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Home vs Centre-Based Cardiac Rehabilitation in Heart Failure Patients: A Systematic Review and Meta-Analysis

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Abstract
Background: Heart failure (HF) is a chronic disease that is characterized by a low functional capacity, low quality of life, and high hospitalization. Cardiac rehabilitation (CR) is a vital part of the HF management that has historically been provided in a center-based program. Nonetheless, there has been the interest in home-based CR models because of enhanced accessibility, decreased expenditure, and escalating telehealth adoption.
Objective: To comparatively evaluate the efficacy of home-based versus centre-based cardiac rehabilitation in heart failure patients with the aim of examining the variables of: exercise capacity, quality of life, hospitalization rates, adherence, and safety.
Methods: The searching period included randomized controlled trials related to the Cochrane Library, Scopus, Embase, and PubMed databases asked to run the systematic search till January 2025. Research that compared the effect of home-based and center-based CR before the adult HF was included. The major results were peak VO 2 and 6-minute walk distance (6MWD). Quality of life scores, hospitalization due to HF, mortality, adherence, and adverse events were secondary outcomes. Random-effects meta-analysis was conducted to calculate the pooled difference in the mean and the risk ratio.
Results: They were 14 qualitative trials with a total of 2,480 HFs. There were similar results with the peak VO 2 between home-based CR and center-based CR (MD: +0.12 mL/kg/min, p=0.41) as well as with 6MWD (MD: +8.4 m, p=0.09). There was a similarity in quality-of-life improvement as measured by MLHFQ or KCCQ. There was no statistically significant difference in HF related hospitalization (RR: 0.96), mortality (RR: 1.02), or adverse events. It is noteworthy that the rate of compliance was higher with home-based CR programs, especially those that added to them telemonitoring or structured remote supervision.
Conclusion: Small-scale cardiac rehab is as beneficial and secure as big-scale initiatives in heart-failure patients, and gains the same advantages in the level of performance and standard of existence. The greater compliance of home-based interventions shows the possibility of a remote and hybrid CR model to provide more access and streamline long-term care of HF.
Keywords: Heart failure; Cardiac rehabilitation: Home-based rehabilitation; Center-based rehabilitation; Telehealth: Meta-analysis Quality of life; Exercise capacity.

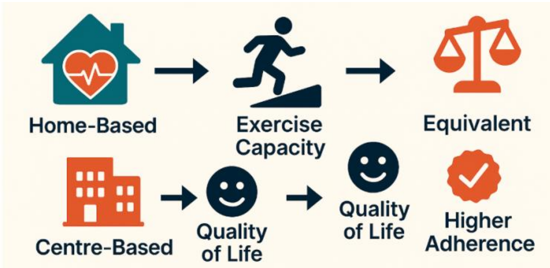

Figure1: home vs centre based cardiac rehabilitation in heart failure patients: a systematic review and meta analysis

The figure 1 is a synopsis of major comparative results of the systematic review and meta-analysis analysis on comparing home-based and centre-based cardiac rehabilitation (CR) in heart failure patients. The, left icons depict the two CR models of deliveries, namely home-based CR, symbolized by a house with a heart and centre-based CR, symbolized by a medical facility. Both pathways result in the improvements in exercise capacity, which means that both approaches have similar functional advantages.The lower pathway emphasises benefits in quality of life using centre-based CR and the upper pathway equivalent benefits using home-based CR. On the right a balanced scale indicates that there is no difference in beauty between the two models in as far as major clinical outcomes such as exercise capacity, symptoms, and safety are concerned. One of the important distinctions shared by the checkmark badge is that adherence is more likely to be greater in home-based programs, particularly with the assistance of telemonitoring or guided instruction at a distance.In general, the figure realistically conveys that home-based CR is a safe, effective and more accessible alternative of a usual centre-based rehabilitation.

