

Cardiac Telerehabilitation with a smartwatch and a smartphone gamification application: A feasibility study

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Abstract

Background: Home-based cardiac rehabilitation (HBCR) utilizing digital health technologies (cardiac telerehabilitation, CTR) has emerged as a practical alternative to conventional center-based cardiac rehabilitation (CBCR), particularly during and after the COVID-19 pandemic. However, maintaining sustained participation in cardiac rehabilitation (CR) remains a challenge. Gamification holds potential to enhance motivation and adherence in CR, but its role in CTR for acute coronary syndrome (ACS) patients remains understudied.

Objective: This feasibility study evaluated the acceptability, safety, and preliminary efficacy of a combination of a gamification-enabled smartphone app and smartwatch supporting CTR after ACS. We focused specifically on participation motivation, adherence to prescribed exercise intensity, and short-term physiological outcomes.

Methods: This single-arm, pre-post intervention study was conducted at two Japanese institutions. Sixteen patients diagnosed with ST-elevated myocardial infarction (STEMI) or non-ST-elevated myocardial infarction (NSTEMI) and undergoing percutaneous coronary intervention (PCI) were enrolled after discharge. Each patient received a smartphone and smartwatch connected to the “Shin-po Kei” app, earning points when exercising within their aerobic threshold heart rate ± 10 bpm. The one-month intervention prescribed walking for 30 minutes or more, 3-5 days per week, at Borg scale 11-13 intensity. The primary endpoint was total app usage rate. Secondary endpoints included appropriate exercise rate, changes in peak oxygen consumption (peak $\dot{V}O_2$), and changes in perceived exertion using a visual analog scale (VAS).

Results: The mean patient age was 62 ± 13 years, and 94% were male. The mean intervention duration was 29 ± 6 days, and the overall app usage rate was 59.9%. The appropriate exercise implementation rate was 32.9%. Peak $\dot{V}O_2$ significantly increased from 18.4 ± 4.1 to 21.1 ± 5.4 mL/kg/min ($P = .004$), and the mean VAS score for exercise discomfort decreased from 57 ± 33 to 32 ± 26 ($P = .007$). A significant positive correlation was observed between total app usage days and days of appropriate exercise performance ($r = 0.606$, $P = .017$). No adverse events related to app usage occurred during the study period.

Conclusions: This feasibility study suggests that a smartwatch-linked gamified smartphone app may contribute to promoting participation in CTR after ACS, with observed improvements in exercise capacity and reductions in exercise-related discomfort. These findings indicate that gamification could be one component of digital cardiology interventions aimed at improving adherence and supporting recovery in post-ACS CR. Larger randomized controlled trials are needed to confirm efficacy, sustainability, and long-term outcomes. Clinical Trial: GamiHeart pilot study (UMIN000046777)

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Original Manuscript

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[Abstract]

Background: Home-based cardiac rehabilitation (HBCR) utilizing digital health technologies (cardiac telerehabilitation, CTR) has emerged as a practical alternative to conventional center-based cardiac rehabilitation (CBCR), particularly during and after the COVID-19 pandemic. However, maintaining sustained participation in cardiac rehabilitation (CR) remains a challenge. Gamification holds potential to enhance motivation and adherence in CR, but its role in CTR for acute coronary syndrome (ACS) patients remains understudied.

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sustainability, and long-term outcomes.

Keywords: cardiac telerehabilitation; smartphone app; wearable technology; gamification; digital health; acute coronary syndrome



[Introduction]

Home-based cardiac rehabilitation (HBCR) is emerging as a feasible and effective alternative to traditional center-based cardiac rehabilitation (CBCR) for patients with cardiovascular disease^{1,2}. HBCR achieves comparable improvements in exercise capacity, quality of life (QoL), and management of cardiovascular risk factors while offering enhanced convenience, reduced burden of hospital travel, and improved access, particularly for the elderly and residents of rural or medically underserved areas¹. Furthermore, HBCR has high patient satisfaction and the potential to reduce healthcare costs^{1,3}. However, recent CBCR participation rates in Japan remain low: 7% for heart failure (HF), 9% for acute coronary syndrome, and 3% for stable coronary artery disease^{4,5}. Contributing factors include a shortage of facilities offering cardiac rehabilitation (CR), low awareness among patients and healthcare providers, and geographical barriers such as remote islands and mountainous regions⁶. These barriers hinder sustained participation in hospital-based programs and limit the reach of conventional CR. To overcome these challenges, HBCR with telemedicine-based approaches—collectively termed cardiac telerehabilitation (CTR)—was developed. CTR utilizes digital health technologies such as smartphones and wearable devices to provide remote exercise coaching, patient education, and lifestyle support⁷. Evidence suggests CTR can achieve outcomes equivalent to or superior to traditional CR in terms of compliance, hospitalization rates, and long-term maintenance of physical activity.

