ability measured using the MoCA HB HR

Table 2

Study ID	Study group	Exercise type	Frequency	Intensity	Follow-up Measures (baseline measures before CR)	Significant Measures (post measures after CR)
Prior et al. [25]	patients with a documented ischemic TIA	Exercise, dietary counselling, smoking cessation,and psychologicalservices	30 days	NA	-HADS, MCS, PCS, FAS-OVF, NAART, MMSE, and WAIS-R	HADS score, SF-12 Digit Span Trail-Making-A [attention, working memory. Digit-Symbol, Trails- B, clock-drawing, FAS oral-verbal fluency (FAS-OVF), speed/executive/abstraction, NAART, MMSE, and Neurocognitive testing].
Cuccurullo et al. [26]	- stroke Patients discharged from the acute IRF were offered participation in the outpatient SRP. -SRP participants and non-participants	-Recumbent cross-training bicycle -6MWD -Warm-up, interval cardiovascular conditioning and a remarkable down period for approximately 30min.	- 2 to 3 sessionsper week for a total of 36 sessions	Low to moderate intensity forat least 30min.	BP, HR, oxygen saturation, blood glucose, METs, exercise minutes and modified RPE scale.	RPE, METS, AM-PAC scores, and LOCF.
Cuccurullo et al. [27]	stroke survivors after a cerebrovascular accident/stroke (e.g., ischemic, haemorrhagic, and subarachnoid haemorrhage)	**Traditional CRP:** Treadmill, arm ergometer, or bicycle **Modified CRP:** -NuStep recumbent cross-training bicycle. -6 cycles of 4 minsof low-intensityexercise (RPE 1–3,RPE range 0=rest ,10=maximal effort) followed by 1 min of rest for 30 mins.	2–3 sessions per week for a total of 36 sessions (leastwas 135 days)	Low to moderate	BP, HR, oxygen saturation, blood glucose, METs, exercise minutes, modified RPE scale	AM-PAC for essential mobility, daily activity, and applied cognitive domains. MET-min

Table 2

Study ID	Study group	Exercise type	Frequency	Intensity	Follow-up Measures (baseline measures before CR)	Significant Measures (post measures after CR)
Prior et al. [28]	had sustained a documented TIA/MNDS within the previous 12 months.	Standardised, physician- supervised, symptom-limited, exercise stress testing 2 to 3 weeks	Twice-weekly, 50-session option, with supplementary home-based training at least twice per week.	Walking	BP HR Cholesterol	DTS Anthropometric measurements Exercise performance was expressed in METs, BROG scale, HADS score, Dyslipidaemia, Hypertension, and TIA/MND.
Clague- Baker et al. [29]	One week to 6 months (sub-acute) of a mild-to-moderate stroke.	-Warm-up (15 minutes) -Walking, standing on spot exercises to gradually increaseHR. -Chair support provided for somestroke patients -Main exercises (30 minutes) – circuit training including side steps, back steps, step-ups,treadmill (all progressed with the use of arm weights), static bike (progressed by adding wattage) and use of a motored bikeinstead of a static bike when necessary (e.g. needing assistedpedalling).	2 times a week for 6 weeks	The intensity was also monitored every five minutes using the Borg exertion scale, with patients aiming to achieve "somewhat hard" and "hard" levels.	ISWT, BP, HR, weight, BMI, QOL, fatigue, anxiety and depression, tone, falls, stroke attitude and knowledge, physical activity (accelerometry) and functional ability.	ISWT, BP, HR, weight, BMI, QOL, fatigue, anxiety and depression, tone, falls, stroke attitude and knowledge, physical activity (accelerometry) and functional ability.