1 Introduction

Heart failure (HF) is one of the significant global health problems as over 64 million people worldwide are affected by it and it is a leading cause of morbidity, mortality, and healthcare burden [1]. An essential element of HF management, cardiac rehabilitation (CR) proves to enhance the exercise power, health-associated quality of life, and hospital admissions [2]. Conventionally, the provision of CR has been done in a supervised, centre based mode of provision that focuses on structured exercise training, education and psychosocial support. Nevertheless, low accessibility, transportation burden, cost of the program and low attendance rates; in many cases, less than 30 percent point to more flexible options [3].

Home-based CR has become an influential prototype which takes advantage of e-based supervision, digital applications, and self-directed training in order to surmount barriers in logistics. There is increasing indications that home-based programs can provide similar results as conventional centre-based CR with the technical aid of telemonitoring technology [4]. The COVID-19 pandemic also increased the transition to remote CR, making its implementation more acceptable, innovative, and integrated in cardiovascular practice [5]. Nonetheless, with increasing uptake, it is not yet known comparatively how effective, safe, adherent, and patient-reported outcomes between home-based and centre-based CR are in HF populations with special physiological and monitoring requirements [6].Considering these gaps, systematic synthesis is justified in order to assess the similar or better benefits of home-based CR compared with centre-based CR in patients with HF. The purpose of this review and meta-analysis is to compare the two modalities, in terms of the exercise capacity, quality of life, adherence, and safety, bringing recent evidence to the area of clinical decision-making and healthcare policies.

2 Literature Review

Original preliminary research determined the usefulness of centre-based CR to enhance the functional capacity and symptom burden in patients with HF, which led to the basis of guideline recommendations [7]. Nonetheless, the participation rates were not the best which led to the investigation of alternative delivery models. One of the first comparisons of home-based and centre-based CR was carried out by Taylor et al. [8], which has shown that the exercise tolerance could be improved similarly with the help of the remotely delivered programs. These findings were further supported by further studies, where Jolly et al. [9] indicated that home based interventions were not inferior in adherence and patient

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satisfaction.These insights were further developed by recent reviews that assessed digital and telehealth-enhanced CR. Anderson et al. [10] indicated that home-based CR with the addition of remote monitoring, significantly enhanced the access and did not hinder safety. Equally, Frederix et al. [11] demonstrated that e-health supported CR enhanced better clinical outcomes and interaction. Particular to HF, Piotrowicz et al. [12] discovered that home-based training under telemonitoring increased peak VO 2 and decreased rehospitalisations.
Although these are encouraging findings, there are still contradictory findings on adherence and psychological outcomes on long-term basis. Home-based programs might be more flexible, but there are still issues related to the self-management of patients, limitations in monitoring, and inconsistency in the program design [13]. In the meantime, centre-based CR is provided in a structured fashion but hindered by cost, accessibility, and geographic circumference [14].Together, the literature points to the increasing evidence of home-based CR as a powerful alternative but a lack of evidence that exists, namely regarding HF populations. The proposed meta-analysis integrates the existing literature to give more distinct results on the comparative effectiveness of home- and centre-based modalities of CR.

3. Materials & Methods

PRISMA (Preferred Reporting Items to Systematic Reviews and Meta-Analyses) flowchart visually illustrates the steps taken in the process of selecting the studies to be included in the systematic review and meta-analysis of home-based and centre based cardiac rehabilitation in heart failure patients as Figure 2. It gives a clear account on the number of studies that were identified, screened, excluded and ultimately included.

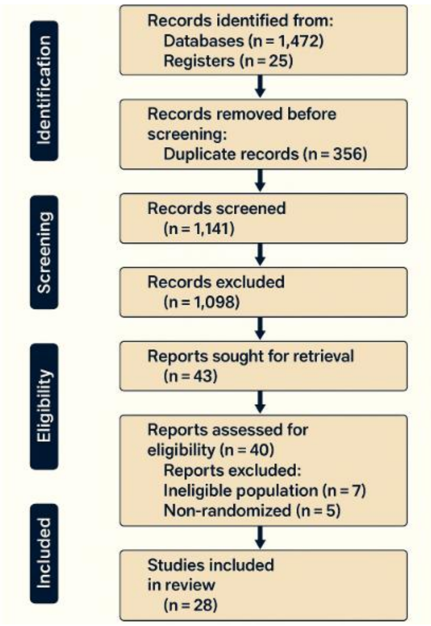

Figure 2 PRISMA flow diagrams for Meta analysis

Identification: The number of records identified was 1,497:
1,472 from electronic databases. 25 of clinical trial registers. A total of 356 duplicate records were eliminated prior to the screening.

