



WeChat-Based Education and Rehabilitation Program Improves Physical Performance and Quality of Life in Patients with Acute Coronary Syndrome after Percutaneous Coronary Intervention

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WeChat provides the chance for online caring program to improve physical recovery and quality of life (QoL) in patients with cardio/cerebral vascular diseases, especially in special period such as coronavirus disease 2019 (COVID-19) spread time. This study intended to evaluate the influence of the WeChat-based education and rehabilitation program (WERP) on physical performance and QoL in patients with acute coronary syndrome (ACS) post percutaneous coronary intervention (PCI). Totally, 180 patients with ACS after PCI were randomized to the WERP (N = 90) and control care (CC) (N = 90) groups, then received corresponding caring program for 3 months. Short physical performance battery (SPPB) score, 6-minute walking distance (6MWT), EuroQol-5 dimensions (EQ-5D) score, and EuroQol-5 Visual Analog Scale (EQ-VAS) score were assessed at discharge, month (M)1, M2, and M3, respectively. Our study showed that SPPB score at M1 ($P = 0.029$), M2 ($P = 0.048$), and M3 ($P = 0.030$) was higher in WERP group than in CC group. Besides, 6MWT at M1 ($P = 0.026$), M2 ($P = 0.023$), and M3 ($P = 0.041$) were longer in WERP group than in CC group. Finally, EQ-5D score at M1 ($P = 0.022$) and M3 ($P = 0.023$) was lower, while EQ-VAS score at M1 ($P = 0.020$), M2 ($P = 0.013$), and M3 ($P = 0.039$) was higher in WERP group than in CC group. Subgroup analyses further showed that patients with baseline SPPB score ≤ 9 benefited more from WERP. Conclusively, WERP could be an option to improve physical performance and QoL in patients with ACS after PCI.

Keywords: acute coronary syndrome; percutaneous coronary intervention; physical performance; quality of life; WeChat-based education and rehabilitation program
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Introduction

Acute coronary syndrome (ACS) is a life-threatening cardiovascular disease with a common symptom of chest pain, and more than 7 million people are diagnosed with ACS worldwide each year (Bhatt et al. 2022). Common risk factors for patients with ACS include smoking, high blood pressure, high blood cholesterol, and diabetes (Bergmark et al. 2022). Percutaneous coronary intervention (PCI) is an effective treatment strategy for patients with ACS, which helps to open the narrowed or blocked sections of the artery and restore blood flow to the heart (Hoole and Bambrough 2020; Atwood 2022; Fanaroff and Nathan 2022).

Unfortunately, nearly 30% of post-PCI patients experi-

ence physical function decline, and fatigue, shortness of breath, and chest discomfort are common symptoms in patients with ACS after PCI; these factors may further impair the quality of life (QoL) in these patients (Tricoci et al. 2013; Skaggs and Yates 2016; Kim et al. 2019; Zhang et al. 2020; Tscharre et al. 2022; Li et al. 2023). Worse still, according to previous studies, even after successful PCI, the cardio-pulmonary function would be affected, which impairs their physical performance and QoL, and increases the risk of mortality in patients with ACS (Tse et al. 2017; He et al. 2022). Notably, some offline rehabilitation programs exhibit the potential to ameliorate these situations in patients with ACS who undergo PCI (Sunamura et al. 2018; Baldasseroni et al. 2022). However, due to the closure policy during the coronavirus disease 2019 (COVID-19) pan-

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demic period in China, patients with ACS who undergo PCI are not encouraged to participate in offline rehabilitation programs (Shi et al. 2020). Therefore, creating an online rehabilitation program to improve the physical performance and QoL in patients with ACS who undergo PCI is meaningful and may further enhance the outcome of these patients.

Currently, some online rehabilitation programs have emerged and exhibited the potential benefit in patients with cardiovascular diseases after PCI (Reid et al. 2012; Widmer et al. 2017; Fang et al. 2019; Li et al. 2022). For example, one study indicates that the 6-week home-based online supervised exercise program improves the physical performance in coronary artery disease (CAD) patients after PCI (Li et al. 2022). WeChat (Tencent Corporation, Shenzhen, China) is a multifunctional application that has been widely applied in China and neighboring countries due to its advantages of convenience, flexibility, and sociability (Nature Methods 2020). Recently, WeChat-based rehabilitation programs have shown certain benefits in improving psychological health, physical performance, and QoL in patients with various diseases, including cardiovascular diseases (Sui et al. 2020; Ma et al. 2021a; Song et al. 2021; Kang and Li 2022; Pang et al. 2022; Wang et al. 2022a). According to a previous study, WeChat-based education combined with a rehabilitation program improves physical function in patients with unstable angina pectoris (UAP) after PCI (Wang et al. 2022a). In addition, another study elucidates that the WeChat-based rehabilitation program attenuates anxiety and depression; it also improves the QoL in patients with unprotected left main coronary artery disease (ULMCAD) who undergo coronary artery bypass grafting (CABG) (Ma et al. 2021a). Although several interesting findings have been revealed by previous studies, the potential benefit of the WeChat-based rehabilitation programs in patients with ACS who undergo PCI remains unknown.

Accordingly, this study designed a WeChat-based Education and Rehabilitation Program (WERP), including education, rehabilitation training, and patient communication, and further explored the potential of WERP in improving physical performance and QoL in patients with ACS who underwent PCI.

Methods

Subjects, inclusion, and exclusion criteria

From October 2020 to August 2022, the randomized, controlled study continuously enrolled a total of 180 patients with ACS who underwent PCI. The inclusion criteria were: (1) diagnosed as ACS with the clinical manifestations of ST-elevation myocardial infarction (STEMI), non-ST-elevation myocardial infarction (NSTEMI), or unstable angina (UA) (Kimura et al. 2019); (2) aged ≥ 18 years; (3) received PCI surgery; (4) voluntarily accepted study and follow-up arrangements; (5) had a WeChat account and were proficient in using the application func-

tions to communicate and training; (6) were able to understand and express themselves. The exclusion criteria contained: (1) had malignancies; (2) had severe dysfunction of liver or kidney; (3) had diseases that affected walking such as knee osteoarthritis or hip osteoarthritis; (4) had cognitive impairment; (5) had active infections. The study was approved by the Ethics Committee of Shanghai Pudong Gongli Hospital. The patients or the guardians signed the informed consent form.

Sample size determination

According to clinical experience, the minimum sample size was calculated per a hypothesis that the mean short physical performance battery (SPPB) score at the 3rd month after discharge (M3) in the WERP group was 11, while the mean SPPB at M3 in the control care (CC) group was 10. The standard deviation (SD) was supposed as 2. With the significance (α) level of 0.05 and the power of 85%, the minimum sample size was 72 for each group and then adjusted to 90 considering the drop-out possibility of 20%.

