INTRODUCTION

Cardiovascular diseases (CVDs) are the major public health problem, claiming the lives of 17.9 million people per year worldwide. In low- and middle-income countries, these non-communicable diseases are causing 82% of premature deaths altogether. Acute coronary syndrome (ACS) is one...
of the most common CVDs, which affects about 12 million people annually, with 600,000 of them dying. These premature deaths can be minimised by using population-wide approaches to mitigate lifestyle risk factors, namely tobacco use, sedentary lifestyle and malnutrition, physical inactivity, and harmful alcohol use. Despite modern cardiovascular early diagnosis and advance medications, these diseases still have high morbidity and mortality.

ACS has been documented in many studies to substantially impact the sufferer’s health-related quality of life (HRQoL), which is as essential as other clinical outcomes. HRQoL is a multidimensional term that encompasses a person’s physical, emotional, and social well-being that is a well-known indicator of mortality in the general population and mortality and morbidity after ACS diagnosis or related event. As a secondary preventive measure, CR is a professionally administered programme first introduced in the 1960s and 1970s as a critical tool for stabilising patients following a severe cardiac event (myocardial infarction or cardiac surgery).

The American Heart Association (AHA) has recommended CR, and it has been advised in clinical practice guidelines, but post-ACS patients’ participation in CR programmes is extremely limited and underutilised. This is especially true in low-resource areas, like Pakistan, where the epidemic is most severe. The reasons are numerous and include obstacles in the healthcare system, programmes, and at the patient level. The problem lies in CR underutilisation as about 20% or fewer patients enrol in them therefore AHA has also stressed the importance of incorporating newer methods for chronic disease treatment that can be delivered over the phone, the internet, or other forms of communication.

Health initiatives are nowadays enabled by mobile health (mHealth), in which smartphone applications have shown positive health effects in secondary prevention. During the ongoing COVID-19 crisis, the role of mhealth in health care is becoming increasingly relevant. There is a need to assess the effectiveness of mHealth-based CR in future studies.

In Pakistan, where the public health system is still underdeveloped, the CR can significantly improve functional outcomes and quality of life, it is rarely used in clinical settings across the country. CR’s mhealth transition can educate and encourage patients in self-management, physical activity, healthy diet and other lifestyle modifications. This randomised controlled trial aimed to develop and evaluate the effectiveness of Mobile health augmented Cardiac rehabilitation (MCard) at improving HRQoL in post-ACS patients.

METHODS

At the Armed Forces Institute of Cardiology (AFIC), a tertiary care hospital in Rawalpindi, Pakistan, a two-arm randomised controlled trial was conducted in which mobile health augmented cardiac rehabilitation (MCard) was developed and implemented on post-ACS patients from January 2019 until March 2021. The trial conforms to the CONSORT statement 2010. The CONSORT checklist is attached in Supplementary File-1. Post-ACS patients (ST-elevation myocardial infarction, non-ST elevation myocardial infarction, and unstable angina) admitted to AFIC during the study period were identified and enrolled after applying eligibility criteria. All the participants were given self-monitoring devices (digital blood pressure apparatus, weight machine and pedometer) along with a booklet to record their measurements.

The intervention group received the MCard intervention, a medically supervised cardiac rehabilitation program in addition to standard post-ACS care. The first phase of the MCard included individualised psychotherapy during the hospital stay. The second phase included diurnal mobile texting of standardised messages about healthy lifestyle changes through a specially developed app. The control group received standard post-ACS care. The trial protocol in its entirety has already been published. The trial is also registered in the Australian New Zealand Clinical Trial Registry (ANZCTR) (ACTRN12619001731189).

Data were collected at three-time points, at baseline, 12 weeks follow-up, and then at 24 weeks follow-up, by a research associate who was blinded to the group status of the enrolled participants. The primary outcome was HRQoL, which was calculated using a standardised HRQoL short form 12 (SF-12) and MacNew quality of life after myocardial infarction (MacNew QLMI Data were entered and analysed in STATA 14. Categorical data were presented as frequencies and percentages, and the two groups were compared using chi-square tests. For continuous data, means with 95% confidence intervals (95% CI) were presented and, for comparisons, independent sample t-tests were used where appropriate. A p-value of <0.05 was taken as significant.

