

7-31-2025

The Effectiveness of Remote Patient Monitoring in Reducing the Risk of Rehospitalizations in COVID-19 Patients: A Meta-Analysis

Dela Riadi

Universitas Pembangunan Nasional Veteran Jakarta, delariadi@upnvj.ac.id

Indang Trihandini

Universitas Indonesia, Depok, dini05@ui.ac.id

Dewi Nirmala Sari

Politeknik Kesehatan Kemenkes Jakarta III, Jakarta, denisakayladenis@gmail.com

Fikri Wijaya

Universitas Indonesia, Depok, fikri@ui.ac.id

Follow this and additional works at: <https://scholarhub.ui.ac.id/kesmas>



Part of the [Biostatistics Commons](#), and the [Public Health Commons](#)

Recommended Citation

Riadi D , Trihandini I , Sari DN , et al. The Effectiveness of Remote Patient Monitoring in Reducing the Risk of Rehospitalizations in COVID-19 Patients: A Meta-Analysis. *Kesmas*. 2025; 20(5): 10-20

DOI: 10.7454/kesmas.v20isp1.1715

Available at: <https://scholarhub.ui.ac.id/kesmas/vol20/iss5/2>

This Review is brought to you for free and open access by the Faculty of Public Health at UI Scholars Hub. It has been accepted for inclusion in Kesmas by an authorized editor of UI Scholars Hub.

The Effectiveness of Remote Patient Monitoring in Reducing the Risk of Rehospitalizations in COVID-19 Patients: A Meta-Analysis

Dela Riadi¹, Indang Trihandini^{2*}, Dewi Nirmala Sari³, Fikri Wijaya⁴

¹Faculty of Medicine, Universitas Pembangunan Nasional Veteran Jakarta, Indonesia

²Department of Biostatistics and Population Studies, Faculty of Public Health, Universitas Indonesia, Depok, Indonesia

³Department of Midwifery, Politeknik kesehatan Kemenkes Jakarta III, Jakarta, Indonesia

⁴Faculty of Public Health, Universitas Indonesia, Depok, Indonesia

Abstract

An integrated analysis of various Remote Patient Monitoring (RPM) studies is needed to evaluate the reduction rate of the risk of rehospitalization in COVID-19 patients. This meta-analysis aimed to provide an overview of the effectiveness of RPM. A literature search through online databases (PubMed, Science Direct, Scopus, ProQuest, and Embase) was conducted from 2019 to 2022. After using the Cochrane Collaboration's risk of bias tool, five studies on COVID-19 were selected. Based on the data collected from 2,685 participants (intervention = 1,060, control = 1,625), the use of RPM was found to reduce rehospitalization by 0.56 times compared to not using RPM ($I^2 = 9\%$; $n = 2,685$; OR 0.56 [95% CI 0.39-0.82]; p -value = 0.003). According to the characteristics analysis, sex, comorbidity of hypertension, heart failure, obesity, chronic lung, and chronic kidney disease had no significant effect on the risk being studied. It was only the comorbidity of diabetes that showed a significant impact. Both RPM intervention duration and long-term monitoring effectively reduced rehospitalization (>14 days). In brief, RPM may reduce hospitalizations in response to an impending epidemic. Future research should look into using RPM to treat chronic post-hospitalization conditions.

Keywords: COVID-19, meta-analysis, rehospitalization, remote patient monitoring, telemedicine

Introduction

The worldwide effects of the COVID-19 pandemic are devastating.¹ The reports from the World Health Organization (WHO) as of December 12, 2022, showed that the pandemic spread continues to spread, with a total of 645,084,824 confirmed cases globally and 6,633,118 deaths.² Any individuals who are severely affected by the disease require hospitalization. Generally, about 20% of affected individuals need to be hospitalized, especially the elderly or those with comorbidities.³ The COVID-19 virus typically causes pneumonia, acute respiratory distress syndrome, septic shock, and cardiovascular complications.⁴

The advent of COVID-19 has increased the demand for advanced information technology solutions as well as basic medical supplies and medicines.⁵ In order to meet the needs of the masses on COVID-19 screening, diagnosis, and monitoring at home, telemedicine has been ideally positioned to fulfill this role.⁶ The use of electronic information and communication technologies for providers and patient contacts across geographic distances is known as telehealth, remote patient monitoring (RPM), and telemedicine.⁷ An easy-to-use e-health platform is important as it enables COVID-19 patients to communicate and quickly find health-related information.⁸

Telemonitoring COVID-19 patients from their homes is a safe, practical, and widely recognized approach. When used in high-risk but non-terminally sick patients, the approach allows for proper clinical surveillance, early disease identification, proper arrangement of care during periods of high demand, and patient and family support. It also contributes to maintaining "social distancing" by reducing the number of visits patients need to make to emergency rooms and clinics.⁹ Overall, RPM is the general name for any combination of medical devices, such as wearable devices

Correspondence*: Indang Trihandini, Department of Biostatistics and Population Studies, Faculty of Public Health, Universitas Indonesia, Depok, Indonesia
Email: dini05@ui.ac.id, Phone: +62 812-1035-617

Received : April 29, 2024

Accepted : January 6, 2025

Published: July 31, 2025

or portable home health monitors, including information technology solutions that enable health data to be sent to healthcare practitioners without physical touch.¹⁰

The RPM collects health information about individuals in one location and securely transmits that data electronically to healthcare professionals in another location for evaluation and advice.¹¹ This type of service allows providers to continuously track healthcare data for patients after they are discharged to their homes or care facilities.¹¹ The procedure is important since it helps to improve patient safety and lower rehospitalization rates. Based on previous studies, patients who transition to the program and enroll on the first post-discharge day are associated with a significantly lower risk of combined emergency department outcomes or readmission to the hospital.¹²