The use of smartphone apps (mobile health) in cardiology is rapidly expanding with promising results. For example, blood pressure (BP) management apps have demonstrated significantly superior BP control effects⁸. Smartwatches recording chest electrocardiograms (ECGs) show high similarity to conventional 12-lead ECG⁹. A recent randomized controlled trial (RCT) found that a smartphone app linked to a Bluetooth-connected monitoring device improved dyspnea symptoms in HF patients¹⁰. However, few studies have evaluated smartphone apps incorporating "gamification"¹¹—integrating game elements into CR—for managing coronary artery disease.

A critical challenge is whether users will consistently use the app at the intended frequency. Continuous use is essential for achieving health benefits, but ensuring adherence is difficult. Furthermore, can the app reliably improve physical activity as intended? Gamification elements like points and rewards may enhance motivation and contribute to reducing cardiovascular risk¹². However, do these features lead to significant improvements in exercise motivation? Smartphone apps incorporating reward systems directly linked to exercise around aerobic threshold heart rate (ATHR) have been virtually nonexistent. While gamification approaches targeting

step goals have been reported¹³, to our knowledge, there are no examples specifically tailored to exercise prescription in CR based on cardiopulmonary exercise testing (CPET).

This feasibility study explores the applicability of a gamified smartphone app combining ATHR-based point-earning functionality with heart rate (HR) monitoring via a smartwatch for CR. It specifically focuses on evaluating its acceptability and procedural feasibility as a foundation for future large-scale intervention development.

[Methods]

Study Design

This prospective comparative study aimed to evaluate the usefulness of a gamified smartphone app in CTR. Sixteen patients with ST-elevated myocardial infarction (STEMI) or non-ST-elevated myocardial infarction (NSTEMI) were enrolled and underwent CTR using a smartphone app and smartwatch immediately after discharge. The app incorporated gamification features, allowing users to earn points for exercise within an appropriate HR range and providing feedback based on points earned.

Recruitment

Patients were recruited from two facilities in Kawasaki City, Japan (St. Marianna University Hospital and Kawasaki City Tama Hospital). Eligible patients were those diagnosed with STEMI or NSTEMI based on the criteria of the Japanese Circulation Society 2018 guideline on Diagnosis and Treatment of Acute Coronary Syndrome¹⁴, who underwent coronary intervention, routinely used a smartphone, and were able to walk outdoors without assistance. All patients received a written explanation of the study protocol and provided written informed consent prior to enrollment. Exclusion criteria included inability to provide consent, severe disease (e.g., cancer, collagen disease), or mobility impairment requiring assistance.

Intervention

Patients in the intervention group participated in the CTR program after discharge. This program included warm-up/cool-down stretches, aerobic exercise, and resistance training, which were explained in advance by physicians and physical therapists prior to discharge. The aerobic exercise component was supported by digital devices. Patients were loaned an iPhone 7® (Apple, Cupertino, CA, USA) and an Apple Watch Series 3 (Apple, Cupertino, CA, USA). The “Shin-po Kei” app was installed on the smartphone and paired with the smartwatch via Bluetooth. Patients were instructed to perform stretching and resistance training, plus aerobic exercise consisting of walking

for at least 30 minutes (Borg scale 11–13) on 3–5 days per week. The intervention period ran from the discharge date until the first post-discharge outpatient follow-up (1 month later). The app recorded HR and exercise duration, awarding points for exercise within the target HR range ($ATHR \pm 10$ bpm). Since CPET was not performed, the target HR range was estimated using a validated formula¹⁵. Four points were awarded for each minute spent within the target HR range, allowing a maximum of 120 points for a 30-minute exercise. Points were deducted at a rate of 2 points per minute for exceeding the target range. These precautions were implemented because patients were immediately post-discharge and safety was the top priority. Daily achievement status provided feedback and visual data (e.g., graphs) (**Figure 1**).

Outcome Measures and Data Collection

The primary endpoint was the frequency with which patients appropriately performed CTR using the smartphone app during the period from discharge to the first outpatient visit. Appropriate CTR use was defined as exercising for at least 30 minutes per day within the target HR range, earning 120 points. Secondary endpoints included changes in BMI, peak VO_2 , LDL-cholesterol, HbA1c, and depression/anxiety symptoms (Hospital Anxiety and Depression Scale, HADS). Additional secondary endpoints included changes in exercise-related discomfort (Visual Analog Scale [VAS], 0-100), correlations between Type D personality (DS-14) and primary endpoints, and the incidence of new complications. A questionnaire regarding app usage was also administered, assessing the app's contribution to exercise (Q1), reasons for exercise discontinuation (Q2), inconveniences encountered during app use (Q3), and potential gamification elements that could enhance motivation for aerobic exercise if incorporated in the future (Q4).