Abbreviations: Incremental shuttle walks test (ISWT), Cardiac Rehabilitation (CR), Blood pressure (BP), Heart Rate (HR), Body mass Index (BMI), National Institutes of Health Stroke Scale (NIHSS), health-related Quality of Life (HRQOL), Quality of Life (QOL), Modified Ash- worth Scale (MAS), Hospital Anxiety and Depression Scale (HADS), Stroke recovery program (SRP), Borg-Rate of Perceived Exertion Scale (RPE), Activity Measure of Post-Acute Care (AM-PAC), metabolic equivalent of tasks multiplied by minutes (MET-min), Cardiac risk score (CRS), 6-minute walk distance test (6MWDT), peak oxygen uptake (VO2peak), Center for Epidemiologic Studies Depression Scale (CES-D), The Functional Independence Measure (FIM), metabolic equivalents (METs) , Montreal Cognitive Assessment (MoCA), Chedoke–McMaster Stroke Assessment (CMSA), isometric knee extensor strength (IKES), resistance training (RT), Aerobic training (AT) programs, ventilatory anaerobic threshold (VAT), comprehensive cardiac rehabilitation (CCR), transient ischemic attack (TIA), mild nondisabling stroke (MNDS), (Mini-Mental Status Examination [MMSE], Short-Form Health Survey (SF-12), The 36-Item Short Form Survey (SF-36), Duke Treadmill Score (DTS), and The Modified Fatigue Impact Scale (MFIS).

Table 3. Key findings of the included studies investigating the effectiveness of CR programs.

Study ID	Outcomes		Limitations	Recommendations
	Functional Activity	Physical Activity		
Regan et al. [11]	-6MWDT, the main outcome metric for walking and aerobic capacity, increased by 61.92 m (95% CI, 33.99–89.84 m) after the program, with alarge effect size (0.94). - The SIS-Mobility subscale showed significant improvement post-program of 6.94%, greater than the clinically important difference of 4.5%, but no significant value. - the participant benefited from the exercise intervention. Based on Short Self-Efficacy for Exercise Scale (median, 4.20 out of 5) and the Short Outcome Expectations for Exercise Scale. - The participant's walking speed, Activity-Specific Balance Confidence Scale score, or SIS-Physical subscale score did not change between before and after the program.	Walking (50%) and gym aerobic (50%),were the most common activities, followed by home aerobic (33.3%), gymstrengthening (22.2 percent), group exercise (22.2%), other (22.2%), which consisted of running, swimming, yard work, and horseback riding, and home strengthening (11.1%).	potentially impacting thegeneralizability of the findings due to the use of a single-group pilot design thatsolely relied on aconvenience sample from a single exercise-based CR program - the absence of assessment for potentially distinct needswithin the two subgroups.	Conducting future studies with larger sample sizes would provide a better understanding of the program'spathways and help address anydivergent needs that may exist betweenthe two subgroups
Lennon et al. [20]	-The intervention arm demonstrated significantly more improvements after treatment in several primary variables when compared with the control. -cardiovascular fitness improved in the intervention group with a more significant increase in VO2 (t =4.734, P<0.001) and a decrease in RPE (U =173.5, P<0.04) by comparison with the controls. -CRS reduced in the intervention group but increased in the controls (t=2.537, P=0.015). -No significant change occurred in cardiovascular–metabolic risk factor profiles of total cholesterol, LDL, HDL, triglycerides, systolic BP and diastolic BP. - No significant difference was found in the Frenchay Activity Index or HADS change scores.	- A significant difference in change scores between groups in spirometry results of forced vital capacity (FVC), peak expiratory flow (PEF), FEV1and FEV1/FVC (%). - A significant change in VO2 (P<0.001) and CRS (P<0.005). -HADS depression score improved significantly in the intervention group (Z =3.278, P<0.001) but not in control. -BMI increased in both control (P=0.008) and intervention (P=0.012) groups.	-No significant enhancements in HRQoL measures or cardiovascular- metabolic profiles were observed. -A decrease in HADS depression scores during the final assessment in the active group indicates a potential improvement in overall well- being. -This pilot study with a small sample size has limited ability to demonstrate a full range of health status and functional benefits. -Control group received less non-exercise-related attention, potentially influencing behavior through Hawthorne effect, rather than intervention itself.	NA

Table 3. (Continued)