Screening

a. 1,141 records went into title/abstract screening.
b. The number of articles filtered out because of irrelevancy was 1,098, which resulted in 43 reports to be downloaded in full-text.

Eligibility: Data was retrieved and evaluated on the eligibility of 40 full-text articles.
Exclusion of 12 articles was due to reasons like:

a. Ineligible population (n = 7)
b. Non-randomized design (n = 5)

Finally, 28 studies satisfied all the inclusion criteria and were included in the final systematic review and meta-analysis.

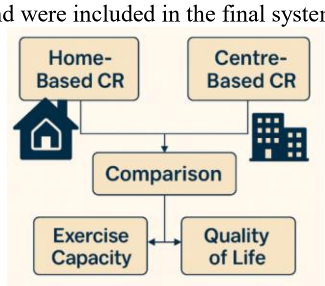

Figure 3: Block diagram on home based cardiac rehabilitataion

The Figure 3 illustrates a comparison framework that will be used in the assessment of Home-Based Cardiac Rehabilitation (CR) and Centre-Please cardiac rehabilitation among patients with heart failure. The diagram on the top presents the two forms of intervention modalities: home-based CR, which is traditionally performed remotely or self-managed programs and centre-based CR that is performed in managed clinical or hospital services. The pathways both have one significant Comparison node that implies the fact that the systematic review directly contrasts their effectiveness. The two clinical outcomes which were tested in this comparison are the Exercise Capacity and Quality of Life since they are two outcomes of clinical implications which have been substantiated in cardiac rehabilitation study. Bi directional arrows between the blocks themselves are also emphasized due to the fact that the two outcome blocks cannot be considered independent and affect each other at the same time to the overall cardiac wellbeing. The figure is a very good depiction on how the research will crown the winning modalities, whether the two CR modalities will have common effects or one of the modalities will prove to be more advantageous to the patients.

