applied sciences

MDPI

Review

Key Factors for a Successful Telemedicine Solution for Cardiovascular Diseases: A Systematic Review

Giuseppe Felice Russo *,†, Ilaria Basile †, Mario Ciampi and Stefano Silvestri *

Institute for High Performance Computing and Networking, National Research Council of Italy (ICAR-CNR), Via Pietro Castellino 111, 80131 Naples, Italy; ilaria.basile@icar.cnr.it (I.B.); mario.ciampi@icar.cnr.it (M.C.)
* Correspondence: giuseppefelice.russo@icar.cnr.it (G.F.R.); stefano.silvestri@icar.cnr.it (S.S.)
† These authors contributed equally to this work.

Featured Application: The potential use of telemonitoring devices in the routine treatment of cardiovascular diseases has been shown by this study. Healthcare professionals might potentially decrease hospital readmissions, improve disease management, and improve patient monitoring by integrating telemonitoring technologies into standard care procedures.

Abstract: Background: Telemonitoring systems in cardiology have shown potential in improving chronic cardiovascular disease (CVD) management. This study aims to evaluate the impact of telemonitoring, mainly through mobile applications, on patient outcomes such as self-care, blood pressure control, quality of life, and hospitalization. Methods: We systematically reviewed studies assessing telemonitoring methods for patients with chronic CVD. The analysis included studies from various geographic regions and healthcare settings, focusing on qualitative outcomes without performing a meta-analysis. Results: Telemonitoring was found to aid in maintaining blood pressure and significantly enhance self-care abilities. Improvements in quality of life were observed in some studies, though results varied. Most studies indicated telemonitoring could effectively manage blood pressure and reduce hypertension-related complications. However, the heterogeneity of interventions and outcomes measured across trials posed challenges for a comprehensive meta-analysis. Conclusions: Integrating telemonitoring systems into routine care can significantly improve disease management and patient outcomes for chronic CVD patients. Future research should standardize telemonitoring interventions and outcome measures, conduct long-term studies, and evaluate the cost-effectiveness of these systems. Greater blindness in future randomized controlled trials and more studies on atrial fibrillation are also necessary. Significant potential exists for telemonitoring to improve patient outcomes and assist in managing chronic illnesses.

Keywords: telemedicine; heart failure; atrial fibrillation; hypertension; telemonitoring

Citation: Russo, G.F.; Basile, I.; Ciampi, M.; Silvestri, S. Key Factors for a Successful Telemedicine Solution for Cardiovascular Diseases: A Systematic Review. *Appl. Sci.* **2024**, *14*, 7633. https://doi.org/10.3390/app14177633

Academic Editor: Qi-Huang Zheng

Received: 6 August 2024
Revised: 20 August 2024
Accepted: 22 August 2024
Published: 29 August 2024

1. Introduction

In recent years, the adoption of telemonitoring systems in cardiology has shown significant potential in improving the management of chronic cardiovascular diseases [1]. Telemedicine, defined as using technology to provide healthcare services remotely [2], has become crucial in treating conditions such as hypertension, atrial fibrillation, and heart failure. This approach allows for constant monitoring of patient's vital parameters, enhancing the timeliness and effectiveness of care.

The benefits of telemonitoring have been documented in various systematic reviews [3,4], which have highlighted how the implementation of such technologies can lead to a significant reduction in hospitalizations and mortality rates, as well as an overall improvement in patient quality of life. However, it is important to note that this systematic review does not include a meta-analysis but focuses on the qualitative analysis of available studies.

The universal definitions of the diseases considered in this review are crucial for contextualizing the results and effectively comparing studies. Hypertension is commonly defined as a systolic blood pressure of at least 140 mmHg and/or a diastolic pressure of at least 90 mmHg [5]. Heart failure is characterized by the heart's inability to pump sufficient blood to meet the body's needs [6,7], while atrial fibrillation is a cardiac arrhythmia that results in an irregular and often rapid heartbeat [8].

The rapid development of telemedicine has been further accelerated by the COVID-19 pandemic, highlighting the need for innovative and remote healthcare solutions [9]. During this period, a significant increase in telemedicine services was observed, making it essential to evaluate the effectiveness and efficiency of these interventions in emergency health contexts. Telemedicine facilitated the continuity of care during the pandemic and opened new perspectives for managing chronic diseases, reducing the need for in-person visits, and improving accessibility to healthcare services [10].