Ethical Approval: (Ref: DIR/KMU-EB/MII/000486, Dated: 19-11-2018).
RESULTS

A total of 185 eligible patients were screened for the study. Twenty-two were not eligible, and three declined to participate. One hundred and sixty post-ACS patients were included and evenly randomised in a 1:1 ratio into two groups of 80 (control and intervention). At 12 weeks follow-up, 121 (75.62%) were analysed as 18 were lost to follow up (control: 13, intervention: 5) and 21 died (control: 17, intervention: 4). An additional one was lost to follow-up (control), and one died (intervention) at 24 weeks, leaving 119 (74.37%) with complete data. (Fig.1).

The participants’ mean age at baseline was 52.66 ± 8.46 years. Overall, predominantly men were enrolled (n=126, 78.75%) as compared to females (n=34, 21.25%). Punjabi ethnicity was the majority (n= 119, 74.38%), followed by Pashtun (n=21, 13.13%) (Table-I).

The mean physical component scores for the control and intervention groups were 41.67, 95% CI 40.62, 42.73 vs 41.78, 95% CI 40.96, 42.59 at baseline (p-value=0.879), 43.87, 95% CI 42.17, 45.58, vs 48.93, 95% CI, 47.35, 50.50 at 12 weeks follow-up (p-value<.001), and 46.82, 95% CI 45.37, 48.26 vs 53.52, 95% CI 52.57, 54.46 at 24 weeks follow-up (p-value<.001). The mean mental component
scores for the control and intervention groups were 43.13, 95% CI 41.97, 44.29 vs 43.36, 95% CI 41.99, 44.73 at baseline (p-value=0.801), 41.40, 95% CI 40.18, 42.62 vs 44.84, 95% CI 43.42, 46.26, at 12 weeks follow-up (p-value <0.001), and 40.12, 95% CI 38.71, 41.53 vs 48.95, 95% CI 47.42, 50.49, at 24 weeks follow-up (p-value <0.001). Consistent with the two component scores, almost all the domains of SF-12 (other than RP and RE domains) showed significant increase among the intervention group, in contrast to the control group, at both follow-up periods (Table-II, Fig.2).
At 12- and 24-weeks follow-up, all the domains of MacNew QLMI showed statistically significant increase among the MCard vs control group in their mean scores. At 12 weeks follow-up, the social MacNew QLMI was 4.05, 95% CI: 3.85, 4.25 vs 4.55, 95% CI: 4.32, 4.78, p-value<.001 and lastly global domain, 4.10, 95% CI: 3.91, 4.29 vs 4.49, 95% CI: 4.32, 4.66, p-value=.002, respectively. At 24 weeks follow-up, the social MacNew QLMI mean score was increased significantly among the intervention groups vs controls (5.28, 95% CI: 5.07, 5.50, p-value<.001 vs 4.08, 95% CI: 3.84, 4.31, p-value<.001). There was also an increased scored of emotional domain, (5.22, 95% CI: 4.99, 5.45 vs 4.04, 95% CI: 3.81, 4.27, p-value<.001), then physical domain, (4.80, 95% CI: 4.58, 5.02 vs 4.20, 95% CI: 3.99, 4.40, p-value<.001) and in global domain (4.96, 95% CI: 4.76, 5.16 vs 4.10, 95% CI: 3.93, 4.28, p-value=0.001) (Table-III, Fig.3).