The RPM activation programs are associated with lower hospitalizations, use of intensive care, and length of stay among COVID-19 patients.¹³ In fact, it is argued that hospitalization was far more common in patients who did not get RPM than in those who did. For instance, a previous study determined that among the 187 patients (83%) initially treated in an outpatient setting, hospitalization rates were higher in those without RPM.¹⁴ In another study, the rate of repeat visits to the emergency department did not significantly differ statistically between the RPM group (8%) and the control group (9.3%) (OR: 0.863; 95% CI: 0.413-1.803); p-value = 0.695).¹⁵

To date, research on the application of RPM in COVID-19 patients has produced contradictory findings. Therefore, this study used a meta-analysis to assess the efficacy of the RPM program in lowering the risk of readmission in the COVID-19 patient population through a comprehensive statistical procedure. The specific aims were to compare the effects of RPM programs and explore potential covariates as effects of RPM programs, including gender, hypertension, diabetes, heart failure, obesity, chronic lung, and chronic kidney disease.

Method

In this meta-analysis, a comprehensive search using databases such as PubMed, Science Direct, Scopus, Proquest, and Embase was conducted from December 2019 to December 2022 and updated on March 20, 2023. Overall, the collected articles were found in English and Indonesian language. Additionally, this study included both free access and paid articles (limited to subscribers by institutions). The protocol review was registered in PROSPERO (register number CRD42022380056). The search was performed using the standard and related keywords, including "COVID-19," "COVID-19 patients," "Remote Patient Monitoring," "Remote Health Monitoring," "Telemonitoring," "Telemedicine," "Digital Health," "Mobile Health," "eHealth," "mHealth," "Telehealth," "Rehospitalization," "Rehospitalization," and "Readmission," as well as their equivalent MeSH terms. Furthermore, the corresponding compounds were also searched in the abovementioned databases using the (AND, OR) operators. The meta-analysis follows the steps of Preferred Reporting Items for Systemic Review and Meta-Analyses (PRISMA).¹⁶

It is vital to evaluate the data in each study closely and determine whether the studies that have been included satisfy internal validity standards. In this analysis, critical assessments were performed using the JBI Critical Appraisal Checklist for Randomized Controlled Trials.¹⁷ The risk of bias assessment was conducted using the Cochrane Collaboration tool. The latest versions used were the Revised Cochrane Risk of Bias Tool for Randomized Trials (Rob 2) for randomized controlled trials (RCTs) and the Risk of Bias in Non-randomized Studies of Interventions (ROBINS-I) for non-RCT studies.^{18,19} Both tools are licensed under Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License. The Robvis tool can be used to present the risk assessment results.²⁰

Article inclusion criteria were COVID-19 patients aged at least 18 years who participated in RPM programs. The study period was between December 1, 2019, and November 30, 2022, and was updated on March 20, 2023. Collected articles were in English and Indonesian language and included both free access and paid articles (limited to being subscribed by the institution). In contrast, the articles were excluded if the participant's age was below 18 years, grey literature, policy brief, commentary, review, or RPM Programs unrelated to COVID-19.

The heterogeneity of the collected articles was assessed by calculating the I^2 statistic. A high I^2 value indicated substantial heterogeneity, while a low I^2 value suggested homogeneity among the studies. Statistical analysis was performed using Revman 5.4. The x-axis of the plot was used to represent the research effect estimates, and the y-axis represented the study sample size or effect size variability (variance, standard deviation, or comparable measure). In order to evaluate publication bias in this study, the collected articles were assessed using a funnel plot.

Results

A thorough evaluation of the RPM in COVID-19 patients has been made in this study. From the PubMed electronic database (n = 103), Science Direct (n = 143), Scopus (n = 335), ProQuest (n = 130), Embase (n = 117), and contributions from other sources (n = 69), a total of 897 articles was found. The results of the literature search and the corresponding queries are shown in Table 1.