The primary objective of this systematic review is to assess whether the use of telemonitoring systems for patients with chronic cardiovascular diseases can improve their quality of life, including psychological and physical health, and increase their awareness of the disease and management methods. Specifically, the focus is on the effectiveness of these systems in improving disease-specific parameters, quality of life, and patients' ability to self-manage their condition.

In this context, telemonitoring presents a promising solution to address the challenges posed by cardiovascular diseases. Several studies [11–16] have demonstrated that using remote monitoring devices and mobile applications can lead to better blood pressure control, reduced heart failure symptoms, and improved patients' quality of life. Moreover, the real-time monitoring of vital parameters allows physicians to intervene promptly in case of a deterioration in the patient's condition, thereby enhancing the effectiveness of prescribed therapies.

Despite the numerous advantages, there are still some barriers to the widespread adoption of telemedicine, including the need for adequate technological and secure infrastructure, training of medical personnel, and resistance to change from older patients [17–19]. However, with continuous technological advancement and the increasing integration of these solutions into healthcare systems, telemonitoring will likely become an integral part of cardiovascular disease management in the near future.

This systematic review aims to provide a comprehensive overview of the current state of telemonitoring for cardiovascular diseases. It analyzes the results of recent studies and identifies best practices and areas needing further research. The ultimate goal is to provide evidence-based recommendations for effectively implementing these technologies to improve clinical outcomes and the quality of life for patients with chronic cardiovascular diseases.

2. Materials and Methods

This systematic review was based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework [20–22]. It should be noted that this review was not registered, and no formal protocol was prepared prior to the initiation of the review. The review aims to answer the following research question: does the use of telemonitoring systems for patients with chronic cardiovascular diseases (CVD) allow for improving their living conditions, including psychological and physical health, and improve their awareness of the disease and management methods?

2.1. Eligibility Criteria

As observed in other studies [23], the PICOS (Population, Intervention, Comparator, Outcomes, Study design) [24] strategy was adopted to perform the research and the selection of the studies to determine the inclusion criteria of articles in the review. In the following subsections, the eligibility criteria for each of the categories of the PICOS strategy are explained in detail.

2.1.1. Population

All studies between 2020 and 2024 analyzing the effects of a telemedicine intervention on patients aged 18 years or older were considered eligible for inclusion if they had one or more of the following cardiovascular diseases: hypertension, heart failure, or atrial fibrillation.

2.1.2. Intervention

The considered trials concerned the use of systems enabling medical practitioners to remotely monitor disease-specific parameters of intervention group participants. Only trials in which patients in the intervention group received a telemonitoring device to collect disease-related parameter values or a smartphone app to send their data to the medical center were included. The remote patient monitoring devices must be able to transmit the collected data to the medical team so that the latter can make appropriate changes to the therapy.

2.1.3. Comparator

Studies in which the usual care (UC) or a more limited intervention (e.g., a version of the app with fewer functionalities concerning the app used in the intervention) was used in the control group were considered eligible for inclusion in the systematic review.

2.1.4. Outcomes

Consideration was given to trials in which the results being measured are related to the improvement of the patient's living condition, understood both as physical or psychological health and as a better awareness of the disease and the techniques for managing it, i.e., improvement in quality of life, disease-specific parameters, ability to measure these parameters, self-care, etc.

2.1.5. Study Design

Only randomized controlled trials (RCTs) were included, while non-randomized or non-controlled trials, study protocols and designs, cross-sectional, retrospective, qualitative, observational, and pilot studies, conference proceedings, feasibility, cost, ancillary, and secondary analyses, and all studies not reporting the use of a telemonitoring system were excluded.

2.2. Search Strategy and Information Sources

The literature search covered articles in the PubMed, Scopus, and Web of Science databases and published in English from 1st January 2020 to 2nd February 2024. The choice to analyze the period between 2020 and 2024 is motivated by the significant increase in telemedicine services found during the COVID-19 pandemic [25–27]. It will be interesting to see whether this topic of research and application is exclusively related to the early times of pandemic-related emergencies or whether it has become common in healthcare. The Supplementary Materials contain a description of the entire search approach and terms.

All records found were exported in Research Information Systems (RIS) formats, which are fed to EndNote (https://myendnoteweb.com, accessed on 21 August 2024), the reference manager used for this review.

All English-language studies were included. The terms used as keywords for the search were 'telemedicine', 'heart failure', 'hypertension', and 'atrial fibrillation', and their synonyms and combinations were obtained using Boolean operators. In particular, the following combination of terms was used: ("telemedicine*" AND ("hypertension*" OR "heart failure*" OR "atrial fibrillation*")).