Random assignment

Using the block randomization method (the block size was set to four), the patients were randomly assigned into two groups in a 1:1 ratio. The random numbers which were generated by SAS 9.2 (SAS Institute, Inc., Cary, NC, USA) software were used to randomly order the six sequences (ABAB, AABB, ABBA, BAAB, BBAA, and BABA) (Shqaidef et al. 2021). The grouping information and patients' information were sealed in the same opaque envelope, and each patient was randomly assigned to a selected group (CC group or WERP group). The process was done by a nurse who was completely unaware of the study.

WERP and CC

Patients were discharged at 8-12 days after PCI, then received CC (for the patients in the CC group) or WERP (for the patients in the WERP group). Restricted by the closed-off management during the COVID-19 pandemic period in China, all patients were discouraged to come to the hospital for education and rehabilitation training except for the necessary follow-up. The interventions in the CC group mainly contained health education, the distribution of health education-related manuals, and guidance on training content and movement details at the time of discharge. Besides, during the following three months, the telephone communication feedback by the doctors or nurses was performed as needed.

For the WERP group, patients were discharged from the hospital with the same guidance as patients in the CC group. In addition to this, we also promoted a professional rehabilitation program based on WeChat (Tencent Corporation). The WERP was performed for three months, which included three parts: (1) Education: The researchers pulled all patients into a WeChat communication group and asked them to follow an official account, which were man-

aged by the nurses who dominated the rehabilitation training. Following that, the researchers would explain in detail how the official account functions and how to use it. If the elders were unfamiliar with some of the functions when using the smartphone, a family member who was well versed in the application could handle it for him or her. On the official account, an information base was established including the disease-related information, treatment-related information, and rehabilitation-related information. Besides, patients were asked to read 2-3 contents in order per week, and communicate with doctors, nurses, or the other patients, when necessary, in the WeChat communication group. (2) Rehabilitation training: The patients were taught how to perform rehabilitation training at home according to the video from the official account by the doctors and nurses, including strength training and walking training. In order to supervise patients' training, they were required to record and upload rehabilitation training videos as requested, including strength training three times a week and walking training at least five times a week. When there was a problem with the rehabilitation training, the doctors or nurses would communicate and guide in the WeChat communication group in time. (3) Patient communication: Patients could share their experiences during the rehabilitation training with each other in the WeChat communication

group and provide timely feedback on the WeChat-based online rehabilitation training.

Follow-up and outcome assessment

Patients were followed up for three months, during which, SPPB score, 6-minute walking distance (6MWT), EuroQol-5 dimensions (EQ-5D), and Visual Analog Scale (EQ-VAS) were evaluated offline for patients at discharge (M0), 1st month (M1), 2nd month (M2), and 3rd month (M3) after discharge. The SPPB is a brief physical performance test that provides the researcher with important short-term prognostic information by summing test scores for standing balance, walking, and repeatedly getting up from a chair to form a composite performance score (range: 0-12), with higher SPPB scores indicating a better physical performance (Volpato et al. 2011). For analysis, the SPPB score was divided as low (4-6), intermediate (7-9), and high (10-12); as well as low-intermediate (4-9) and high (10-12) (Guralnik et al. 1995). The 6MWT measures the distance a patient can walk on a flat hard surface in 6 minutes, which reflects the patient's level of functional exercise; the longer the distance, the better condition of the patient (ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories 2002). The EQ-5D is a system that measures five dimensions which include mobility, self-care,

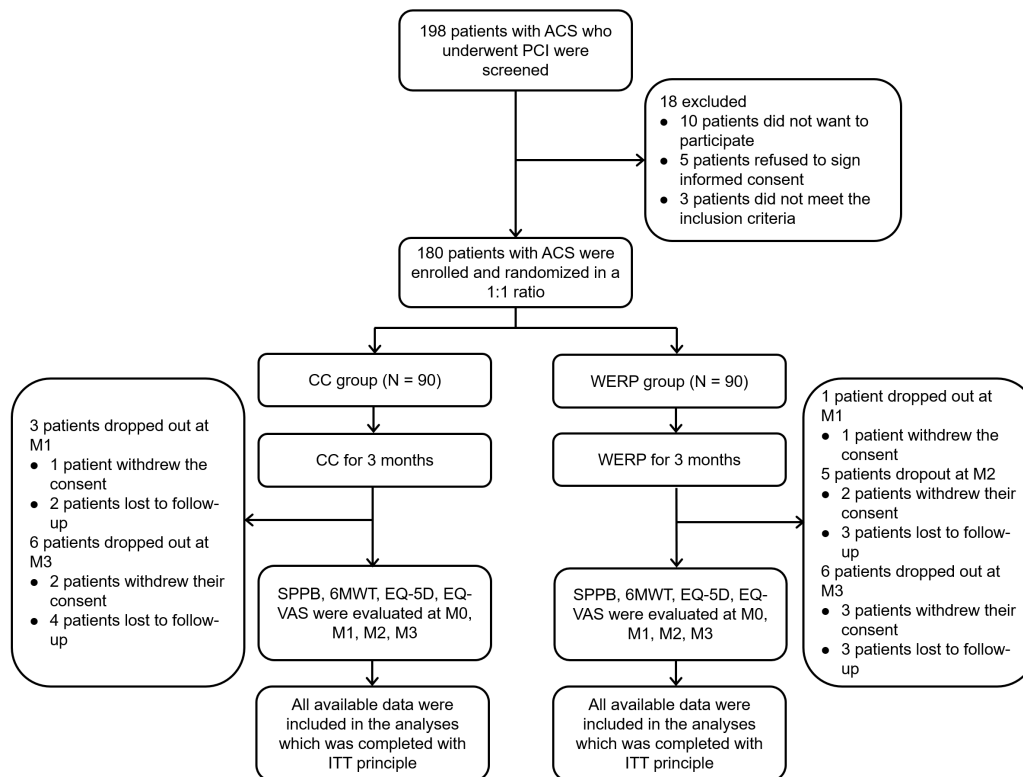


Fig. 1. Flow chart.

ACS, acute coronary syndrome; PCI, percutaneous coronary intervention; CC, control care; WERP, WeChat-based education and rehabilitation program; SPPB, short physical performance battery; 6MWT, 6-minute walking distance; EQ-5D, EuroQol-5 dimensions; EQ-VAS, EuroQol-visual analogue scale; ITT, intention-to-treat; M0, at discharge; M1, 1st month after discharge; M2, 2nd month after discharge; M3, 3rd month after discharge.

Table 1. Clinical characteristics of patients with acute coronary syndrome (ACS).