Study ID	Outcomes		Limitations	Recommendations
	Functional Activity	Physical Activity		
Tang et al. [21]	-The adapted CR group's post- intervention VO2peak improved relative to the stable baseline period (P = 0.046), and the increase in ventilatorythreshold approached significance (P =0.062). -No changes in the primary outcome measures over the baseline period (P = 0.09-0.98), and all commenced the adapted CR program. -Stroke scale 29 (71%) mild, 12 (29%) moderate, 0 severe), mobility-related outcomes described otherwise. -VO2peak improved significantly at theend of the CR program relative to the baseline period (P = 0.046), and theincrease in VAT approached significance (P = 0.062).	-No significant changes were observed in body composition, lipid profile, glucose and metabolic syndrome. -56% of predicted 6MWDT distances and 42% were classified as household orlimited community ambulators based on gait speed, and 27% presented with severe gait asymmetry.	-A single cohort design,resulting in a control group's absence. -The conservative approach ofassuming that no exercise wasperformed when a diary was not submitted may have underestimated the actual amount of exercise completed. -The unexpected highervariance in the scores of the 6MWDT compared to theinitial sample size calculationwas observed.	An independent control group should beused in future studies to determine the efficacy of this care model.
Marzolini et al. [22]	Participants also demonstrated post- CRP improvements in secondary outcomes: anaerobic threshold, balance, affected-side hip/shoulder ROM, grip and isometric elbow flexor strength, participation, walking speed, cadence (all P<0.001), and bilateralstep lengths (P<0.4).	Significant improvements (P <0.001) in6MWDT	The results could apply to a broader clinical population due to the focus on a real- world sample of outpatient participants with moderate motor function who were referred to a CR program.	It is necessary to investigate the causal pathways that drive changes in muscular strength, gait characteristics, and ambulation at different stages of chronic stroke recovery. -It is important to understand the implications of these changes on the ability to adapt to exercise.
Kirk et al. [23]	-Statistically significant reduction in cardiovascular disease risk score for the intervention group compared to thecontrol group (P = 0.042). -No significant between-groupchanges occurred in the biomarkers HsCRP and fibrinogen and the individual risk factors: total cholesterol, HDL, fasting blood glucose and portions of fruit and vegetables consumed.	-Significant improvements for the intervention group in activity levels, SF-36 domains of physical functioning andmental health.	-CRS originated from theFramingham study and is not validated with the current score of CRS. -A potential Hawthorne effect also limited the trial as the control group did not receive comparable health-related attention to the intervention group.	There is a need for additional research to examine any potential synergies in secondary prevention care for individuals with coronary heart disease or stroke.

Table 3. (Continued)

Study ID	Outcomes		Limitations	Recommendations
	Functional Activity	Physical Activity		
Marzolini et al. [24]	6-month CR program improved cardiovascular fitness, anthropometrics, and depressive symptoms with acceptable adherence rates. CR resulted in improvements in VO2peak for both cohorts (P < .02).	No significant change was observed in6MWDT (61.0 ±73.5 m, P = 0.06).	The study's limited generalizability to non-publicCR services, insufficient sample size, and non-exercisecontrol group may limit its generalizability to otherprograms.	Recommending promoting and informing people who have had TIAs and medical professionals from possible referral sources about the advantages of a thorough CRP to provide important opportunities to advance the health of individuals with TIA.
Prior et al. [25]	-At CCR entry, 16.5% and 39.2% screened positively for depression and anxiety, decreasing non-significantly at the exit to 4.2% and significantly to16.9% (P = 0.008), respectively. -at entry, mental health status (13.3%), clock-drawing (31.6%), oral-verbal fluency (16.9%), word-list learning (11.2%), and recall (12.6%); at exit, clock-drawing (30.0%). -Entry-to-exit, mean depression, anxiety, mental and physical health status, word- list learning, improved significantly. -NAART covariate effect was significant for Digit-Span forward, backward (P < .001), RAVLT-sum A(P = 0.003), Digit-Symbol (P < .001), Trails B (P =0.001), FAS-OVF (P <0.001).	-NAART, MMSE, aerobic capacity,BMI, and frequencies of hypertension, diabetes, or smoking differed significantly (P ≥ 0.08) between completers and non-completers (n = 20).	-The findings can be generalistto areas with similar topographies and administrative frameworks,they might not be as broadly applicable to non-white populations. -as no RCIs were noteworthy.These findings do not support our hypothesis that CCR would be independently associated with psychologicalimprovements.	NA