Prior to the screening stage by study title, all duplicate papers were eliminated via a reference management tool.

2.3. Study Selection

The studies were selected using the appropriate tool produced by Clarivate Analytics, EndNote. In the first step, the title and abstract of the papers from the database search were analyzed, eliminating all articles that did not meet the inclusion criteria. Subsequently, full texts were examined to exclude all articles that did not include remote monitoring of disease-specific parameters in their interventions.

2.4. Data Extraction

We performed independent data extraction and obtained the following information for each trial: authors, year, country, and reference; number of participants and their age and sex; health condition; type of intervention (how the data are transmitted, follow-up duration, etc.); comparator (usual care, different interventions, etc.); outcomes (primary and secondary); impact of telemonitoring intervention on outcomes, compared to the control group.

2.5. Risk of Bias Assessment

We performed an independent risk of bias assessment of all papers using the Cochrane Risk of Bias 2 [28–30], the standard de facto for the evaluation of bias in studies (https://methods.cochrane.org/bias/resources/rob-2-revised-cochrane-risk-bias-tool-randomized-trials, accessed on 21 August 2024). All included studies were classified into five different domains according to three levels of bias: low, medium, and high. Some outcomes, such as hospitalizations and mortality, are unlikely to be influenced by the lack of blindness. In contrast, others, such as improvement in quality of life (QoL), disease-specific knowledge, or self-care, are likely influenced by patient subjectivity.

3. Results

3.1. Study Selection and Characteristics

There were 866 articles found in all. The remaining 831 records were assessed for inclusion/exclusion criteria based on their title and abstract after 35 duplicates were removed. According to this screening, 793 works that did not fit the inclusion requirements were dropped. After reading 38 whole texts in all, 22 of them [31–52] were considered appropriate after the selection process since they met all the standards (Figure 1).

Tables 1–3 show the characteristics of the studies included in the analysis, respectively, for the three diseases reviewed, i.e., hypertension, atrial fibrillation, and heart failure. Less than 100 patients were included in each arm of a large number (12/22, 54.5%) of RCTs, and sample sizes range from 40 [50] to 3628 [39]. Most of the included studies were carried out in China (5/22, 22.7%), with a smaller number of studies carried out in Sweden, Germany, and the USA (2/22, 9.1%). Additionally, 4.5% (1/22) of the investigations were conducted in each of the following nations: Iran [32], Jordan [37], Spain [38], UK [46], Greece [42], South Korea [33], Denmark [34], Belgium (in combination with Italy) [35], Australia [36], Singapore [40] and Argentina [50]. The average age ranged from 48 to 80, with a greater percentage of males. Patients in the majority of trials (16/22, 72.7%) were followed for fewer than a year, and follow-up time ranges from 8 weeks [37] to 24 months [38,41]. The variables that were most frequently monitored were blood pressure, quality of life (9/22, 40.91%), patient adherence, self-care (7/22, 31.82%), and hospitalization (4/22, 18.2%). In particular, QoL was measured through SF-36 (consisting of MCS and PCS) [53], EQ-5D-5L [54], MLHFQ [55], AFEQT (2/22, 9.1%) [56], SF-12 [57] and MacNew Heart Disease HRQoL (1/22, 4.5%) [58]. Furthermore, current European recommendations [59] state that a mean office systolic blood pressure (SBP) of at least 140 mmHg and/or a diastolic blood pressure (DBP) of at least 90 mmHg constitute uncontrolled blood pressure. Manual input was the most common data entry method (14/22, 63.6%). At the same time, eight of the strategies under study (36.36%) stated automatic interfaces using external devices that were wirelessly connected (e.g., scales, blood pressure monitors, etc.). Most trials (18/22, 81.8%)

compared the intervention with standard care, which included in-person meetings with general practitioners or the hospital care team and routine visits (outpatient clinics).