Table 1. Literature Search Results

Database	Query	Total
PubMed	("covid 19"[MeSH Terms] OR "sars cov 2"[MeSH Terms] OR ("covid 19"[Title/Abstract] OR "sars cov 2 coronavirus"[Title/Abstract] OR "severe acute respiratory syndrome coronavirus"[Title/Abstract] OR "novel coronavirus disease"[Title/Abstract] OR "novel coronavirus pneumonia"[Title/Abstract] OR "2019-novel CoV"[Title/Abstract] OR "2019 nCoV"[Title/Abstract])) AND ("Telemedicine"[MeSH Terms] OR ("Remote patient monitoring"[Title/Abstract] OR "remote health monitoring"[Title/Abstract] OR "telemonitoring"[Title/Abstract] OR "Telemedicine"[Title/Abstract] OR "digital health"[Title/Abstract] OR "mobile health"[Title/Abstract] OR "eHealth"[Title/Abstract] OR "mHealth"[Title/Abstract] OR "telehealth"[Title/Abstract])) AND ("Patient Readmission"[MeSH Terms] OR ("Re-hospitalization"[Title/Abstract] OR "Readmission"[Title/Abstract] OR "hospital discharge"[Title/Abstract] OR "continuity of patient care"[Title/Abstract] OR "patient discharge"[Title/Abstract]))	103
Science Direct	(Covid-19 OR Sars-cov-2) AND ("Remote patient monitoring" OR telemonitoring OR telemedicine OR "mobile health") AND (Rehospitalization OR Rehospitalization OR Readmission)	143
Scopus	(TITLE-ABS-KEY (covid-19) OR TITLE-ABS-KEY (sars-cov-2) OR TITLE-ABS-KEY (coronavirus) OR TITLE-ABS-KEY ("severe acute respiratory syndrome coronavirus") OR TITLE-ABS-KEY ("novel coronavirus disease") OR TITLE-ABS-KEY ("novel coronavirus pneumonia") OR TITLE-ABS-KEY ("2019-novel cov") OR TITLE-ABS-KEY ("2019 ncov")) AND (TITLE-ABS-KEY ("remote patient monitoring") OR TITLE-ABS-KEY ("remote health monitoring") OR TITLE-ABS-KEY (telemonitoring) OR TITLE-ABS-KEY (telemedicine) OR TITLE-ABS-KEY ("digital health") OR TITLE-ABS-KEY ("mobile health") OR TITLE-ABS-KEY (ehealth) OR TITLE-ABS-KEY (mhealth) OR TITLE-ABS-KEY (telehealth)) AND (TITLE-ABS-KEY (re-hospitalization) OR TITLE-ABS-KEY (readmission) OR TITLE-ABS-KEY ("hospital discharge") OR TITLE-ABS-KEY ("continuity of patient care") OR TITLE-ABS-KEY ("patient discharge"))	335
Proquest	(MAINSUBJECT.EXACT("COVID-19") OR abstract(Covid-19 OR Sars-cov-2 Coronavirus OR "severe acute respiratory syndrome coronavirus" OR "novel coronavirus disease" OR "novel coronavirus pneumonia" OR "2019-novel CoV" OR "2019 nCoV")) OR title(Covid-19 OR Sars-cov-2 Coronavirus OR "severe acute respiratory syndrome coronavirus" OR "novel coronavirus disease" OR "novel coronavirus pneumonia" OR "2019-novel CoV" OR "2019 nCoV")) AND (MAINSUBJECT.EXACT("Telemedicine") OR abstract("Remote patient monitoring" OR "remote health monitoring" OR telemonitoring OR telemedicine OR "digital health" OR "mobile health" OR eHealth OR mHealth OR telehealth) OR title("Remote patient monitoring" OR "remote health monitoring" OR telemonitoring OR telemedicine OR "digital health" OR "mobile health" OR eHealth OR mHealth OR telehealth)) AND (MAINSUBJECT.EXACT("Outpatient care facilities") OR abstract(Rehospitalization OR Readmission OR "hospital discharge" OR "continuity of patient care" OR "patient discharge") OR title(Rehospitalization OR Readmission OR "hospital discharge" OR "continuity of patient care" OR "patient discharge"))	130
Embase	Covid-19 OR Sars-cov-2 Coronavirus OR "severe acute respiratory syndrome coronavirus" OR "novel coronavirus disease" OR "novel coronavirus pneumonia" OR "2019-novel CoV" OR "2019 nCoV" AND "Remote patient monitoring" OR "remote health monitoring" OR telemonitoring OR telemedicine OR "digital health" OR "mobile health" OR eHealth OR mHealth OR telehealth AND Rehospitalization OR Readmission OR "hospital discharge" OR "continuity of patient care" OR "patient discharge"	117
Other sources (manual)	"remote patient monitoring" AND "COVID-19 patient" AND "rehospitalization" OR "rehospitalization" OR "readmission"	69
Grand Total		897

Out of 897 articles, 634 papers proceeded to title and abstract screening after removing duplicates (n = 263). The authors estimated that about 608 of these items were not suitable for inclusion in further screening. Overall, six articles were included in the study and proceeded to data extraction and qualitative synthesis. Only five studies were then included in the meta-analysis after 26 papers underwent full-text eligibility assessment. The final results of the article review are presented in the PRISMA flow diagram in Figure 1.