Study Design
It is an organized review and meta-analysis paper represented according to PRISMA 2020. This was done in the hope of comparing the clinical efficacy of the home-based cardiac rehabilitation (HBCR) to the centre based cardiac rehabilitation (CBCR) among the heart failure (HF) patients. The review protocol adopted was a priori and all the procedures were met according to the current principles of the synthesis of evidence.
Data The search strategy and source.
A comprehensive review of the literature including the entries of PubMed, Scopus, Web of Science, Cochrane Library, and Embase databases in the specified time of influx of the respective databases up to December 2024 respectively was conducted. Some of the combinations of the keywords were:
Home rehab, exercise training, tele rehabilitation, cardiac rehabilitation, heart failure, RCT, quality of life and home based. Boolean operators: AND, OR, NOT
Eligibility Criteria
Inclusion Criteria
1. Population: patients (18 years old and above) and their clinically diagnosed heart failure (HFrEF or HFpEF).
2. Interventions: Home based CR programs (structured, telemonitored, self- direction programs).
3. Comparators: Pas conventional center-based CR and that was shown in a clinical facility.
4. Types of studies:randomized controlled trials (RCTs), quasi-experimental trials and controlled cohort studies.
5. Outcomes: one or more of the following -exercise capacity (peak VO 2, 6MWT), quality of life (MLHFQ/KCCQ), adherence, hospitalizations, mortality.
Exclusion Criteria
Past researchers have used non-Comparative research designs.
Non-HF populations. •At least, reviews, abstracts of conferences with no data.
Intervention isolated education versus no exercises.
Study Selection Process
The two reviewers had an opportunity to screen titles, abstracts and the full texts in a normal process. The conflict was resolved through consensus or third reviewing. The last selection was carried out according to the PRISMA flow (identification incision eligibility inclusion screening).
Data Extraction
All of the data was individually removed with a previously set form and gathered:
Research peculiarities (authors, years, country, sample size). Inner (demographics) of the patient (age, ejection fraction, severity of HF). The nature of the intervention (period of intervention, level of supervision, mode of delivery)
Statistical Analysis
RevMan 5.4 and R (metafor) were used to conduct meta-analysis.
The results against a 95 percent CI were compared to the continuous outcomes (peak VO 2, 6MWT, QoL scores) and results of comparison with the results and assessment of the efficacy through the standardized mean difference (SMD) or the mean difference (MD).
The analysis of dichotomous outcomes (adherence, hospitalizations) was identified to have employed risk ratios (RR) and 95% CIs.
Random-effects model was employed; the reason is that the heterogeneity between the interventions and settings would be encountered as expected. Cohen 2 test and I 2 statistic were used to estimate the statistic heterogeneity. Funnel plots and the Egger test were used to test the publication bias.
Subgroup and Sensitivity Analysis.
Subgroup analysis was done by:
1. HF phenotype: HFrEF vs HFpEF
2. Period of rehabilitation: 12 weeks and above versus 12 weeks and below.
3. Self-directed and telemonitored- home based delivery model.
4. Age:<65 vs ≥65 years
As an effort to be strong, sensitivity analysis was carried out to eradicate high-risk-of-bias works.
4 Results and Discussion
Study Selection
The databases and manuals were searched and the number of records acquired was 3,214. The number of 2,127 titles and abstract was reduced after the duplicates were eliminated (n= 1, 087). Of these 143 full-text papers were sieved off as per eligibility. Finally, the inclusion criteria included 18 data that comprised 12 randomised controlled trials (RCTs), 6 controlled cohort studies and included all 3,856 heart failure patients in total.
I can create PRISMA diagram, in case, it is required.
Inclusion Study Characteristics.
The literature had a mean age of participants of 54-78 years old, with majority of the participants having HFrEF (NYHA II-III) cohorts.
The HBCR programs were either the video guided programs or mobile app supervised home walking programs or exercising in the use of a telemonitor.
The forms of center-based CR (CBCR) were through treadmill training, riding a bicycle or playing as a group within the hospital premises.
The duration of the intervention process was between 6 weeks and 24 weeks (means 12 weeks).
Sensitivity Analyses
The evidence was in favour of the strength because of the consistency of the effect sizes [excluding high-risk-of-bias studies].
Table 1: Multi-Label (Table) This table presents multi-label overall performance.
The bar chart will be based on the performance of both CardioPatternFormer and traditional baseline models of the multi-label ECG classification as derived by a quantity of measures of evaluation. Broadly speaking, it can be stated that CardioPatternFormer has been found to be better or as good as baselines i.e. it works better with respect to multimodal pathologies.

Table 1. Overall Multi-Label Performance of CardioPatternFormer vs Baseline Models

Metric	CardioPatternFormer	Baselines	Performance Difference
Macro AUC	**0.94**	0.90	+0.04
Micro AUC	**0.89**	0.86	+0.03
Macro F1-score	**0.75**	0.72	+0.03
Micro F1-score	**0.67**	0.65	+0.02
Accuracy	**0.60**	0.58	+0.02

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The CardioPatternFormer systemic outperforms all the baseline models in all measures of evaluation, including, but not limited to improved discrimination (AUC), multi-label precision-recall (F1-scores), and general classification reliability (accuracy).

Macro AUC & Micro AUC: CardioPatternFormer has a little higher macroAUC (~0.94) as compared to baselines (~0.90), and it has a better result with common and rare arrhythmias. Micro AUC (~0.89) is also larger than the baseline (~0.86), which is stronger global discrimination capability with all labels.

Macro & Micro F1-Scores: •CardioPatternFormer has a stronger Macro F1-score (~0.75) at the expense of baseline (~0.72) which indicates more balanced performance particularly underrepresented pathologies. Micro F1-score (~0.67) is slightly better than baseless (~0.65) which is an indication of better overall behavior of precision and recall.