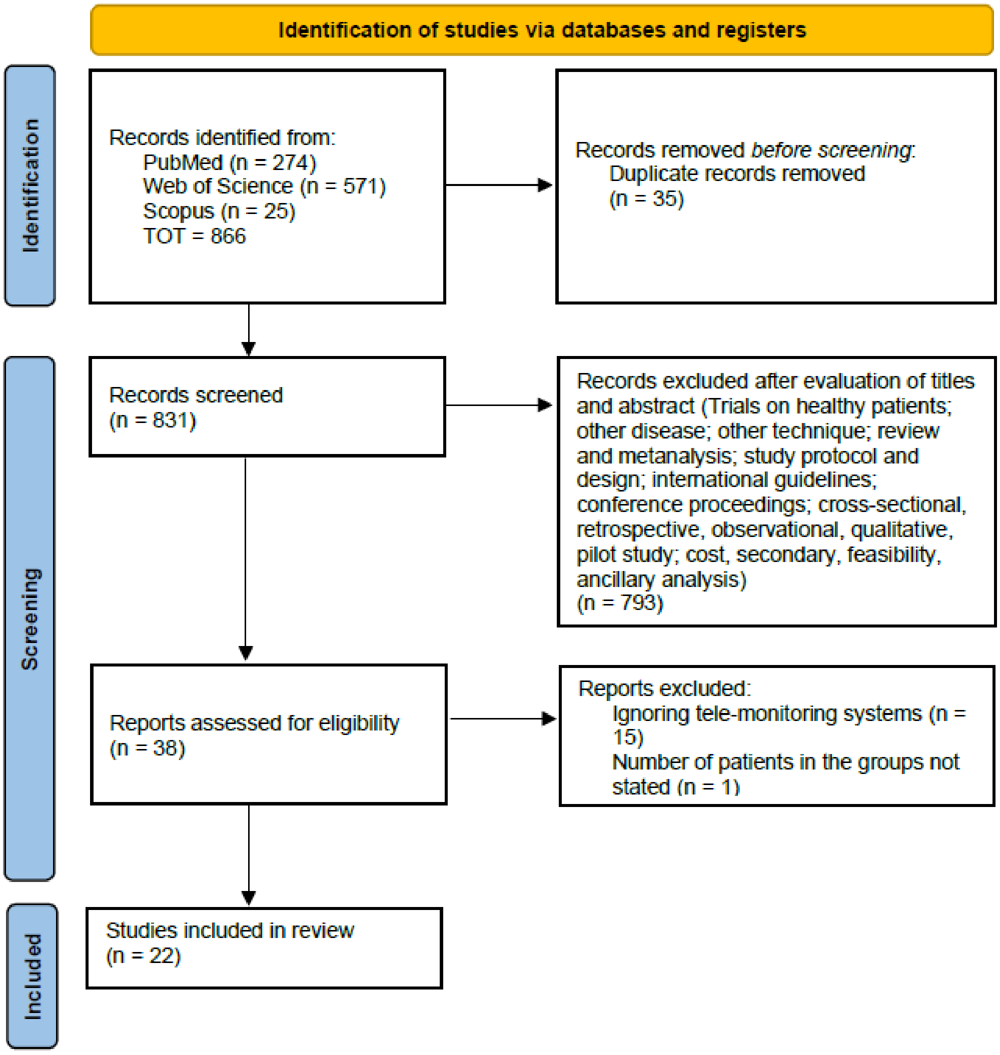

Figure 1. PRISMA diagram depicting the screening and study selection process.

Table 1. Description of the studies relative to hypertension.

Study	Intervention/ Comparator (Patients)	Mean Age in Years (SD), Men (%)	Follow-Up, Patients after Follow-Up	Outcomes	Impact
Andersson et al., 2023, Sweden [31]	Web-based TM system (482); UC (467)	I: 62.8 (9.8), 283 (58.7); C: 63.0 (10.0), 259 (55.5) *at baseline*	12 months; I: 442, C: 420	% patients with a controlled BP	Positive effect, with uncertain long-term effect
Bozorgi et al., 2021, Iran [32]	Mobile app (60); UC (60)	I: 52.0 (8.1), 35 (58.3); C: 51.6 (9.4), 36 (60.0) *at baseline*	24 weeks; I: 58, C: 60	Adherence to treatment; adherence to DASH diet, regular monitoring of BP, physical activity	Positive effect
Dwairej et al., 2022, Jordan [37]	Mobile app (75); UC (75)	I: 50.0 (7.3), 32 (56.1); C: 51.0 (5.1), 31 (52.5) *after follow-up*	8 weeks; I: 57, C: 59	Self-care, self-efficacy, knowledge, % patients with a controlled BP	Positive effect