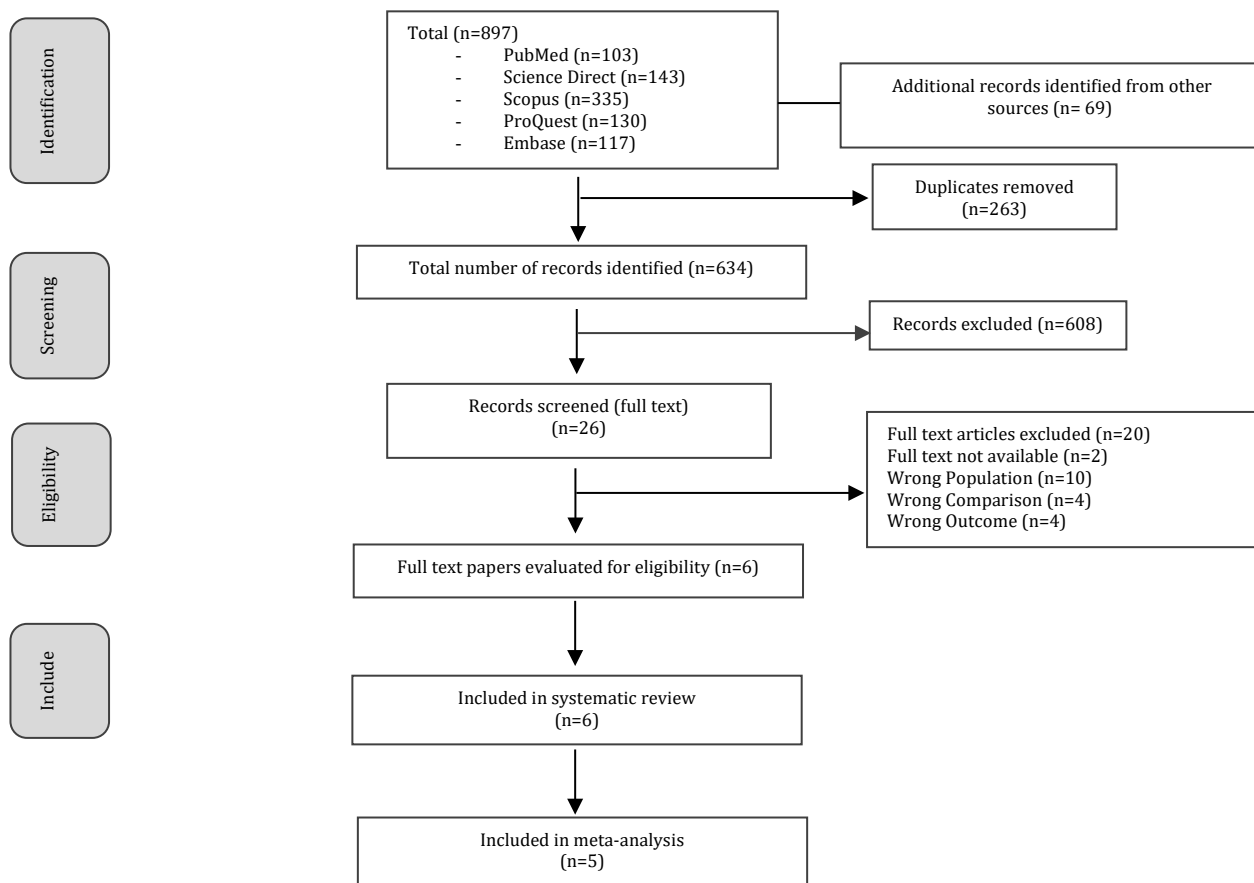


Figure 1. PRISMA Study Flow Diagram

Table 2 provides an overview of the articles included in the systematic review. Both non-random corrected and random corrected study designs were used in each analysis. A total of 2,683 participants from six studies included in the systematic intake were enrolled (intervention = 1,097, control = 1,586), with 1,471 (53.4%) male and 1,282 (46.6%) female. Three studies (50%) were conducted in the US, two (33%) in Spain, and one (16.7%) in the Netherlands. Across the six studies, participants' ages ranged from 53 to 70 years (n=2683). There were four long-term follow-up studies (>2 weeks; 66.7%) and two short-term follow-up studies (2 weeks; 33.3%), ranging in length from 14 days to 90 days.

All six studies included in the systematic review consisted of four non-RCTs and two RCTs. Using the ROBINS-I tool, all four non-RCTs (100%) were identified as having a moderate risk of bias.¹⁹ The two RCTs were assessed with the RoB 2 tool. In one RCT, participants were aware of the intervention, resulting in contamination of assessment results and a high risk of bias.¹⁸ The other RCT was identified as having a low risk of bias.²¹

Table 2. Summary of the Selected Articles

Authors, Country	Journal, Year of Publication	Study Design	Participant Characteristics	Measurement	Average and Mean Age (SD) of the Participants	Intervention (n=1,097) and Control (n=1,586)	Duration of Therapy	Results
Suárez-Gil et al., Spain ³	Journal of Personalized Medicine April 10, 2022	Retrospective Cohort	COVID-19 patients from ASLAM health services	<ul style="list-style-type: none"> • Temperature • Oxygen saturation • Respiratory symptoms 	Average age: I: 66.5 (SD 16.1) C: 70.8 (SD 16.7) Sex: I: 247 (52%) male C: 39 (51.3%) male	Intervention (475) Control (76)	90 days	Although the telemedicine-monitored group was older, no appreciable variations in the illness baseline were found.

Authors, Country	Journal, Year of Publication	Study Design	Participant Characteristics	Measurement	Average and Mean Age (SD) of the Participants	Intervention (n=1,097) and Control (n=1,586)	Duration of Therapy	Results
Gordon <i>et al.</i> , USA ¹²	Applied Clinical Informatics November 25, 2020	Retrospective Cohort	COVID-19 patient discharged from hospital	<ul style="list-style-type: none"> • Oxygen saturation • Temperature • Survey for symptoms of shortness of breath, cough, appetite, weakness, and vomiting 	Average age of admission: 55 (17%) Sex: 63 (49%) male	Intervention (225) Control (1,061)	30 days	On the other hand, the group that was not under telemedicine monitoring had more readmissions and a higher death rate ninety days following discharge. Participants in the RPM program who were enrolled successfully on the first post-discharge day were linked to a lower chance of the composite endpoint of readmission presentation; however, those who were not enrolled successfully were not linked to a lower chance of the composite endpoint.
Marquez-Algaba <i>et al.</i> , Spain ²¹	Journal of Personalized Medicine January 1, 2022	RCT	COVID-19 patient after being discharged from hospital	<ul style="list-style-type: none"> • Temperature • Oxygen saturation • Heart frequency • Respiratory frequency • Patient-Reported Outcomes Measurement Information System (PROMIS) questionnaire • Hospital Anxiety and Depression Scale (HADS) 	Average age: I: 53.5 (46-59) C: 53.5 (43.2-63) Sex: I: 42 (56.8) male C: 43 (56.6) male	Intervention (n= 74) Control (n=76)	14 days	According to the protocol analysis, the control group experienced considerably more readmissions to the emergency department due to COVID-19.
Kuo <i>et al.</i> , USA ²²	JAMIA July 1, 2022	Retrospective Cohort	Post-acute care COVID-19 pneumonia patients	<ul style="list-style-type: none"> • Patient's clinical symptoms, vital signs, oxygen saturation 	Average age: I: 56 (51-68) C: 59 (47-68)	Intervention (75) Control (150)	30 days	For the control and RPM groups, 30-day all-