Items	CC group (N = 90)	WERP group (N = 90)	P value
Demographic characteristics			
Age (years), mean \pm SD	64.0 \pm 5.8	62.8 \pm 6.5	0.203
Sex, No. (%)			0.867
Male	65 (72.2)	66 (73.3)	
Female	25 (27.8)	24 (26.7)	
BMI (kg/m ²), mean \pm SD	24.7 \pm 3.3	25.5 \pm 3.2	0.110
Marital status, No. (%)			0.611
Married	68 (75.6)	65 (72.2)	
Single/divorced/widowed	22 (24.4)	25 (27.8)	
Employment status before PCI, No. (%)			0.697
Employed	15 (16.7)	17 (18.9)	
Unemployed	75 (83.3)	73 (81.1)	
Level of education, No. (%)			0.408
Primary school or less	21 (23.3)	16 (17.8)	
Middle or high school	40 (44.4)	57 (63.3)	
Undergraduate or above	29 (32.2)	17 (18.9)	
Location, No. (%)			1.000
Urban	82 (91.1)	82 (91.1)	
Rural	8 (8.9)	8 (8.9)	
Smoke, No. (%)			0.134
No	54 (60.0)	44 (48.9)	
Yes	36 (40.0)	46 (51.1)	
Medical history			
Hypertension, No. (%)			0.266
No	33 (36.7)	26 (28.9)	
Yes	57 (63.3)	64 (71.1)	
Hyperlipidemia, No. (%)			0.095
No	59 (65.6)	48 (53.3)	
Yes	31 (34.4)	42 (46.7)	
Diabetes, No. (%)			0.488
No	70 (77.8)	66 (73.3)	
Yes	20 (22.2)	24 (26.7)	
Biochemical indexes			
WBC (10 ⁹ /L), median (IQR)	10.5 (8.4-12.7)	10.4 (8.2-12.3)	0.444
FBG (mmol/L), median (IQR)	5.5 (4.8-6.3)	5.7 (4.6-6.6)	0.813
Scr (μ mol/L), median (IQR)	81.3 (69.6-90.3)	76.1 (69.6-87.4)	0.339
TG (mmol/L), median (IQR)	1.9 (1.0-2.6)	1.8 (1.0-2.1)	0.094
TC (mmol/L), median (IQR)	4.6 (3.9-5.5)	4.7 (3.9-5.5)	0.856
LDL-C (mmol/L), median (IQR)	3.2 (2.5-4.0)	3.3 (2.6-4.0)	0.901
HDL-C (mmol/L), median (IQR)	0.9 (0.8-1.2)	1.0 (0.8-1.2)	0.296
CRP (mg/L), median (IQR)	4.6 (3.3-6.5)	5.5 (3.7-6.9)	0.170
cTnI (ng/mL), median (IQR)	2.9 (0.08-4.0)	3.2 (0.4-5.0)	0.148
CK-MB (ng/mL), median (IQR)	17.8 (4.7-37.2)	24.2 (6.8-43.8)	0.279
Disease characteristics			
Clinical manifestation, No. (%)			0.176
STEMI	42 (46.7)	50 (55.6)	
NSTEMI	18 (20.0)	18 (20.0)	
UA	30 (33.3)	22 (24.4)	
Symptom-to-balloon time (h), median (IQR)	10.9 (3.4-21.6)	6.5 (2.5-18.3)	0.106
Culprit lesion, No. (%)			0.528

LAD	40 (44.4)	46 (51.1)	
LCX	17 (18.9)	18 (20.0)	
RCA	33 (36.7)	26 (28.9)	
Multivessel disease, No. (%)			0.881
No	50 (55.6)	51 (56.7)	
Yes	40 (44.4)	39 (43.3)	
PCI type, No. (%)			0.720
Stent	85 (94.4)	87 (96.7)	
Balloon	5 (5.6)	3 (3.3)	
Stent diameter (mm), median (IQR)	3.0 (2.8-3.5)	3.0 (3.0-3.5)	0.999
Stent length (mm) (total), median (IQR)	33.0 (23.0-38.0)	33.0 (23.0-38.0)	0.348
Assessment at M0			
SPPB score, mean ± SD	8.6 ± 1.5	8.3 ± 1.7	0.304
SPPB score, No. (%)			0.867
≤ 9	65 (72.2)	66 (73.3)	
> 9	25 (27.8)	24 (26.7)	
6MWT (m), mean ± SD	326.3 ± 74.8	323.9 ± 74.2	0.835
EQ-5D score, mean ± SD	10.5 ± 1.5	10.3 ± 1.7	0.422
EQ-VAS score, mean ± SD	69.4 ± 14.4	70.0 ± 15.1	0.801

CC, control care; WERP, WeChat-based education and rehabilitation program; SD, standard deviation; BMI, body mass index; PCI, percutaneous coronary intervention; IQR, interquartile range; WBC, white blood cell; FBG, fasting plasma glucose; Scr, serum creatinine; TG, triglyceride; TC, total cholesterol; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; cTnI, cardiac troponin I; CK-MB, creatine kinase-myocardial band isoenzyme; STEMI, ST-elevation myocardial infarction; NSTEMI, non-ST-elevation myocardial infarction; UA, unstable angina; LAD, left anterior descending branch; LCX, left circumflex artery; RCA, right coronary artery; M0, at discharge; SPPB, short physical performance battery; 6MWT, 6-minute walking distance; EQ-5D, EuroQol-5 dimensions; EQ-VAS, EuroQol-visual analogue scale.

usual activities, pain/discomfort, and anxiety/depression, with a range from 0 to 15, the higher the score, the worse the health condition (Balestroni and Bertolotti 2012). The EQ-5D score also includes a VAS assessment, with a range from 0 to 100 (from the worst health status to the best health status) (Balestroni and Bertolotti 2012).

Statistical analysis

SPSS 22.0 (IBM, Armonk, NY, USA) was used for statistical analyses, and GraphPad Prism 7.0 (GraphPad Software Inc., San Diego, CA, USA) was used for figure plotting. Comparison between the CC group and the WERP group used the Mann-Whitney U test, student t-test, X² test, or Fisher's exact test. $P < 0.05$ was considered significant.

Results

Study flow and clinical features of the WERP and CC groups

Initially, 198 patients with ACS who underwent PCI were screened, and 18 patients were excluded. Subsequently, 180 patients with ACS were included and randomized allocated to the CC group (N = 90) and the WERP group (N = 90) as a 1:1 ratio. Patients in both groups received the corresponding CC or WERP intervention for 3 months. In the WERP group, 1 patient dropped out at M1, 5 patients dropped out at M2, and 6 patients dropped out at M3. In the CC group, 3 patients dropped out

at M1 and 6 patients dropped out at M3. In both groups, SPPB score, 6MWT, EQ-5D score, and EQ-VAS score were assessed at M0, M1, M2, and M3. All available data were included in the analyses with the intention-to-treat (ITT) principle (Fig. 1).