Table 1. *Cont.*

Study	Intervention/ Comparator (Patients)	Mean Age in Years (SD), Men (%)	Follow-Up, Patients after Follow-Up	Outcomes	Impact
Echeazarra et al., 2021, Spain [38]	Telegram chatbot (55); UC (57)	I: 50.2, 32 (58.2); C: 53.9, 33 (57.9) *at baseline*	24 months; 88	Adherence to checking schedule, knowledge and skills on BP checking best practices, satisfaction with intervention	No change on adherence, positive effect on knowledge and skills
Leupold et al., 2023, Germany [43]	Patient app connected with a practice management centre (331); UC (305)	I: 56.9 (8.7), 181 (54.7); C: 59.2 (9.7), 154 (50.5) *at baseline*	6 months; I: 311, C: 305	BP control rate, BP changes, satisfaction with intervention	Positive effect
Liu et al., 2023, China [44]	Mobile app (148); UC (149)	I: 48.58 (9.54), 78 (52.7); C: 50.64 (8.72), 70 (47) *at baseline*	6 months; I: 111, C: 115	BP control rate, knowledge, changes in lifestyle behavior, blood glucose levels, blood lipid levels, waist-hip ratio, BMI	Positive effect
McManus et al., 2021, UK [46]	Self-monitoring of BP (305); UC (317)	I: 65.2 (10.3), 160 (52.46); C: 66.7 (10.2), 174 (54.89) *at baseline*	12 months; I: 271, C: 282	Change in BP, drug adherence, HRQoL (EQ-5D-5L)	Positive effect
Meng et al., 2023, China [47]	Smart device and a mobile app (95); UC (95)	I: 50.96 (10.50), 50 (59.5); C: 51.45 (12.22), 51 (58.0) *after follow-up*	12 weeks; I: 84, C: 88	BP reduction, % patients achieving the target BP	Positive effect
Yuting et al., 2023, China [51]	Smart device and a mobile app (74); UC (74)	I: 61.37 (11.73), 45 (68.18); C: 62.09 (10.66), 38 (55.88) *after follow-up*	12 weeks; I: 66, C: 68	Change in BP, in waist and hip circumference, height and weight; HT adherence, change in self-efficacy and QoL (SF-12)	No change in diastolic BP, positive effect on diastolic BP, HT compliance, mental health
Zhang et al., 2022, China [52]	Smart device and a mobile app (164); UC (143)	I: 56.7 (9.3), 44 (42.3); C: 62.6 (10.1), 31 (35.2) *after follow-up*	6 months; I: 104, C: 88	Reduction in BP and weight	Positive effect

Table 2. Description of the studies relative to atrial fibrillation.

Study	Intervention/ Comparator (Patients)	Mean Age in Years (SD), Men (%)	Follow-Up, Patients after Follow-Up	Outcomes	Impact
Guo et al., 2020, China [39]	Mobile app (1786); UC (1842)	I: 67.0 (15.0), 1021 (62.0); C: 70.0 (12.0), 1041 (62.0) *after follow-up*	286 days (mean); I: 1646, C: 1678	Composite of stroke/thromboembolism, all-cause death, hospitalization	Positive effect
Lazaridis et al., 2022, Greece [42]	Mobile app (40); Limited version of the app (40)	I: 58.8 (7.9), 27 (68); C: 57.5 (9.4), 26 (65) *at baseline*	6 months; I: 40, C: 40	QoL (AFEQT, EQ-5D-5L), app adherence	Positive effect
Marcus et al., 2021, USA [45]	Trigger testing with a mobile app (251); Monitoring only with a mobile app (248)	I: 58 (14), 149 (59); C: 58 (14), 140 (56) *at baseline*	10 weeks; I: 136, C: 184	QoL (AFEQT)	No change

Table 3. Description of the studies relative to heart failure.