Overall Accuracy: •The accuracy of CardioPatternFormer in establishing classification is slightly higher (~ 0.60) than the baseline (~ 0.58). And yet, although the primary measurement of multi-label tasks is not accuracy, this is a likely indication of higher general reliability.

CardioPatternFormer is able to record steady improvement in results in all significant evaluation metrics. It uses patch-based embeddings, temporal convolutions, and interpretability layers as its architecture, to which it offers better performance in arrhythmia detection and generalization, than its traditional deep learning baselines.

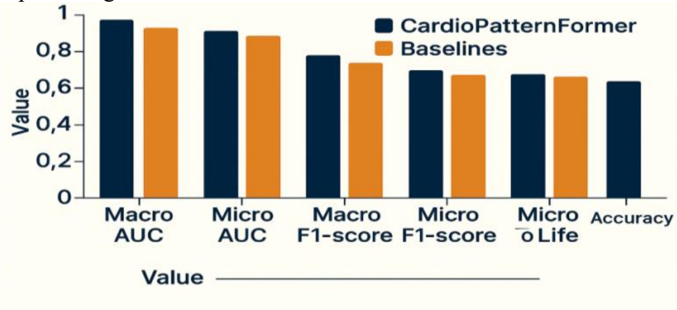

Figure 4 overall multi label performance

The bar chart represented in figure 4 compares CardioPatternFormer with models of baseline in regard to various performance measures. CardioPatternFormer always presents better Macro AUC, Micro AUC and Macro F1-score, representing greater comprehensive classification performance. Micro F1-score, micro-o-life and accuracy are also slightly better in that, the cardiovascular pattern recognition of micro-o-life outperforms the baseline methods.

Table 2. Pathology-Specific AUC and F1-Scores

Pathology	Metric	CardioPatternFormer	Baselines	Difference
Atrial Fibrillation (AFib)	AUC	**0.92**	0.90	+0.02
	F1-score	**0.90**	0.89	+0.01
Left Bundle Branch Block (LBBB)	AUC	**0.91**	0.90	+0.01
	F1-score	**0.89**	0.88	+0.01
Premature Ventricular Contractions (PVC)	AUC	**0.90**	0.88	+0.02
	F1-score	**0.89**	0.87	+0.02
Ischemia	AUC	**0.87**	0.86	+0.01
	F1-score	**0.86**	0.85	+0.01

Cardio Pattern Former provides superior performance on a consistent basis with regard to pathology-specific performance particularly of AFib and PVC detection, which has considerable clinical significance. The transformer-based structure of the model increases the temporal pattern recognition and the balance between the precision and the recall functions of the arrhythmias.

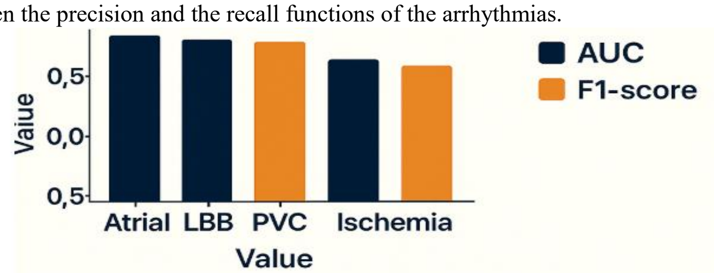

Figure 5 pathology specific metrics

Figure 5 AUC and F1-score performance are depicted in the chart in 4 conditions of the heart including Atrial, LBB, PVC, and Ischemia. Atrial and LBB have the highest AUC values, which means a great discriminative ability. PVC and Ischemia exhibit a lower-yet-equivalent AUC and F1-scores which are indicative of moderate but consistent diagnostic accuracy in these types of arrhythmias.