Authors, Country	Journal, Year of Publication	Study Design	Participant Characteristics	Measurement	Average and Mean Age (SD) of the Participants	Intervention (n=1,097) and Control (n=1,586)	Duration of Therapy	Results
				<ul style="list-style-type: none"> Health Index score 9-question satisfaction survey 	Sex: I: 50 (67%) male C: 96 (64%) male			cause readmission rates were 9.3% (7/75) and 14.7% (22/150), respectively.
Ye <i>et al.</i> , USA ²³	The Journal of General Internal Medicine January 14, 2021	Case series	Adult patients hospitalized with COVID-19 disease in an out-of-home setting	<ul style="list-style-type: none"> New or worsening symptoms of cough, new or worsening shortness of breath with light activity, subjective or objective fever, oxygen saturation, and pulse (if the device is available) via Telehealth Guides. Generalized Anxiety Disorder-2 (GAD-2) and the Patient Health Questionnaire-2 items (PHQ-2). Loneliness was assessed using a single item ("not at all" to "almost every day"). Patient satisfaction, they would recommend the program (0, not at all likely; 10, very likely). 	Average age: I: 56.7 ± 15.2 C: 58.0 ± 18.0 Sex: I: 137 (63.1%) male C: 108 (56.3%) male	Intervention (217) Control (192)	14 days	Compared with non-referred patients, patients referred for remote monitoring had fewer ED visits and readmissions.
Goor <i>et al.</i> , Netherland ^{s24}	Journal of Clinical Medicine December 17, 2021	RCT	COVID-19 patient being treated in hospital are in the recovery stage of the disease	<ul style="list-style-type: none"> Score for cough Shortness of breath and general well-being scores Temperature Oxygen saturation 	Average age: I: 55.1 (SD 7.5) C: 55.4 (SD 13.2) Sex: I: 14 (45.1%) female C: 13 (41.9%) female	Intervention (n= 31) Control (n=31)	30 days	A total of 62 patients were randomized (31 intervention, 31 control). The incidence of readmission due to COVID-19 was 2 for the intervention group (2/31) and 1 for the control group (1/31). The study showed no statistically significant differences.

Notes: SD = standard deviation, ASLAM = the Área Sanitaria de Lugo, A Mariña, y Monforte de Lemos healthcare, I = intervention, C = control, RPM = remote patient monitoring, ED = emergency department

A meta-analysis of the findings from the five studies on the effectiveness of RPM interventions in keeping COVID-19 patients out of hospital revealed statistically significant differences between the intervention group and the control group. The intervention group displayed a 0.56 times lower risk of rehospitalization ($I^2 = 9\%$; $n=2,685$; OR 0.56 [95% CI 0.39-0.82]; p -value = 0.003) in low variation (homogeneous) studies. A technique that was used to identify potential publication bias in meta-analyses was funnel plots. Based on the duration of the intervention, a reduction in the incidence of hospitalization of 0.61 times was observed in the intervention group compared to the control group in two studies of short-term RPM duration (2 weeks), albeit with no statistically significant difference ($I^2 = 60\%$; $n = 553$; OR 0.61 [95% CI 0.31-1.20]; p -value = 0.15). Three studies of long-term RPM training (over two weeks) found that the intervention group experienced 0.54 times fewer readmissions than the control group, and this difference was statistically significant ($I^2 = 0\%$; $n=2,132$; OR 0.54 [95% CI 0.34-0.86]; p -value = 0.009), as shown in Figure 2. The visual funnel plot used to illustrate the likelihood that a COVID-19 patient will need to be readmitted to the hospital showed no publication bias. It was funnel-shaped and symmetrical, as shown in Figure 3.

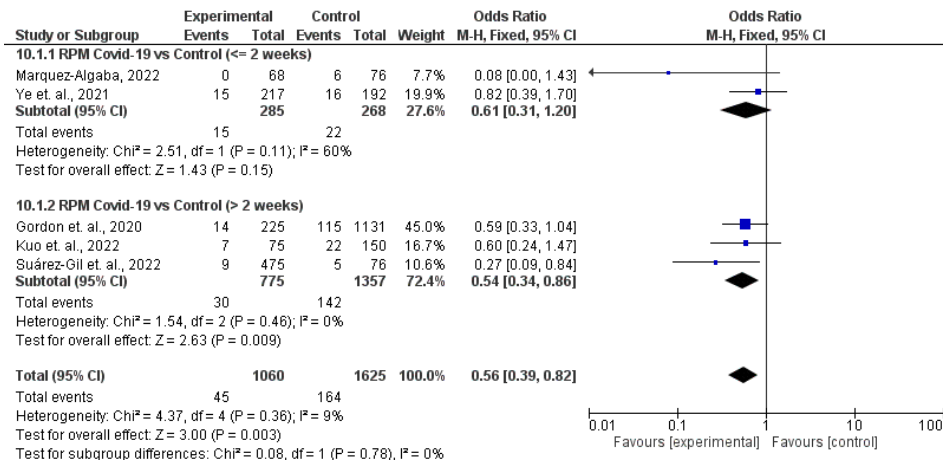


Figure 2. Forest Plot of Effectiveness of Remote Patient Monitoring Intervention to Reduce Readmission Compared to Control (Fixed Effect Model)

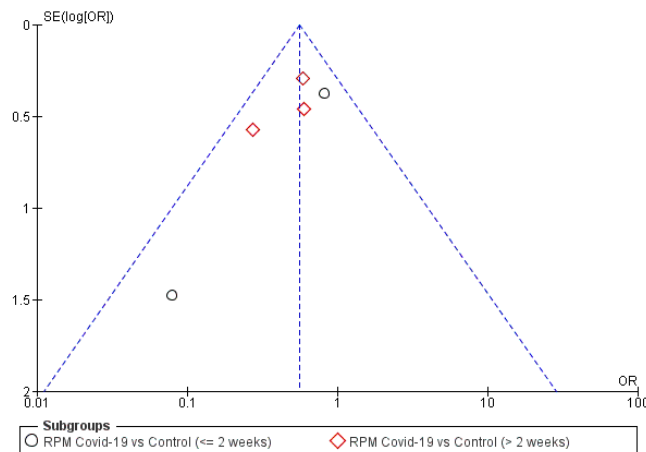


Figure 3. Funnel Plot of the Effectiveness of Remote Patient Monitoring Interventions to Lower Back Hospitalizations Compared to Controls

The authors then examined the data based on the pre-determined characteristics. It was found that males did not affect the reduction rate of the rehospitalization of COVID-19 patients, with a combined effect value of $Z = 0.58$. This value can be considered to be very small. Apart from that, there was no difference in overall OR, with an OR value of 1.06 and a 95% CI of 0.88-1.28. The p -value of 0.56 was greater than <0.05 , showing no statistically significant difference. The degree of heterogeneity was low (p -value = 0.77), and the I^2 was 0%. Females also did not substantially reduce the rehospitalization rate of COVID-19 patients, with a combined effect value of $Z = 0.77$, an OR value of 0.93, and a 95% CI of 0.77-1.12. The p -value of 0.44 was greater than <0.05 , meaning there was no statistically significant difference. Furthermore, the degree of heterogeneity was low (p -value = 0.81), and I^2 was 0%.