The mean ages of the WERP and CC groups were 62.8 ± 6.5 years and 64.0 ± 5.8 years, respectively ($P = 0.203$). There were 66 (73.3%) males and 24 (26.7%) females in the WERP group, as well as 65 (72.2%) and 25 (27.8%) females in the CC group ($P = 0.867$). Demographic characteristics, medical history, biochemical indexes, and disease characteristics were not different between the two groups (all $P > 0.05$). Meanwhile, the assessment at M0, including SPPB score, 6MWT, EQ-5D score, and EQ-VAS score did not differ between the WERP and CC groups either (all $P > 0.05$). Specific clinical information on patients with ACS in the two groups is listed in Table 1.

Comparison of SPPB score and 6MWT between the WERP and CC groups

SPPB score at M0 was not different between the two groups ($P = 0.304$). However, SPPB score at M1 ($P = 0.029$), M2 ($P = 0.048$), and M3 ($P = 0.030$) was increased in the WERP group compared to the CC group (Fig. 2). Then SPPB score was further classified as low (4-6), intermediate (7-9), and high (10-12). It was found that physical performance classified by SPPB score at M0 did not differ

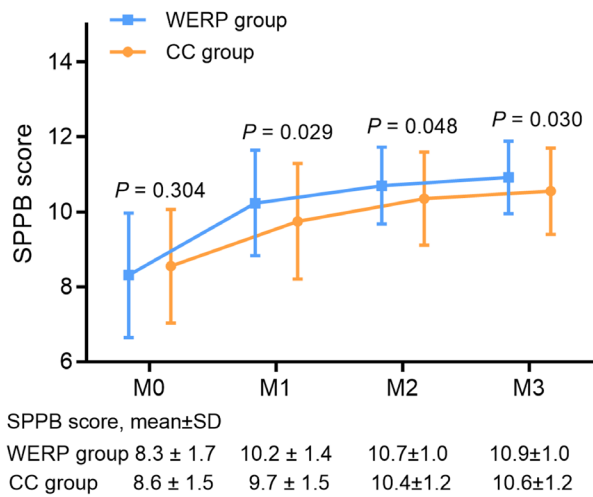


Fig. 2. Comparison of short physical performance battery (SPPB) score at multiple time points between the WeChat-based education and rehabilitation program (WERP) and control care (CC) groups. Student t-test was used in statistics. Data are shown as mean ± SD.

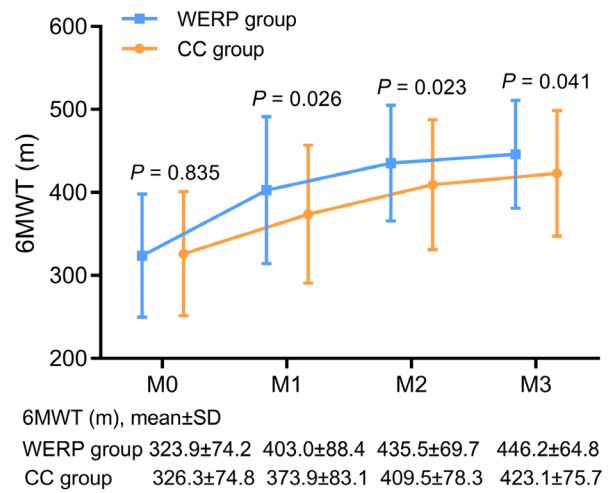


Fig. 4. Comparison of 6-minute walking distance (6MWT) at multiple time points between the WeChat-based education and rehabilitation program (WERP) and control care (CC) groups. Student t-test was used in statistics. Data are shown as mean ± SD.

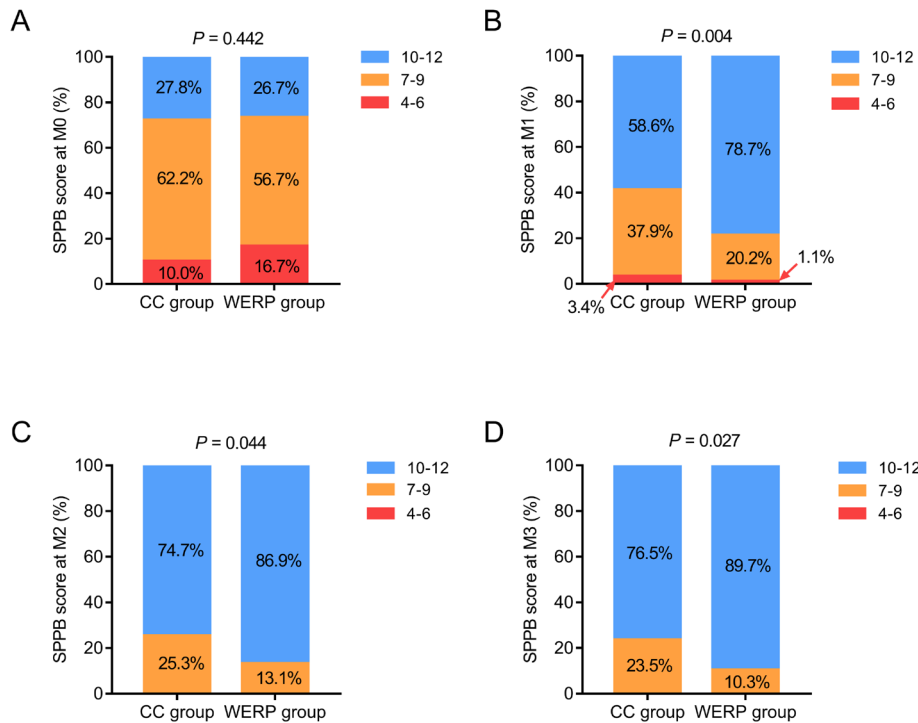


Fig. 3. Comparison of physical performance classified by short physical performance battery (SPPB) score at multiple time points between the WeChat-based education and rehabilitation program (WERP) and control care (CC) groups. Comparison of physical performance classified by SPPB score at month (M)0 (A), M1 (B), M2 (C), and M3 (D) between the WERP and CC groups. Chi square test and/or Fisher's exact test were used in statistics.