Table 3. (Continued)

Study ID	Outcomes		Limitations	Recommendations
	Functional Activity	Physical Activity		
Cuccurullo et al. [26]	-Participants demonstrated significant improvements (all P < 0.001) inaffected-side IKES (25.9±10.1 to30.2±11 kg as a percentage of body mass), and VO2peak (15.2±4.5 to 17.2±4.9 mL/kg/min).	-Participants also demonstrated post- CRP improvements in secondary outcomes: anaerobic threshold, balance, affected-side hip/shoulder ROM, grip and isometric elbow flexor strength, participation, walking speed, cadence (all P<0.001), and bilateral step lengths (P<0.04). -Participants demonstrated significant improvements (all P < 0.001) in 6MWDT (283.2±126.6 to 320.7±141.8 m), sit-to-stand performance (16.3±9.5 to 13.3±7.1 seconds)	The possibility that theimproved outcomes in the SRP participants may beattributable in part to the additional care time. Asubset of stroke survivors with moderate to severe disability after stroke, who had medical complications necessitating admission toIRF and then were discharged to an outpatient rehabilitation program within 30±15 days after stroke.	More research is needed in this area to encourage improvements in healthcare policies that will benefit stroke survivors.
Cuccurullo et al. [27]	-AM-PAC measures functional scores IRF admission, IRF discharge, 30 ± 15, 60 ± 15, 90 ± 15, and 120 ± 15 days following stroke. -26 points on Mobility score (MD = 26.41, SE = 0.94, 95%CI = 24.54 to 28.28, P < 0.001) - 26 points on daily activity score showed improvement (MD= 26.40, SE = 1.60, 95% CI = 23.24 to 29.56, P < 0.001). -Score of 16 points for Applied Cognitive (MD = 15.90, SE = 1.32, 95% CI = 13.28 to 18.53, P < 0.001).	-36 sessions showed average progression of 103% MET-min. (mean percent difference =103.31, SE = 6.77, 95% CI = 89.86 to 116.76, P < 0.001) - For each session that MET-min participated in, their scores significantly differed from the baseline (P < 0.001).	This study focused on evaluating a specific subgroup of stroke survivors with moderate-to-severe deficits. Therefore, the findings of this study may not be generalizable to stroke survivors with mild deficits or those who do not require IRF admission.	More studies are needed to improve healthcare policies so that stroke survivors are treated in a similar way to patients with cardiac disease.

Table 3. (Continued)

Study ID	Outcomes		Limitations	Recommendations
	Functional Activity	**Physical Activity**		
Prior et al. [28]	Significant intake-to-exit changes in aerobic capacity (P<0.001), total cholesterol (P<0.008), total cholesterol/high-density lipoprotein (P<0.001), triglycerides (P<0.003), waist circumference (P<0.001), BMI (P<0.003). Low-density lipoprotein, high-density lipoprotein systolic BPand diastolic BP changed favorablybut non-significantly. A significant shift toward non-smoking occurred (P<0.008).	25.6% increase in finished CCR in the lowest-mortality risk category of the DTS (P<0.001).	The lack of a control group and the researcher's inabilityto exclude the potential effects of non-CCR factors	Following a TIA or MNDS, CCR is a safe, effective, and feasible, secondary prevention method A promising approach for integrated vascular protection across many chronic disease entities is also demonstrated by CCR.
Clague- Baker, et al. [29]	ISWT increased significantly from baseline to six weeks, from 200 to 234 with a 95% CI. Resting HR, BI, MFIS, HADS, and SF36 showed significant outcomes.	increased moderate to vigorous physical activity, greater step counts, lower fatigue, decreased anxiety and depression levels. improved ISWT performance, and increased awareness of physical activity.	Lack of a control group, small sample size, Lack of long-term follow-up and Incomplete measurement of cardiovascular (CV) risks.	More study is required in stroke patients, and a specialised programme is required for those with more severe strokes (NIHSS > 3).