| Table-II: Health-related quality of life, assessed by Short Form 12, at baseline and follow-up. |
|--------------------------------------------------------------------------------------------------------------|
| **Baseline** | **12 weeks** | **24 weeks** |
| Mean (95% CI) | p-value | Mean (95% CI) | p-value | Mean (95% CI) | p-value |
| **Physical function** | | | | | |
| Control | 38.93 (36.91,40.94) | 0.467 | 42.26 (39.97, 44.55) | <.001 | 45.65 (43.25, 48.05) | <.001 |
| Intervention | 39.80 (38.51,41.09) | | 48.96 (46.61, 51.31) | | 54.81 (53.48, 56.13) | |
| **Role physical** | | | | | |
| Control | 39.95 (38.71, 41.19) | 0.495 | 40.87 (39.52, 42.22) | 0.311 | 41.40 (40.26, 42.53) | 0.111 |
| Intervention | 40.53 (39.37, 41.69) | | 41.84 (40.55, 43.14) | | 43.43 (41.47, 45.40) | |
| **Bodily pain** | | | | | |
| Control | 41.71 (39.88, 43.55) | 0.460 | 41.49 (39.42, 43.56) | <.001 | 43.92 (41.73, 46.11) | <.001 |
| Intervention | 42.62 (41.03, 44.21) | | 48.45 (46.65, 50.25) | | 53.34 (51.89, 54.80) | |
| **General Health** | | | | | |
| Control | 44.91 (42.52, 47.31) | 0.122 | 46.69 (42.26, 47.11) | <.001 | 47.14 (45.37, 48.91) | <.001 |
| Intervention | 47.22 (45.48, 48.96) | | 51.41 (49.69, 53.14) | | 56.01 (54.94, 57.08) | |
| **Vitality** | | | | | |
| Control | 49.55 (47.65, 51.46) | 0.075 | 49.46 (47.77, 51.15) | 0.003 | 48.26 (46.45, 50.07) | <.001 |
| Intervention | 51.77 (50.21, 53.32) | | 53.22 (51.47, 54.96) | | 59.46 (58.27, 60.65) | |
| **Social functioning** | | | | | |
| Control | 40.22 (39.07, 41.37) | 0.789 | 40.35 (38.91, 41.80) | 0.460 | 40.56 (38.96, 42.15) | <.001 |
| Intervention | 40.44 (39.26, 41.62) | | 41.24 (39.51, 42.96) | | 48.64 (46.97, 50.31) | |
| **Role emotional** | | | | | |
| Control | 35.68 (33.86, 37.50) | 0.914 | 35.90 (34.22, 37.59) | 0.281 | 36.55 (35.18, 37.91) | 0.111 |
| Intervention | 35.81 (34.28, 37.34) | | 37.17 (35.60, 38.74) | | 39.05 (36.63, 41.47) | |
| **Mental health** | | | | | |
| Control | 44.77 (43.22, 46.33) | 0.387 | 42.63 (40.70, 44.57) | <.001 | 42.19 (40.06, 44.33) | <.001 |
| Intervention | 45.78 (44.07, 47.48) | | 51.36 (49.59, 53.13) | | 55.27 (53.98, 56.56) | |
| **Physical component score** | | | | | |
| Control | 41.67 (40.62, 42.73) | 0.879 | 43.87 (42.17, 45.58) | <.001 | 46.82 (45.37, 48.26) | <.001 |
| Intervention | 41.78 (40.96, 42.59) | | 48.93 (47.35, 50.50) | | 53.52 (52.57, 54.46) | |
| **Mental component score** | | | | | |
| Control | 43.13 (41.97, 44.29) | 0.801 | 41.40 (40.18, 42.62) | <.001 | 40.12 (38.71, 41.53) | <.001 |
| Intervention | 43.36 (41.99, 44.73) | | 44.84 (43.42, 46.26) | | 48.95 (47.42, 50.49) | |
### Table-III: Myocardial infarction specific MacNew QLMI among the control and intervention groups.

|                  | Baseline | 12 weeks | 24 weeks |
|------------------|----------|----------|----------|
|                  | Mean (95% CI) | p-value | Mean (95% CI) | p-value | Mean (95% CI) | p-value |
| **MacNew Global**|  |  |  |  |  |  |
| Control          | 3.94 (3.87, 4.01) | 0.141 | 4.10 (3.91, 4.29) | 0.002 | 4.10 (3.93, 4.28) | <0.001 |
| Intervention     | 3.87 (3.81, 3.93) |  | 4.49 (4.32, 4.66) |  | 4.96 (4.76, 5.16) |  |
| **MacNew Physical**|  |  |  |  |  |  |
| Control          | 4.07 (3.98, 4.17) | 0.079 | 4.05 (3.85, 4.25) | 0.001 | 4.20 (3.99, 4.40) | <0.001 |
| Intervention     | 3.98 (3.92, 4.03) |  | 4.55 (4.32, 4.78) |  | 4.80 (4.58, 5.02) |  |
| **MacNew Emotional**|  |  |  |  |  |  |
| Control          | 3.77 (3.71, 3.82) | 0.565 | 3.92 (3.68, 4.17) | <0.001 | 4.04 (3.81, 4.27) | <0.001 |
| Intervention     | 3.79 (3.73, 3.85) |  | 4.73 (4.51, 4.94) |  | 5.22 (4.99, 5.45) |  |
| **MacNew Social**|  |  |  |  |  |  |
| Control          | 4.03 (3.98, 4.09) | 0.810 | 4.05 (3.82, 4.29) | <0.001 | 4.08 (3.84, 4.31) | <0.001 |
| Intervention     | 4.02 (3.97, 4.08) |  | 4.96 (4.75, 5.17) |  | 5.28 (5.07, 5.50) |  |

### DISCUSSION

This trial used mHealth to encounter the underutilisation of CR and provided evidence-based results that the two-component score (PCS and MCS) and the eight domains measured by SF-12 were significantly better among the intervention group than the control group. Similarly, a disease-specific measure of HRQoL, the MacNew QLMI, also demonstrated improvements in the intervention group at 12- and 24-weeks follow-up.