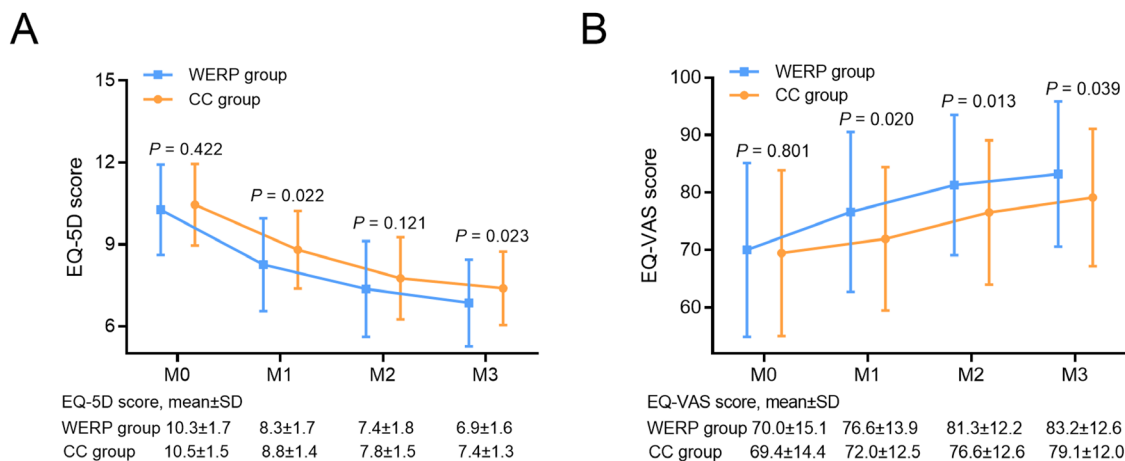


Fig. 5. Comparison of quality of life (QoL) at multiple time points between the WeChat-based education and rehabilitation program (WERP) and control care (CC) groups. Comparison of EuroQol-5 dimensions (EQ-5D) score (A) and EuroQol-visual analogue scale (EQ-VAS) score (B) at month (M)0, M1, M2, and M3 between the WERP and CC groups. Student t-test was used in statistics. Data are shown as mean ± SD.

Table 2. Subgroup comparison of short physical performance battery (SPPB), 6-minute walking distance (6MWT), EuroQol-5 dimensions (EQ-5D), and EuroQol-visual analogue scale (EQ-VAS) between control care (CC) group and WeChat-based education and rehabilitation program (WERP) group.

Items	SPPB score at M0 ≤ 9		P value	SPPB score at M0 > 9		P value
	CC group	WERP group		CC group	WERP group	
SPPB score, mean ± SD						
M0	7.9 ± 1.2	7.6 ± 1.4	0.268	10.3 ± 0.5	10.2 ± 0.5	0.403
M1	9.6 ± 1.5	10.2 ± 1.4	0.028	10.1 ± 1.7	10.5 ± 1.5	0.467
M2	10.2 ± 1.2	10.6 ± 1.0	0.037	10.8 ± 1.1	11.0 ± 1.2	0.540
M3	10.4 ± 1.1	10.9 ± 1.0	0.008	11.0 ± 1.1	10.9 ± 0.9	0.846
6MWT (m), mean ± SD						
M0	300.5 ± 61.1	302.5 ± 67.2	0.854	393.4 ± 65.7	382.8 ± 60.3	0.562
M1	365.6 ± 76.5	398.3 ± 86.5	0.026	394.4 ± 96.3	415.7 ± 94.2	0.439
M2	405.8 ± 74.6	434.3 ± 75.0	0.036	418.7 ± 87.6	438.9 ± 53.3	0.353
M3	414.9 ± 70.5	443.2 ± 63.6	0.026	442.6 ± 85.2	454.9 ± 69.2	0.608
EQ-5D score, mean ± SD						
M0	10.6 ± 1.3	10.3 ± 1.6	0.293	10.0 ± 1.9	10.0 ± 1.8	0.998
M1	8.9 ± 1.3	8.3 ± 1.7	0.030	8.7 ± 1.7	8.2 ± 1.8	0.356
M2	7.9 ± 1.4	7.5 ± 1.7	0.144	7.5 ± 1.8	7.1 ± 2.0	0.484
M3	7.6 ± 1.3	6.9 ± 1.6	0.012	7.0 ± 1.4	6.8 ± 1.5	0.720
EQ-VAS score, mean ± SD						
M0	68.2 ± 14.3	68.0 ± 14.9	0.962	72.8 ± 14.3	75.4 ± 14.7	0.531
M1	70.5 ± 12.1	75.1 ± 14.2	0.051	75.6 ± 12.9	80.8 ± 12.5	0.156
M2	75.0 ± 12.8	79.8 ± 12.6	0.036	80.4 ± 11.4	85.5 ± 10.1	0.116
M3	77.5 ± 12.1	81.9 ± 12.9	0.065	82.9 ± 10.8	87.0 ± 11.3	0.229

SD, standard deviation; M0, at discharge; M1, 1st month after discharge; M2, 2nd month after discharge; M3, 3rd month after discharge.

between the two groups ($P = 0.442$) (Fig. 3A). However, physical performance classified by SPPB score at M1 ($P = 0.004$) (Fig. 3B), M2 ($P = 0.044$) (Fig. 3C), and M3 ($P = 0.027$) (Fig. 3D) was improved in the WERP group com-

pared to the CC group.

It was also found that 6MWT at M0 did not differ between the two groups ($P = 0.835$). Nevertheless, 6MWT at M1 ($P = 0.026$), M2 ($P = 0.023$), and M3 ($P = 0.041$) were

Table 3. Subgroup comparison of short physical performance battery (SPPB), 6-minute walking distance (6MWT), EuroQol-5 dimensions (EQ-5D), and EuroQol-visual analogue scale (EQ-VAS) between control care (CC) group and WeChat-based education and rehabilitation program (WERP) group based on hypertension.