Study	Intervention/ Comparator (Patients)	Mean Age in Years (SD), Men (%)	Follow-Up, Patients after Follow-Up	Outcomes	Impact
Choi et al., 2023, South Korea [33]	Mobile app (38); UC (38)	I: 70.31 (10.55), 19 (52.8); C: 79.42 (7.59), 16 (42.1) *after follow-up*	3 months; I: 36, C: 38	Differences in BMI, waist circumference, BP, NYHA functional classes [60], TTE, depression, QoL (MacNew), medication adherence	Positive effect on physical factors, no change in psychosocial and behavioral factors
Cichosz et al., 2020, Denmark [34]	Tablet and smart devices (145); UC (154)	I: 70, 83 (57.24); C: 69, 79 (51.3)	12 months; I: 93, C: 100	Change in HRQoL (SF-36)	Positive effect on MCS, no change on PCS
Clays et al., 2021, Belgium & Italy [35]	Smart devices (38); UC (23)	I: 61.8 (11.0), 26 (76.47); C: 65.2 (9.6), 17 (77.27) *after follow-up*	6 months; I: 34, C: 22	Change in HRQoL (MLHFQ), self-care, exercise capacity, illness perception, mental and sexual health	Positive effect on mental and sexual health and in self-care, no change in other factors
Ding et al., 2020, Australia [36]	Smart devices (91); UC (93)	I: 69.5 (12.3), 66 (73); C: 70.8 (12.4), 75 (81) *at baseline*	6 months; I: 67, C: 81	Patient compliance with self-monitoring	Positive effect
Jiang et al., 2021, Singapore [40]	A: toolkit for self-care (71); B: additional mobile app (70); C: UC (72)	A: 69.08 (10.51), 35 (71.4); B: 66.82 (11.81), 40 (70.2); C: 68.82 (13.14), 37 (66.1) *after follow-up*	6 months; A: 49, B: 57, C: 56	HF self-care, cardiac self-efficacy, anxiety and depression, HRQoL (MLHFQ), perceived social support	Positive effect
Koehler et al., 2020, Germany [41]	Smart devices (339); UC (335)	I: 67.13 (10.92), 272 (80.2); C: 66.88 (10.56), 276 (82.4) *at baseline*	24 months; I: 198, C: 210	Change in depression and HRQoL (SF-36)	Positive effect
Sahlin et al., 2022, Sweden [48]	Home-based medical device (62); UC (62)	I: 80 (8), 39 (67.24); C: 77 (11), 32 (53.3) *after follow-up*	240 days; I: 58, C: 60	HF self-care, Number of HF-related in-hospital days	Positive effect
Upshaw et al., 2023, USA [49]	Remote monitoring of parameters and symptoms via a tablet (159); telephone-based management (53)	I: 68, 115 (72); C: 74, 35 (66) *at baseline*	90 days; I: 156, C: 52	Number of days hospitalized for HF	No change
Yanicelli et al., 2020, Argentina [50]	Mobile app (20); UC (20)	52 y.o., I: 14 (93); C: 10 (66) *after follow-up*	90 days; I: 15, C: 15	Change in HF self-care, treatment adherence, re-hospitalizion	Positive effect

3.2. Interventions

For hypertension, Andersson et al. [31] provided participants with a Microlife BP A6 BT monitor and nightly reminders to measure and report blood pressure and other vital signs via a web portal accessible to both patients and healthcare providers. Bozorgi et al. [32] used an app for blood pressure logging, medication reminders, and informational support, alerting family and clinicians if readings were abnormal. Dwairej et al. [37] also offered an app for blood pressure recording and access to educational materials, with data available to clinicians through a web tool. Echeazarra et al. [38] implemented a Telegram bot for twice-daily blood pressure reminders and recording, with data available to healthcare providers. Leupold et al. [43] used a BOSO Medicus family 4 monitor, an app and an online eLearning system for data transmission and graphical analysis. Liu et al. [44] provided an app for logging blood pressure and other health metrics, such as heart rate and medication intake, viewable by healthcare providers. McManus et al. [46] had participants measure blood pressure with an Omron M3 monitor twice each morning for a week each month, with out-of-range values alerting clinicians via email. Meng et al. [47] equipped participants with a sphygmomanometer that automatically uploaded readings to an app accessible by patients and clinicians. Yuting et al. [51] provided a wrist blood pressure monitor that sent daily readings via Bluetooth to a website. Zhang et al. [52] used a Sanjian Tech Co. digital bracelet and app for patients and healthcare providers to log and monitor data automatically.

In atrial fibrillation studies, Guo et al. [39] used an app and photoplethysmography (PPG) smart devices for heart rhythm monitoring, allowing remote or hospital-based management of critical events. Lazaridis et al. [42] had both intervention and control groups use an app to log heart rate, with the intervention group logging additional parameters like blood pressure, weight, glucose levels, oxygen saturation, and therapy adherence. Marcus et al. [45] provided an app for selecting and statistically analyzing triggers for atrial fibrillation episodes, offering probabilistic feedback on potential triggers.