According to comorbidity of hypertension in three studies,^{3,22,23} there were no significant differences in the effect of using RPM, with a combined effect value of $Z = 0.67$, an OR value of 1.82, a 95% CI of 0.31–10.61, and a p-value of 0.50, which is greater than <0.05 . These results indicated no statistically significant difference. The degree of heterogeneity was high (p-value <0.001), and I^2 was 96%. For the COVID-19 patients with comorbidity of diabetes in these three studies,^{3,22,23} a significantly different effect of using RPM was observed, with a combined effect value of $Z = 2.67$. The overall OR was 0.66 with a 95% CI of 0.49–0.90, a low degree of heterogeneity (p-value = 0.57), and an I^2 value of 0%.

Two studies^{3,23} showed no significant effect in patients with comorbidity of heart failure, with a combined effect value of $Z = 0.50$ and an overall OR of 0.86 with a 95% CI of 0.48–1.54. The degree of heterogeneity (p-value = 0.77) was low, and an I^2 was 0%. In contrast, COVID-19 patients who had obesity in two studies^{3,22} showed no significant effect, with a combined effect value of $Z = 0.79$. Overall, there was no difference in OR, where the value was 0.85, with a 95% CI of 0.56–1.28, a low degree of heterogeneity (p-value = 0.43), and I^2 of 0%.

Patients with chronic lung disease in three studies^{3,22,23} displayed no significant effect, with a combined effect value of $Z = 0.24$ and an overall OR of 0.94 with a 95% CI of 0.60–1.50. There was a low degree of heterogeneity (p-value = 0.71) and an I^2 value of 0%. Similarly, a meta-analysis of chronic kidney disease from two studies^{22,23} showed no effect, with an odds ratio of 0.67 and a 95% CI of 0.18–2.49. The test results for the overall effect were $Z = 0.60$, with a p-value of 0.55, which is greater than <0.05 , indicating no statistically significant difference. The heterogeneity for chronic kidney disease was high, with an I^2 value of 75%.

Discussion

This meta-analysis used information from a global library of scientific literature to offer a thorough assessment of RPM concerning COVID-19. Along with demonstrating RPM's effectiveness in lowering rehospitalization rates for COVID-19 patients, the results also point to RPM's potential as a game-changing instrument in contemporary healthcare delivery. As part of the systematic review procedure, 897 entries from five major databases and other sources were thoroughly screened. Six articles were considered suitable for inclusion in the qualitative synthesis after duplicates and irrelevant studies were eliminated, and only five articles, totaling 2,691 participants, contributed to the meta-analysis. A concentrated evaluation of RPM's efficacy during the pandemic was ensured through this stringent selection procedure, which also enhanced the validity of the findings. This meta-analysis showed that RPM dramatically lowers rehospitalization rates among COVID-19 patients, with consistent findings across studies.

Three studies using a pulse oximeter, thermometer, and smartphone provide information on the RPM device used, respectively.^{3,12,23} Another study stated smartphone and video consultations were combined with the use of portable oxygen.²² This combination was made due to the characteristics of COVID-19 patients with pneumonia-related disorders.²² Using smartphones, video consultations, and pulse oximeters, Marquez-Algaba *et al.*'s study²¹ was in line with a systematic review of RPM from 272 studies showing that wireless devices or smartphone applications were the most popular strategies (75.7%) in RPM.²⁵ Two studies^{12,23} provided once-daily data, whereas three studies reported data twice a day.^{3,21,22} Three studies^{3,12,21} reported daily data starting at 8 am, while two studies did not mention the start time of reporting daily data.^{22,23}

It should be noted how simple RPM is to use. According to Delone & McLean's idea of the Information Success Model, which looks at how users behave in using information systems, system quality, information quality, service quality, and user happiness are aspects that influence a person's decision to use.²⁶ The users express satisfaction with the remote training experience, the ease of use of remote monitoring technology, the short learning curve for managing their health condition with a program, the lack of privacy concerns when using the technology, and the increased sense of security they receive from having a nurse that regularly checks on them.²² However, Suarez-Gil *et al.*'s study makes no mention of language use in applications.³ A study by Gordon *et al.* require participants to be released (with or without fellowship services), able to activate a patient portal account, and capable of completing an English or Spanish survey on their own or with a proxy.¹²

Being contactable by telephone was one of the inclusion criteria for Ye *et al.*'s study.²³ Referrals are made by emailing the contact information of the remote care coordinator who assigned the case to the Telehealth Guidance team to the patient. One of the barriers to inclusion criteria of Marquez-Algaba *et al.*'s study was the accessibility of mobile devices, such as smartphones or tablets with internet connectivity.²¹ Regarding the application used in this study, it was run by a healthcare monitor (hcM) (a doctor or nurse certified in COVID-19), who was also responsible for servicing alarms and responding to inquiries.²¹