![Fig.2: Comparison of HRQOL domains mean score changes at baseline, 12 weeks and 24 weeks among the two groups.](image1)

![Fig.3: Comparison of MacNew QLMI mean scores at baseline, 12 weeks and 24 weeks follow-ups among the two groups.](image2)
up in all domains (social, emotional, physical and
global) compared with the baseline.

The average age of the enrolled participants
was 71.1±10 years, which is higher than the average
age of the participants in this sample (52.69 ±
8.47 years), most likely due to the Pakistani ACS’s
population’s low median age. However, 160 post-
ACS patients were included, which is similar to
the number achieved by Saadi et al.10 The majority
(73.5%) of the study population were male, similar
to this study (80 per cent). A mhealth based study11
on a total of 34 participants at 12 months follow-
up period concluded that HRQoL was significantly
improved in terms of both PCS and MCS using SF-
36, similar to the result observed in this analysis
showed improvements in two-component scores
and eight HRQOL domains as measured by SF-12.
At 24 weeks, the mean PCS was 49 (95% CI: 48, 51),
while the mean MCS was 52. (95% CI: 50, 54). These
findings are comparable to this research, in which
the mean PCS and MCS in the intervention group
were 53.62 (95 percent CI: 52.73, 54.52) and 48.87 (95
percent CI: 47.42, 50.33) at 24 weeks, respectively.

According to the findings of one randomised trial,
a home-based CR programme with monthly rein-
forcements has no additional long-term functional
benefit over a regular, 4-week outpatient CR pro-
gramme.16 This study contradicts this because it
was a home-based clinical trial in which reinforce-
ments were provided through mobile texting. The
advanced mhealth technology used in this study
design may be the reason for the discrepancy but
needs further multicenter trial to validate.16

Another study concluded that all the MacNew
QLMI domains (physical, emotional, social, over-
all) showed a substantial difference in their
mean scores (P<0.001, P<0.001, P=0.003, and
P=0.001 respectively) which are consistent with
this study’s results in which improved MacNew
QLMI domains were observed as well. A systematic
review also concluded that those receiving CR
have shown improved HRQOL domains (global,
physical, emotional and social) compared to
the control group.17 Even though the changes in
HRQOL were slight, they nevertheless represent
general improvements in effectiveness compared
with standard treatment. This is similar to this
study results as all MacNew QLMI parameters have
improved in the MCard group. Also, the MCard is
low cost as the application has been made, and it
will be only the cost of text messages to bear.

Limitations of the study: Firstly, it was a single-
centre study; a larger study in future can be planned
as multi-centre trials to see the effect in a larger
patient population across different geographical
sites. Secondly, different subgroups of patients who
completed the MCard intervention may benefit
differently from the intervention. This research
had key strengths, one of which was that all of the
analyses were done based on intention to treat.
Furthermore, extended follow-up was included to
investigate whether benefits achieved at 12 months
persisted after that.

Our findings do not undermine the significance
of conventional CR; alternately, they demonstrate
the value of mhealth in CR by increasing CR utilisa-
tion, especially for patients who may not otherwise
join in CR due to various circumstances. Since be-
aviour change is a gradual process, any long-term
effects of MCard CR can be measured after 2–5
years, thereby addressing a gap in current knowl-
edge. Expanding MCard services around the coun-
try could help many post-ACS patients improve
their physical and mental well-being and decrease
the country’s non-communicable disease burden.

**CONCLUSION**

The MCard intervention is acceptable in a
developing country hospital setting and has
shown significant improvement in all domains of
generic and disease-specific HRQoL compared to
the control group. There was an improvement in
the physical, mental, social, emotional and global
domains among the MCard group compared to the
control group. Hence, our MCard program may be
adapted and added to the secondary prevention of
post-ACS in all tertiary care hospitals. Our findings
suggest this may also improve patient outcomes
and reduce the burden on the health care setting,
including outpatient physicians, in the longer run.

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Authors’ Contributions:

AH: Conceived and designed trial design, data acquisition and analysis, drafting work. Responsible and accountable for the accuracy or integrity of the work.

ZUH: Conception, design of the work and manuscript revision critically.

SA: Design of the work and conduct of the trial design, review of the final manuscript.

PD, JP: Review and final approval of the manuscript to be published.