For heart failure, Choi et al. [33] offered an app for daily logging of blood pressure, weight, medication, meals, and exercise, including informational content and direct Q&A with clinicians. Cichosz et al. [34] provided a Samsung Galaxy Tab2, a UA-767 blood pressure monitor, and a precision scale, with data transmitted to a central system and alerts for out-of-range values. Clays et al. [35] used a comprehensive system with a blood pressure monitor, scale, pill organizer, and wristband sensor, with data processed by a decision support system and displayed via a smartphone app installed on a Nokia 6 TA-1021 smartphone. Ding et al. [36] used a digital scale and Samsung Galaxy Tab A to transmit weight data to an online decision support system, generating six possible alerts about weight fluctuation or low-level battery. Jiang et al. [40] combined educational and self-management toolkits with three home visits and an app, only available for experimental group B, for reminders, symptom logging, and communication with medical staff. Koehler et al. [41] provided devices for collecting blood pressure, weight, and electrocardiogram (ECG), which were connected via Bluetooth to a digital assistant transmitting data to a medical center. Sahlin et al. [48] offered the OPTILOGG device, a tablet connected to a scale featuring symptom monitoring, interactive education, and diuretic adjustments, with data shareable to medical practitioners at the patient's discretion. Upshaw et al. [49] used an app for daily logging of weight, heart rate, blood pressure, and symptoms, with healthcare provider alerts for concerning data. Yanicelli et al. [50] provided a system that included an app for daily logging of health metrics, processing data online, and sending risk alerts to medical staff, with additional educational features and interactive content.

3.3. Risk of Bias Assessment

Each included study's RoB2 domain scores are displayed in Figure 2. Twenty-one (95.5%) RCTs raised at least some concerns about bias. At the same time, only one (4.5%) was classified as having minimal risk of bias [52].

In particular, two studies (9.1%) showed some concerns about bias in the randomization process. Because of the deviations from the intended interventions, most of the findings (19/22, 86.36%) either raised some concerns or demonstrated a significant risk of bias. Due to incomplete outcome data, three RCTs (13.6%) had problems or a high risk of bias. Of the 22 studies, thirteen (59.1%) have some issues or a significant risk of bias in measuring outcomes. Lastly, only a small number of RCTs (5/22, 22.73%) revealed significant issues or a high risk of bias in the reported outcome selection.

3.4. Outcomes

Most of the blood pressure studies involved (8/9, 88.9%) showed a positive effect of telemonitoring intervention on patients' BP control ratios. Concerning quality of life, it must be remembered that the studies do not use a unique metric to measure it, so it is impossible to compare the various trials objectively. However, four out of nine studies (44.4%) monitoring QoL show improvements compared to the control group due to the telemedicine intervention. Most studies (5/7, 71.43%) examining patient adherence indicated a positive effect due to telemonitoring, highlighting its role in improving adherence to treatment regimens. Furthermore, six out of seven studies (85.71%) focusing on self-care demonstrate increases in this variable due to the telemedicine intervention with the control group. Finally, studies concerning hospitalization showed, for the biggest part (3/4, 75%), a positive impact of telemedicine on these outcomes when compared to the control patients.