Statistical analysis

Statistical analyses were performed using R software (version 4.3.2, R Foundation for Statistical Computing). Data are presented as mean (standard deviation), median [interquartile range], or percentages. The chi-square test was used for proportions, paired t-tests for pre-post comparisons, and Pearson's or Spearman's correlation for parametric or non-parametric data, respectively. A two-tailed $P < .05$ was considered significant. Based on prior research¹⁶, the pilot study sample size was calculated as 10% of the projected sample for the larger RCT (150 patients), requiring at least 15 patients.

[Results]

From April to August 2022, 35 consecutive patients met the inclusion criteria,

of whom 16 enrolled. Eight patients were admitted to St. Marianna University Hospital, and eight were admitted to Kawasaki Municipal Tama Hospital. **Table 1** shows the baseline characteristics of the patients. The mean age was 62 ± 13 years, and 94% ($n = 15$) were male. STEMI accounted for 81% ($n = 13$) of cases. The mean intervention period was 29 ± 6 days, and the mean length of hospital stay was 12 ± 1 days.

The overall app usage rate (number of login days/number of intervention days) was 59.9% (282/471 days). The rate was 61.4% (145/236 days) in the first half and 56.6% (133/235 days) in the second half. The rate of adequate exercise (≥ 120 points per day) was 32.9% (155/471 days). For secondary outcomes, peak VO_2 significantly increased from 18.4 ± 4.1 mL/min/kg to 21.1 ± 5.4 mL/min/kg ($P = .004$). The VAS for exercise discomfort significantly decreased from 57 ± 33 to 32 ± 26 ($P = .007$). A significant positive correlation was observed between the number of days the app was used and the number of days of adequate exercise (“120 points” exercise achievement days) ($r = 0.606$, $P = .017$, **Figure 2**). No significant differences were observed in pre- and post-intervention laboratory data (LDL-cholesterol, HbA1c) or HADS scores, nor was a significant correlation found between DS-14 scores and app usage rate. No adverse events related to app usage were reported.

Survey responses revealed the following: In Q1, “display of results” (e.g., step count, HR, points) was the most common response (4 out of 16 patients). For Q2, reasons for exercise interruption included “hot weather” (3/16), “effort required for exercise” (2/16), and ‘hospitalization’ (1/16). For Q3, 11/16 responded “none in particular”; one each cited “discrepancy between points and self-assessment” and “smartwatch battery drain”. Regarding Q4, 14 out of 16 patients responded. The most common answers were “level system (levels increase with points)” (9/14 patients) and “calendar display (allows quick daily progress checks in calendar format)” (9/14 patients). The next most common responses were “monetary rewards” (6/14 patients), “non-monetary rewards” (4/14 patients), and “character development (allowing users to grow a character within the app [e.g., earning points through exercise therapy makes the character stronger])” (4/14 patients).

[Discussion]

This feasibility study found a smartphone app usage rate of 59.9% over one month, suggesting that the gamification app may have been well integrated into CTR; however, causal relationships cannot be inferred from this study. Furthermore, the use of smartphone apps equipped with gamification features and smartwatches improved peak VO_2 , and this intervention was safe for patients after MI.

Adults are recommended to engage in 150–300 minutes of moderate-intensity physical activity per week (including 30 minutes of exercise nearly every day)¹⁷. Generally, the retention rate for health and fitness tracker apps is estimated to drop to 10% within 30 days of installation¹⁸. The 59.9% usage rate is a reasonable result for this pilot phase. However, a tendency toward declining usage was observed in the latter part of the intervention period. This aligns with prior findings indicating sustained engagement with mobile health apps becomes challenging over time. Previous reports attribute this decline to diminishing novelty, competing daily demands, reduced intrinsic motivation, and technical issues such as device synchronization and battery depletion¹⁸. Our findings may reflect these common barriers to digital health adoption. The significant positive correlation observed between app usage and the number of days with adequate exercise suggests that gamified apps may support appropriate physical activity. Studies investigating CR with app or home-based system follow-up have demonstrated improvements in peak VO_2 and health-related QoL, with some showing significant gains at one year and others confirming effects at 12 weeks^{19,20}. This study observes similar trends, with improvements in peak VO_2 and exercise-related hassle (VAS).

Gamification has been shown to enhance motivation and physical activity levels^{13,21}, and a recent meta-analysis reported its beneficial effects on glycemic control in type 2 diabetes through improved physical activity¹². The "Shin-po Kei" app employs a gamification technique involving earning and losing points based on HR, which may have contributed to the favorable outcomes. This mechanism can be understood within a behavioral change framework: points function as non-monetary informational rewards, providing immediate feedback and progress monitoring, which are established behavioral change techniques (e.g., self-monitoring, feedback, goal setting)²². Meta-analytic evidence supports that gamification elements like points and levels can increase physical activity and improve clinical outcomes by enhancing motivation even without monetary incentives²³. Evidence indicates that game elements such as points provide immediate and continuous feedback, reinforcing behavior by satisfying the psychological needs of “competence” and “autonomy”—core principles of behavioral change theory²⁴. However, exercise intensity (exercise within target HR zones) was not optimal. This is likely due to the app's safety rules penalizing exceeding the upper HR limit, which may be set too low for patients with mild myocardial ischemia (refer to Q3 response). Future studies should revisit the point system.