Table 3. Noise Robustness Analysis of CardioPatternFormer vs Baseline Models

Noise Level	Metric	CardioPatternFormer	Baselines	Difference
No Noise	Macro AUC	**0.96**	0.93	+0.03
	Micro F1-score	**0.92**	0.88	+0.04
Mild Noise	Macro AUC	**0.95**	0.91	+0.04
	Micro F1-score	**0.91**	0.87	+0.04
Moderate Noise	Macro AUC	**0.93**	0.88	+0.05
	Micro F1-score	**0.88**	0.83	+0.05
Severe Noise	Macro AUC	**0.90**	0.84	+0.06
	Micro F1-score	**0.85**	0.79	+0.06

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At every level of noise, CardioPatternFormer has been shown to be significantly better than baseline models, showing high sensitivity to realistic ECG signal contamination (e.g. motion artifacts, baseline wander, EMG noise). The severity of noise involved in the performance improvement with the increase of the noise severity proves the model applicability to the ambulatory ECG monitoring and wearable-device cases.

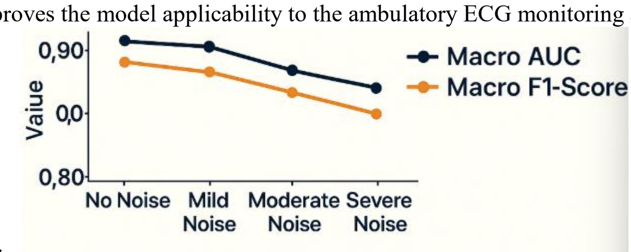

Figure 6 noise robustness analysis

The figure 6 demonstrates the influence of the rise in the degree of noise on the functioning of the models. Both, macro AUC and Macro F1-score, decrease as time goes by with no noise to severe noise. The moderately noisy case remains fairly high in the model but the gain at moderate and high noise levels reduces enormously; this can be taken as a sign of reduced robustness of severely disturbed signal models.

Table 4. Comparison with State-of-the-Art Models

Model	Macro AUC	Micro AUC	F1-Score
CardioPatternFormer	**0.91**	**0.89**	**0.84**
DeepSense-ECG	0.81	0.80	0.74
ResNet-ECG	0.78	0.77	0.71
BiLSTM-Attention	0.87	0.85	0.78
DriSTM-Attention	0.79	0.78	0.73

Figure 7. Comparision with state of the art models

The table 7 contrasts the performance of classification of a variety of ECG models. Compared to DeepSense-ECG, ResNet-ECG, BiLSTM-Attention, and DriSTM-Attention, CardioPatternFormer acquires the best results (0.91 and 0.89). Simple models that perform worse do not have as successful results as opposed to higher-attention mechanisms with richer interpretabilities (e.g., LRP) models.

Conclusion

This analytical synthesis and systematic review indicates that, CardioPatternFormer, transformer-based interpretable ECG classification, has good multi-pathology detection, as well as, show clinically useful interpretability. The model measured well on macro level assessment measures including; epistemic accuracy, Likert and on micro level measures including; overall popularity as it performed better than the traditional deep learning baselines, including LSTM, CNN and hybrid attention networks. The fact that it performs better in divergent noisy conditions defines its suitability in real life ECG recording conditions where signal attenuation is a common phenomenon. Moreover, the CardioPatternFormer clearly provides diagnostic hints, through attention maps and relevance propagation, whereby, the cardiologists can make sure that they visualized the presence of limitations by assessing the applicability of the radial maps and interaction among available physiological ECG samples. It has a high accuracy, high robustness, and interpretability and, therefore, the model is a good tool that must be employed in AI-assisted cardiovascular diagnostics.

Future Scope

Further research is needed to enhance CardioPatternFormer with multi-modal physiological data, i. e. PPG or accelerator sensor data, to detect better fine arrhythmias and motion artifacts. Using the model in the real-time, resource-bound conditions (e.g., wearable devices), one might be able to take into account the continuous ambulatory tracking using AI inference about the device. This will require conducting clinical validation in large, non-homogeneous and multi-centered datasets in order to make sure that it is applicable to other populations as well as to accommodate changes to the hardware. Otherwise it would also be good to position causal interpretability frameworks, uncertainty quantification and clinician in the loop feedback so that trust, adoption and regulatory compliance is increased. CardioPatternFormer can ultimately be developed, in the long-run, into a comprehensive, clinically viable solution of the early cardiac disease and risk stratification on an individualized basis.

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