Items	No hypertension		P value	Hypertension		P value
	CC group	WERP group		CC group	WERP group	
SPPB score, mean \pm SD						
M0	8.8 \pm 1.4	8.3 \pm 1.9	0.257	8.4 \pm 1.6	8.3 \pm 1.6	0.757
M1	9.7 \pm 1.5	10.2 \pm 1.4	0.229	9.8 \pm 1.6	10.3 \pm 1.4	0.080
M2	10.5 \pm 1.3	10.6 \pm 1.1	0.798	10.3 \pm 1.2	10.8 \pm 1.0	0.025
M3	10.7 \pm 1.2	11.1 \pm 0.8	0.128	10.5 \pm 1.1	10.9 \pm 1.0	0.085
6MWT (m), mean \pm SD						
M0	342.1 \pm 78.9	328.3 \pm 76.0	0.500	317.1 \pm 71.4	322.2 \pm 74.0	0.702
M1	380.3 \pm 98.1	401.1 \pm 89.9	0.408	370.2 \pm 73.7	403.7 \pm 88.6	0.028
M2	412.5 \pm 81.7	436.3 \pm 71.9	0.263	407.7 \pm 77.0	435.2 \pm 69.4	0.046
M3	429.7 \pm 83.5	454.5 \pm 73.0	0.253	419.1 \pm 71.0	442.4 \pm 61.2	0.075
EQ-5D score, mean \pm SD						
M0	10.6 \pm 1.3	10.4 \pm 1.6	0.563	10.4 \pm 1.6	10.2 \pm 1.7	0.617
M1	8.9 \pm 1.3	8.2 \pm 1.8	0.087	8.7 \pm 1.5	8.3 \pm 1.7	0.122
M2	7.7 \pm 1.6	7.2 \pm 1.9	0.344	7.8 \pm 1.5	7.4 \pm 1.7	0.197
M3	7.3 \pm 1.6	7.0 \pm 1.7	0.406	7.4 \pm 1.2	6.8 \pm 1.6	0.024
EQ-VAS score, mean \pm SD						
M0	72.1 \pm 13.2	70.4 \pm 15.4	0.642	67.9 \pm 15.0	69.8 \pm 15.2	0.479
M1	75.0 \pm 12.2	77.7 \pm 15.0	0.454	70.2 \pm 12.4	76.2 \pm 13.5	0.013
M2	79.4 \pm 12.2	82.9 \pm 13.0	0.300	74.9 \pm 12.6	80.7 \pm 11.9	0.013
M3	81.6 \pm 12.9	84.6 \pm 13.8	0.416	77.6 \pm 11.2	82.6 \pm 12.2	0.032

SD, standard deviation; M0, at discharge; M1, 1st month after discharge; M2, 2nd month after discharge; M3, 3rd month after discharge.

longer in the WERP group versus the CC group (Fig. 4).

Comparison of EQ-5D score and EQ-VAS score between the WERP and CC groups

EQ-5D score at M0 ($P = 0.422$) and M2 ($P = 0.121$) was not different between the two groups. Notably, EQ-5D score at M1 ($P = 0.022$) and M3 ($P = 0.023$) was reduced in the WERP group compared with the CC group (Fig. 5A). In addition, EQ-VAS score at M0 did not differ between the two groups ($P = 0.801$). Nevertheless, EQ-VAS score at M1 ($P = 0.020$), M2 ($P = 0.013$), and M3 ($P = 0.039$) was elevated in the WERP group compared to the CC group (Fig. 5B).

Subgroup analyses based on the SPPB score at M0 between the WERP and CC groups

In patients with SPPB score at M0 ≤ 9 , SPPB score and 6MWT at M1, M2, and M3 were increased in the WERP group compared to the CC group (all $P < 0.05$); EQ-5D score at M1 ($P = 0.030$) and M3 ($P = 0.012$) was decreased, while EQ-VAS score at M2 ($P = 0.036$) was increased in the WERP group compared with the CC group. However, in patients with SPPB score at M0 > 9 , SPPB score, 6MWT, EQ-5D score, and EQ-VAS score at M1, M2, and M3 were not different between the two groups (all $P >$

0.05) (Table 2).

Subgroup analyses based on hypertension, hyperlipidemia, and diabetes between the WERP and CC groups

In patients with hypertension, SPPB score at M2 ($P = 0.025$), 6MWT at M1 ($P = 0.028$) and M2 ($P = 0.046$), and EQ-VAS score at M1 ($P = 0.013$), M2 ($P = 0.013$), and M3 ($P = 0.032$) were increased, but EQ-5D score at M3 ($P = 0.024$) was decreased in the WERP group versus the CC group (Table 3).

In patients without hyperlipidemia, 6MWT at M2 was increased in the WERP group compared to the CC group ($P = 0.044$). In patients with hyperlipidemia, EQ-5D score at M1 ($P = 0.045$) was decreased, but EQ-VAS score at M1 ($P = 0.022$), M2 ($P = 0.037$), and M3 ($P = 0.040$) were increased in the WERP group versus the CC group (Table 4).

In patients without diabetes, SPPB score at M2 ($P = 0.016$), 6MWT at M2 ($P = 0.026$), and EQ-VAS score at M2 ($P = 0.037$) were elevated in the WERP group versus the CC group. In patients with diabetes, 6MWT at M1 ($P = 0.021$) was increased, but EQ-5D score at M1 ($P = 0.031$) was reduced in the WERP group versus the CC group (Table 5).

Table 4. Subgroup comparison of short physical performance battery (SPPB), 6-minute walking distance (6MWT), EuroQol-5 dimensions (EQ-5D), and EuroQol-visual analogue scale (EQ-VAS) between control care (CC) group and WeChat-based education and rehabilitation program (WERP) group based on hyperlipidemia.

Items	No hyperlipidemia		P value	Hyperlipidemia		P value
	CC group	WERP group		CC group	WERP group	
SPPB score, mean \pm SD						
M0	8.7 \pm 1.5	8.2 \pm 1.7	0.096	8.2 \pm 1.5	8.4 \pm 1.7	0.576
M1	9.8 \pm 1.5	10.1 \pm 1.5	0.277	9.7 \pm 1.6	10.4 \pm 1.3	0.062
M2	10.4 \pm 1.3	10.7 \pm 1.0	0.126	10.3 \pm 1.1	10.7 \pm 1.0	0.183
M3	10.6 \pm 1.1	10.9 \pm 1.0	0.174	10.4 \pm 1.2	10.9 \pm 1.0	0.068
6MWT (m), mean \pm SD						
M0	333.3 \pm 77.8	320.6 \pm 74.8	0.396	312.9 \pm 68.0	327.7 \pm 74.2	0.385
M1	376.7 \pm 87.9	405.5 \pm 90.3	0.103	368.2 \pm 73.8	400.2 \pm 87.4	0.112
M2	409.6 \pm 76.8	439.7 \pm 70.7	0.044	409.3 \pm 82.6	430.7 \pm 69.2	0.249
M3	426.3 \pm 74.8	440.6 \pm 56.9	0.281	415.6 \pm 78.8	453.0 \pm 73.7	0.068
EQ-5D score, mean \pm SD						
M0	10.6 \pm 1.5	10.6 \pm 1.5	0.981	10.2 \pm 1.5	9.9 \pm 1.7	0.409
M1	8.9 \pm 1.5	8.7 \pm 1.5	0.395	8.6 \pm 1.2	7.8 \pm 1.8	0.045
M2	7.8 \pm 1.6	7.7 \pm 1.7	0.584	7.6 \pm 1.4	7.0 \pm 1.8	0.145
M3	7.5 \pm 1.4	7.0 \pm 1.6	0.187	7.3 \pm 1.3	6.6 \pm 1.5	0.107
EQ-VAS score, mean \pm SD						
M0	69.7 \pm 14.4	67.3 \pm 14.7	0.403	69.0 \pm 14.7	73.1 \pm 15.2	0.256
M1	72.1 \pm 11.7	74.3 \pm 14.6	0.406	71.7 \pm 14.2	79.3 \pm 12.8	0.022
M2	76.6 \pm 12.2	79.8 \pm 12.5	0.192	76.6 \pm 13.4	83.1 \pm 11.7	0.037
M3	79.3 \pm 12.1	81.6 \pm 13.6	0.368	78.8 \pm 11.9	85.1 \pm 11.2	0.040

SD, standard deviation; M0, at discharge; M1, 1st month after discharge; M2, 2nd month after discharge; M3, 3rd month after discharge.