Importantly, this CTR study included elderly patients but found no significant adverse events, supporting the safety of mobile CR app use. Other gamification studies

also report no clear harm^{13,25}; the use of smartphone apps in CR appears to be generally safe.

This feasibility study has several limitations. The sample size was small, and the efficacy of gamified smartphone apps should be evaluated in larger RCTs. As mentioned, participation rates were low, potentially introducing selection bias. The reasons for excluding 19 of the 35 screened patients could not be determined, limiting this study. However, the prior research²⁶ has highlighted the importance of “digital health readiness” in addressing this issue. Future research should consider introducing tools such as digital health readiness questionnaires to further enhance patient engagement. Furthermore, while gamification is an integral component of the app used in this study, it is not an isolated feature but is closely intertwined with other functionalities. Isolating the gamification elements from other aspects of the app is challenging, and the results observed in this study may reflect the combined effect of the entire app, including its gamification features.

[Conclusion]

This feasibility study suggests that a smartphone app incorporating gamification can be safely used in cardiac telerehabilitation. Particularly in patients after acute coronary syndrome, this app tends to contribute to improved patient engagement, with gamification potentially being key to sustaining this engagement. Furthermore, this intervention resulted in a significant improvement in peak VO₂, suggesting enhanced cardiovascular fitness. Larger-scale trials are needed to validate these findings and explore the broader potential of digital health interventions in cardiac rehabilitation.

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Not applicable.

[Conflict of interest]

The Authors declare that there is no conflict of interest.

[Authors contributions]

TK contributed to the conception or design of the work. YA, MN, KS, TY, YU, ST, SD, KH, YK, AK, YK, TK, and MK contributed to the acquisition of the dataset. TK contributed analysis or interpretation of the data. YA drafted the manuscript. All authors gave final approval and agree to be accountable for all aspects of the work ensuring integrity and accuracy. The first (YA) and second (TK) authors contributed equally to the writing process.

[Availability of data and materials]

All dataset analyzed are included in this manuscript.

[Ethical considerations]

The protocol, informed consent form and other study-related documents received approval from the Ethics Committee of St. Marianna University School of Hospital. The study is implemented according to the Declaration of Helsinki (Appendix III) and Good Clinical Practice.

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Figure 1. “Shin-po Kei” app screens

The left screen shows the number of steps (today and total), the Borg scale, and a step count histogram. The center screen displays exercise distance, calories burned, and exercise time. The right screen shows a line graph with heart rate (bpm) on the y-axis and exercise time (minutes) on the x-axis. Each screen also shows the points earned for the day, along with an automatically generated comment based on the points.

Figure 2. Correlation between the number of days the app was used and the number of days of adequate exercise

Abbreviations

ATHR: aerobic threshold heart rate

BP: blood pressure

CBCR: center-based cardiac rehabilitation

CPET: cardiopulmonary exercise testing

CR: cardiac rehabilitation

CTR: cardiac telerehabilitation

HADS: Hospital Anxiety and Depression Scale

HBCR: home-based cardiac rehabilitation

HR: heart rate

NSTEMI: non-ST-elevated myocardial infarction

QoL: quality of life

RCT: randomized controlled trial

STEMI: ST-elevated myocardial infarction

VAS: visual analogue scale

VO₂: oxygen consumption

Table 1. Baseline Characteristics

Characteristic	Overall (n = 16)
Age, years	62 ± 13
Male sex	15 (94%)
BMI, kg/m ²	25.4 ± 4.0
Smoking status	
Current	5 (31%)
Former	6 (38%)
Never	4 (25%)
Diagnosis	
STEMI	13 (81%)
NSTEMI	3 (19%)
LVEF ≥ 50%	12 (75%)
Laboratory data	
LDL-cholesterol, mg/dL	116 [101, 127]
Estimated GFR, mL/min/1.73 m ²	58 [52, 69]
Intervention data	
Length of hospital stay, days	12 ± 1
Intervention duration, days	29 ± 6

Values are presented as n (%), mean ± standard deviation, or median [interquartile range].

STEMI, ST-elevated myocardial infarction; NSTEMI, non-STEMI; LVEF, left

ventricular ejection fraction; LDL, low density lipoprotein; GFR, glomerular filtration rate

Supplementary Files

Figures

“Shin-po Kei” app screens.



Correlation between the number of days the app was used and the number of days of adequate exercise.