The department receives and evaluates data on vital signs (temperature and oxygen saturation) as well as responses to a breathing guide questionnaire every eight hours before deciding whether to refer the patient to hospitalization again.²² The department team contacts the patient if any suspicious events occur, such as a change in the patient's biometrics or clinical status, as determined by the questionnaire.¹³ The RPM maintenance team monitors the platform and contacts patients based on their Health Index score, the home absolute threshold for vitals measurements, or patient-initiated requests for assistance. In the study, patient response questionnaires and biometric information were used to construct Health Index scores.²²

Messages will be sent to the Electronic Health Report (HER) inbox if one of three conditions occurs: first, the patient reports worsening symptoms in the questionnaire; second, O₂ saturation recorded alone is less than 92%; or third, the monitoring task assigned has not been completed within 24 hours.¹² When the patient is unresponsive or when the symptoms worsen, the EHR notifies the nursing staff, who then telephones the patient. The following criteria were used to identify if the patients are at increased risk during distance training: new or worsening mild activity-related shortness of breath; a new or intensifying cough; if a thermometer is not available; a new or intensifying fever.¹² Vital signs include a temperature of 100.4°F (if a thermometer is available), an oxygen saturation level of 95% (if a pulse oximeter is available), and a pulse rate of 110 beats per minute.¹² Patients in the control group trial received routine follow-ups in the primary care setting via telephone calls to track patients' symptoms.²¹

The length of intervention in patients at risk for COVID-19 is deemed successful after long-term (>2 weeks) RPM monitoring. The Health Resources and Services Administration (HRSA), a US Department of Health and Human Services division, established the RPM recommendation that data from remote physical monitoring should be collected for at least 16 to 30 days.²⁷ This recommendation fits these criteria and highlights the suitability of the approach. In addition, other research noted that the average gap between the discharge of the first and second COVID-19 patients ranged from 6 to 27 days.²⁸

When discussing the issue of COVID-19, diabetes has always been associated with worse outcomes. In Wuhan City, a study of 161 COVID-19 patients revealed that diabetic patients had a longer time to get rid of the virus. In addition, diabetes predisposes to infection due to typical factors, such as impaired neutrophil chemotaxis and phagocytosis. In general, several variables, such as increased expression of ACE-2, increased furin, decreased T-cell activity, and increased interleukin-6 (IL-6), contribute to the increased likelihood and severity of SARS-CoV2 infection in patients with diabetes.²⁹

This study revealed that RPM can be used more often by the government to manage, avoid, promote, and combat the negative impacts of COVID-19. For healthcare administrators to provide high-quality treatment, they must also keep up with current developments using personnel and equipment that track patient health. It is recommended that additional research be done on the use of RPM in the treatment of chronic post-hospitalization conditions such as diabetes, heart failure, hypertension, chronic kidney disease, and chronic obstructive pulmonary disease (COPD). This study's limitations include the following: a) the number of studies examined is small; b) research studies are only available in English and Indonesian; c) the results cannot be applied to the entire population because most COVID-19 patients are over 50; d) coronavirus mutations may impact the results; and e) access to paid articles is restricted.

Conclusion

The use of RPM during home treatment is effective in reducing the incidence of COVID-19 patient rehospitalization. Based on the characteristics, effect variation is seen for patients with comorbidity of diabetes. The duration of RPM intervention is more than two weeks, and patient compliance, as well as the expertise of doctors and nurses in monitoring, are very important for the effectiveness of RPM. The best RPM in this study is a combination of monitoring tools, smartphones, video consultations, and twice-daily monitoring. Implementing RPM can be useful in facing future pandemics or other chronic diseases to reduce rehospitalization.

Abbreviations

RPM: remote patient monitoring; Rob 2: Revised Cochrane Risk of Bias Tool for Randomized Trials; RCTs: randomized controlled trials; ROBINS-I: Risk of Bias in Non-randomized Studies of Interventions; CI: confidence interval; OR: odds ratio; EHR: electronic health report.

Ethics Approval and Consent to Participate

The ethical approval for this study is obtained from the Research Ethics and Public Health Services Commission, Faculty of Public Health, Universitas Indonesia (approval number: KET-646/UN2.F10.D11/PPM.00.02/2022).

Competing Interest

The authors have no conflicts of interest to declare.

Availability of Data and Materials

Data used in this study is available from the corresponding author upon reasonable request.

Authors' Contribution

DR and IT were responsible for conceptualization and methodology. DR and FW collected data. DR and DNS performed an investigation. DR wrote the original draft. IT supervised the study. All authors read and approved the final manuscript.

Acknowledgment

No funding.