Subgroup analysis based on clinical manifestation between the WERP and CC groups

In patients with UA, 6MWT at M2 ($P = 0.022$) and M3 ($P = 0.028$) and EQ-VAS score at M2 ($P = 0.034$) were increased, but EQ-5D score at M2 ($P = 0.006$) was reduced in the WERP group versus the CC group (Table 6).

Discussion

WeChat-based rehabilitation programs have exhibited the potential to improve the physical performance of cardiovascular disease patients after PCI, but relevant evidence regarding patients with ACS who undergo PCI is scarce (Ma et al. 2021b; Wang et al. 2022a). A previous study reports that Cardiac Rehabilitation Therapy Combined with WeChat Platform Education improves the physical status in UAP patients after PCI (Ma et al. 2021b). Another study elucidates that Home-Based Cardiac Rehabilitation Model Delivered by WeChat enhances the exercise capacity in coronary heart disease patients after PCI (Wang et al. 2022a). Partly in line with these previous studies, it was found that physical performance was improved by WERP compared to CC in patients with ACS who underwent PCI. The potential reasons would be that: (1) WERP provided an information base, which was beneficial for patients to understand the knowledge about the disease and rehabilita-

tion after the treatment (Wang et al. 2022a). (2) WERP contained rehabilitation training and guided patients on how to conduct strength and walking training at home, which directly assisted in enhancing their physical performance (Su and Yu 2021; Wang et al. 2022a). (3) WERP also provided a chance for patients to share their experiences with other patients and doctors; thus, patients could learn from each other and their questions would be solved timely, which might help them to better understand the rehabilitation, thereby improving physical performance (Wang et al. 2022a).

WeChat-based rehabilitation programs also exhibit the potency to enhance the QoL in patients with various diseases, including cardiovascular diseases (Jiang et al. 2020; Zhou et al. 2020a; Zhou et al. 2020b; Li et al. 2021; Ma et al. 2021a; Xu et al. 2021; Wang et al. 2022a; Wang et al. 2022b). For instance, one previous study suggests that the QoL is enhanced by WeChat-based rehabilitation programs in acute myocardial infarction patients after PCI (Xu et al. 2021).

In line with previous studies (Ma et al. 2021a; Xu et al. 2021), the present study also discovered that WERP was effective in enhancing the QoL in patients with ACS who underwent PCI. The potential explanations might be that: (1) WERP helped patients to learn about disease-, rehabili-

Table 5. Subgroup comparison of short physical performance battery (SPPB), 6-minute walking distance (6MWT), EuroQol-5 dimensions (EQ-5D), and EuroQol-visual analogue scale (EQ-VAS) between control care (CC) group and WeChat-based education and rehabilitation program (WERP) group based on diabetes.

Items	No diabetes		<i>P</i> value	Diabetes		<i>P</i> value
	CC group	WERP group		CC group	WERP group	
SPPB score, mean ± SD						
M0	8.8 ± 1.4	8.4 ± 1.6	0.158	7.7 ± 1.6	8.0 ± 1.9	0.634
M1	9.8 ± 1.5	10.2 ± 1.4	0.112	9.5 ± 1.7	10.3 ± 1.3	0.110
M2	10.3 ± 1.3	10.8 ± 1.0	0.016	10.4 ± 1.1	10.4 ± 1.0	0.888
M3	10.6 ± 1.2	10.9 ± 1.0	0.096	10.5 ± 1.1	11.0 ± 0.8	0.162
6MWT (m), mean ± SD						
M0	338.6 ± 74.5	328.4 ± 76.3	0.431	283.2 ± 59.6	311.8 ± 68.1	0.149
M1	381.4 ± 87.8	403.4 ± 90.2	0.157	346.9 ± 57.8	401.8 ± 85.3	0.021
M2	413.3 ± 81.5	443.7 ± 69.9	0.026	395.9 ± 65.8	415.1 ± 66.4	0.349
M3	428.5 ± 76.2	452.0 ± 67.3	0.076	403.1 ± 72.3	430.3 ± 56.0	0.199
EQ-5D score, mean ± SD						
M0	10.5 ± 1.4	10.5 ± 1.6	0.869	10.2 ± 1.7	9.6 ± 1.7	0.315
M1	8.8 ± 1.5	8.4 ± 1.7	0.171	8.9 ± 1.0	7.9 ± 1.8	0.031
M2	7.8 ± 1.6	7.6 ± 1.7	0.474	7.6 ± 1.3	6.8 ± 1.7	0.093
M3	7.5 ± 1.4	6.9 ± 1.6	0.053	7.1 ± 1.1	6.6 ± 1.5	0.333
EQ-VAS score, mean ± SD						
M0	69.9 ± 14.0	69.5 ± 14.9	0.900	68.0 ± 16.1	71.3 ± 16.0	0.507
M1	72.1 ± 11.9	76.5 ± 14.0	0.053	71.6 ± 14.6	77.1 ± 14.0	0.216
M2	76.8 ± 11.8	81.2 ± 11.8	0.037	75.8 ± 15.4	81.7 ± 13.4	0.188
M3	79.2 ± 11.3	83.0 ± 12.1	0.080	78.8 ± 14.5	83.8 ± 14.3	0.296

SD, standard deviation; M0, at discharge; M1, 1st month after discharge; M2, 2nd month after discharge; M3, 3rd month after discharge.

tation-, and treatment-related knowledge, which was beneficial to improve their self-care ability and relieve postoperative discomforts, then further assisted in improving their QoL (Ma et al. 2021a; Xu et al. 2021). (2) Due to the closure policy during COVID-19, it was hard and inconvenient for outpatients; while WERP's group chat mode allowed patients to timely communicate with the doctors and nurses, and their questions would be solved timely; additionally, patients could also talk with other patients who had the similar situations and support each other, which could eliminate their negative emotions, thereby improving QoL (Ma et al. 2021a; Wang et al. 2021). (3) As discussed above, WERP's rehabilitation training directly improved physical performance by guiding patients in conducting physical training and supervising their completion, which could help to enhance mobility and usual activity, then improved their QoL.