References

1. Zorlu SA, Oz A. A Novel Combined Model to Predict the Prognosis of COVID-19: Radiologicalmetabolic Scoring. *Curr Med Imaging*. 2024; 20: e110523216780. DOI: 10.2174/1573405620666230511093259.
2. Carvalho ARB, Sousa Neto AR, Silva MDFD, et al. Global research trends related to coronavirus disease 2019 and the aged: A bibliometric analysis. *Sao Paulo Med J*. 2023; 142 (2): e2022662. DOI: 10.1590/1516-3180.2022.0662.R1.190523.
3. Suárez-Gil R, Casariego-Vales E, Blanco-López R, et al. Efficacy of telemedicine and telemonitoring in at-home monitoring of patients with COVID-19. *J Clin Med*. 2021; 10 (13): 2893. DOI: 10.3390/jcm10132893.
4. Mallah SI, Ghorab OK, Al-Salmi S, et al. COVID-19: Breaking down a global health crisis. *Ann Clin Microbiol Antimicrob*. 2021; 20 (1): 35. DOI: 10.1186/s12941-021-00438-7.
5. Javaid M, Haleem A, Vaishya R, et al. Industry 4.0 technologies and their applications in fighting COVID-19 pandemic. *Diabetes Metab Syndr*. 2020; 14, (4): 419-422. DOI: 10.1016/j.dsx.2020.04.032.
6. Lukas H, Xu C, Yu Y, et al. Emerging Telemedicine Tools for Remote COVID-19 Diagnosis, Monitoring, and Management. *ACS Nano*. 2020; 14 (12): 16180–16193. DOI: 10.1021/acsnano.0c08494.
7. Alwan M, Bravinder J, Burnstein P, et al. Telehealth and remote patient monitoring for long-term and post-acute care: A primer and provider selection guide. Washington DC: The LeadingAge Center for Aging Services Technologies (CAST); 2015.
8. Pappot N, Taarnhøj GA, Pappot H. Telemedicine and e-Health Solutions for COVID-19: Patients' Perspective. *Telemed J E Health*. 2020; 26 (7): 847–849. DOI: 10.1089/tmj.2020.0099.
9. Martínez-García M, Bal-Alvarado M, Santos Guerra F, et al. Monitoring of COVID-19 patients via telemedicine with telemonitoring. *Rev Clin Esp (English Edition)*. 2020; 220 (8): 472–479. DOI: 10.1016/j.rceng.2020.07.001.
10. Roblyer D. Perspective on the increasing role of optical wearables and remote patient monitoring in the COVID-19 era and beyond. *J Biomed Opt*. 2020; 25 (10): 102703. DOI: 10.1117/1.JBO.25.10.102703.
11. Patel H, Hassell A, Cyriacks B, et al. Building a Real-Time Remote Patient Monitoring Patient Safety Program for COVID-19 Patients. *Am J Med Qual*. 2022; 37 (4): 342-347. DOI: 10.1097/JMQ.0000000000000046.
12. Gordon WJ, Henderson D, Desharone A, et al. Remote patient monitoring program for hospital discharged COVID-19 patients. *Appl Clin Inform*. 2020; 11 (5): 792–801. DOI: 10.1055/s-0040-1721039.
13. Crotty BH, Dong Y, Laud P, et al. Hospitalization Outcomes Among Patients with COVID-19 Undergoing Remote Monitoring. *JAMA Netw Open*. 2022; 5 (7): e2221050. DOI: 10.1001/jamanetworkopen.2022.21050.
14. Pritchett JC, Borah BJ, Desai AP, et al. Association of a Remote Patient Monitoring (RPM) Program With Reduced Hospitalizations in Cancer Patients with COVID-19. *JCO Oncol Pract*. 2021; 17 (9): e1293–e1302. DOI: 10.1200/OP.21.00307.
15. Oh SM, Nair S, Casler A, et al. A prospective observational study evaluating the use of remote patient monitoring in ED discharged COVID-19 patients in NYC. *Am J Emerg Med*. 2022; 55: 64-71. DOI: 10.1016/j.ajem.2022.02.035.
16. Siregar KN, Sari DN, Wathan FM, et al. Langkah Demi Langkah Systematic Literature Review dan Meta-Analysis di Bidang Kesehatan. Depok: Universitas Indonesia Publishing; 2021
17. Aromataris E, Lockwood C, Porritt K, et al. JBI Manual for Evidence Synthesis. JBI; 2024. DOI: 10.46658/JBIMES-24-01.
18. Higgins JP, Savović J, Page MJ, et al. Revised Cochrane risk-of-bias tool for randomized trials (RoB 2) SHORT VERSION (CRIBSHEET); 2019.
19. Sterne JA, Higgins JP, Elbers RG, et al. Risk Of Bias In Non-randomized Studies of Interventions (ROBINS-I): Detailed guidance; 2016.
20. Evidence Synthesis Hackathon. Robvis (visualization tool); 2022.
21. Marquez-Algaba E, Sanchez M, Baladas M, et al. COVID-19 follow-app. Mobile app-based monitoring of COVID-19 patients after hospital discharge: A single-center, open-label, randomized clinical trial. *J Pers Med*. 2022; 12 (1): 24. DOI: 10.3390/jpm12010024.
22. Kuo S, Aledia A, O'Connell R, et al. Implementation and impact on length of stay of a post-discharge remote patient monitoring program for acutely hospitalized COVID-19 pneumonia patients. *JAMIA Open*. 2022; 5 (3): ooac060. DOI: 10.1093/jamiaopen/ooac060.
23. Ye S, Hiura G, Fleck E, et al. Hospital readmissions after implementation of a discharge care program for patients with COVID-19 illness. *J Gen Intern Med*. 2021; 36 (3): 722–729. DOI: 10.1007/s11606-020-06340-w.
24. Goor HMR van, Breteler MJM, Loon K van, et al. Remote hospital care for recovering COVID-19 patients using telemedicine: A randomised controlled trial. 2021; 10 (24): 5940. DOI: 10.3390/jcm10245940.
25. Farias FAC, Dagostini CM, Bicca YA, et al. Remote Patient Monitoring: A Systematic Review. *Telemed J E Health*. 2020; 26 (5): 576-583. DOI: 10.1089/tmj.2019.0066.
26. Ghosh A, Gupta R, Misra A. Telemedicine for diabetes care in India during COVID19 pandemic and national lockdown period: Guidelines for physicians. *Diabetes Metab Syndr*. 2020; 14 (4): 273-276. DOI: 10.1016/j.dsx.2020.04.001.
27. Health Resources and Services Administration. Telehealth and remote patient monitoring. Washington, DC: U.S. Department of Health and Human Services; 2023.

28. Chen M, An W, Xia F, et al. Clinical characteristics of rehospitalized patients with COVID-19 in China. *J Med Virol*. 2020; 92 (10): 2146-2151. DOI: 10.1002/jmv.26002.
29. Singh AK, Gupta R, Ghosh A, et al. Diabetes in COVID-19: Prevalence, pathophysiology, prognosis and practical considerations. *Diabetes Metab Syndr*. 2020; 14 (4): 303-310. DOI: 10.1016/j.dsx.2020.04.004.