The current study found that WERP improved physical performance and QoL in patients with ACS who underwent PCI. However, whether the effect of WERP would be influenced by baseline physical performance remained unknown. Therefore, a subgroup analysis based on baseline SPPB score was carried out, and it was found that patients with ACS who underwent PCI with SPPB score at M0 ≤ 9 could benefit more from the WERP at most time points in improv-

ing physical performance and QoL. A reason behind this might be that a lower SPPB score represented a worse physical performance. Thus, the effect of WERP on enhancing physical performance and QoL might be strong in these patients (Ma et al. 2021a; Wang et al. 2022a).

It should be mentioned that although offline rehabilitation programs had shown the potential benefit to improve physical performance and QoL, restricted by the closure policy, patients with ACS who underwent PCI were not encouraged to participate in the offline rehabilitation programs during the COVID pandemic period in China (Sunamura et al. 2018; Baldasseroni et al. 2022). Considering that postoperative rehabilitation was crucial for patients with ACS who underwent PCI, WERP was designed for these patients. Interestingly, we found that WERP might help to improve physical performance and QoL, which was in line with previous studies (Ma et al. 2021a; Wang et al. 2022a). However, more studies were required to validate our findings. It should be clarified that during the COVID-19 pandemic period, patients in both WERP and CC groups were not encouraged to come to hospital except for regular follow-up, and this inconvenience existed in all patients with ACS.

Several limitations could not be omitted. Firstly, since this study screened patients who were able to use WeChat

Table 6. Subgroup comparison of short physical performance battery (SPPB), 6-minute walking distance (6MWT), EuroQol-5 dimensions (EQ-5D), and EuroQol-visual analogue scale (EQ-VAS) between control care (CC) group and WeChat-based education and rehabilitation program (WERP) group based on clinical manifestation.

Items	STEMI		P value	NSTEMI		P value	UA		P value
	CC group	WERP group		CC group	WERP group		CC group	WERP group	
SPPB score, mean ± SD									
M0	8.5 ± 1.6	8.5 ± 1.5	0.894	8.3 ± 1.4	7.9 ± 1.7	0.461	8.8 ± 1.5	8.2 ± 1.9	0.165
M1	10.0 ± 1.4	10.5 ± 1.2	0.095	9.7 ± 1.3	10.3 ± 1.3	0.184	9.4 ± 1.8	9.7 ± 1.8	0.623
M2	10.3 ± 1.3	10.7 ± 1.0	0.085	10.5 ± 1.2	10.5 ± 1.2	0.937	10.4 ± 1.2	10.8 ± 1.0	0.217
M3	10.6 ± 1.2	10.9 ± 1.0	0.220	10.3 ± 1.2	10.9 ± 0.9	0.190	10.7 ± 1.1	11.0 ± 1.0	0.184
6MWT (m), mean ± SD									
M0	324.6 ± 77.8	327.9 ± 75.2	0.839	333.3 ± 85.6	309.6 ± 69.6	0.367	324.3 ± 65.4	326.8 ± 77.4	0.903
M1	382.8 ± 80.1	412.9 ± 80.4	0.076	392.3 ± 89.5	398.5 ± 105.7	0.859	352.1 ± 82.3	383.7 ± 92.3	0.200
M2	410.7 ± 74.1	432.5 ± 69.2	0.158	428.3 ± 103.3	431.3 ± 73.9	0.928	398.3 ± 70.3	444.9 ± 70.1	0.022
M3	425.4 ± 71.4	444.8 ± 61.4	0.202	440.0 ± 93.0	433.7 ± 67.1	0.832	411.5 ± 72.0	457.3 ± 70.6	0.028
EQ-5D score, mean ± SD									
M0	10.4 ± 1.6	10.6 ± 1.7	0.655	10.8 ± 1.7	9.4 ± 1.8	0.031	10.3 ± 1.2	10.3 ± 1.2	0.855
M1	8.6 ± 1.5	8.2 ± 1.8	0.281	9.1 ± 1.7	8.0 ± 1.5	0.070	8.9 ± 1.2	8.5 ± 1.6	0.264
M2	7.4 ± 1.6	7.6 ± 1.7	0.487	8.0 ± 1.3	7.2 ± 1.8	0.169	8.2 ± 1.3	7.0 ± 1.7	0.006
M3	7.2 ± 1.5	7.1 ± 1.5	0.846	7.7 ± 1.2	6.2 ± 1.5	0.004	7.5 ± 1.2	6.9 ± 1.8	0.154
EQ-VAS score, mean ± SD									
M0	68.6 ± 14.6	68.6 ± 16.4	0.993	68.3 ± 15.8	73.9 ± 12.9	0.256	71.3 ± 13.6	70.0 ± 13.8	0.730
M1	72.4 ± 13.8	75.2 ± 13.4	0.324	72.0 ± 15.2	80.6 ± 15.2	0.121	71.3 ± 9.0	76.8 ± 13.9	0.116
M2	77.6 ± 13.9	80.2 ± 12.0	0.350	77.3 ± 12.8	84.4 ± 13.6	0.150	74.7 ± 10.4	81.4 ± 11.7	0.034
M3	80.0 ± 13.1	82.0 ± 12.7	0.507	78.7 ± 12.5	85.3 ± 14.6	0.189	78.3 ± 10.4	84.1 ± 11.4	0.063

SD, standard deviation; STEMI, ST-elevation myocardial infarction; NSTEMI, non-ST-elevation myocardial infarction; UA, unstable angina; M0, at discharge; M1, 1st month after discharge; M2, 2nd month after discharge; M3, 3rd month after discharge.

and understand the contents of WERP, all patients were under 75 years, which limited the generalization of WERP. Secondly, caregivers might impact the effect of WERP in patients with ACS who underwent PCI, but this study did not control the interferences of caregivers (Zhang et al. 2021; Kang and Li 2022). Thirdly, due to the acute conditions of patients with ACS who underwent PCI, most patients were local, and more than 90% of patients were urban residents. Thus, our results could not reflect the role of WERP in people living in rural areas, resulting in the limited applicability of this study. Fourthly, since the program was based on WeChat, the patients might be unavoidably aware of their groups.

In summary, WERP improves physical performance and QoL in patients with ACS who undergo PCI. Although WERP is designed and assessed during the COVID-19 pandemic, it may have the potential to be broadly applied for the postoperative rehabilitation of patients with ACS who undergo PCI after the end of the COVID-19 pandemic, considering the prevalence, versatility, and convenience of WeChat. However, more shreds of evidence are warranted to validate these findings.

Conflict of Interest

The authors declare no conflict of interest.

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