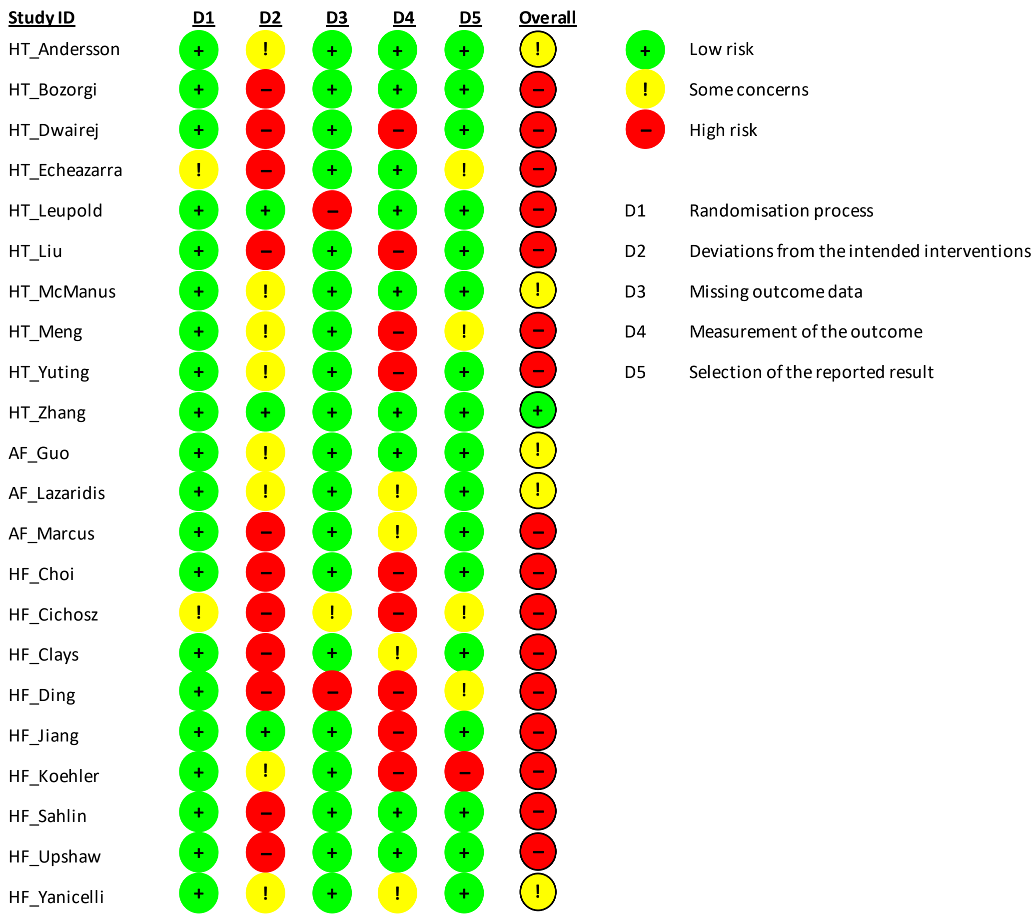

Figure 2. Risk of bias assessment for included studies undertaken using the Risk of Bias 2 (RoB2) tool [29].

4. Discussion

4.1. Principal Findings

The impact of telemonitoring methods with mobile applications on patients with chronic cardiovascular illnesses was assessed in this systematic review. Using them enhances self-care and blood pressure control ratios. Some effects varied between the RCTs concerning quality of life. The majority of studies raised at least some bias-related issues. For some of the papers analyzed, the analysis of the risk of bias raised discordant opinions among reviewers and was, therefore, subject to further evaluation.

A significant concern in interpreting these findings is the variability in sample sizes across the studies. Many of the included trials had small sample sizes, with over half (54.5%) of the studies involving fewer than 100 patients per arm. This variability in sample sizes introduces challenges in detecting real differences in outcomes and increases the risk of type II errors, where true effects may not be observed due to insufficient statistical power. For instance, smaller sample sizes may limit the ability to generalize findings and accurately assess the efficacy of telemonitoring interventions. Larger and more consistent sample sizes are crucial for drawing more reliable conclusions and ensuring that observed effects are not merely due to random variation or sampling error.

Most studies showed that telemonitoring helped CVD patients maintain their blood pressure. These results imply that telemonitoring can be very helpful in controlling blood pressure and possibly lowering complications associated with hypertension. Improvements in quality of life were found in four out of nine trials (44.4%), suggesting that telemonitoring approaches could benefit patients' mental and emotional health. In 83.3% of the trials, improved self-care abilities were observed, highlighting the potential of telemonitoring to enable patients to manage their health conditions better.

4.2. Comparison with Prior Works

Our results are consistent with earlier studies showing the advantages of telemonitoring in treating chronic illnesses. We discovered substantial improvements in blood pressure control [4,12–14], and capacity for self-care [15,16], which is in agreement with the findings reported by other authors. Our research reveals a significant influence on quality of life, in contrast to certain previous studies [3,4], and suggests that recent developments in telemonitoring technology may contribute to these good outcomes.

4.3. Strengths and Limitations

This review's inclusion of a broad range of research from various geographic regions and healthcare settings is one of its strongest points; it offers a thorough summary of the current state of telemonitoring in CVD management. This review does have some limitations though.

One major issue is the considerable variability among the studies included in this review. The studies differed in the telemonitoring methods used, the specific outcomes they measured, and the characteristics of the patient populations they examined. This heterogeneity made it challenging to compare the results across studies directly. More importantly, it impeded the ability to perform a meta-analysis, a statistical method combining data from multiple studies to draw stronger and more generalizable conclusions. Because a meta-analysis was not feasible, the overall conclusions drawn from this review are less robust, as they rely on individual study findings rather than a consolidated analysis. This variability introduces uncertainty and limits the ability to make definitive statements about the effectiveness of telemonitoring in managing cardiovascular diseases.

Additionally, the review was limited to studies published in English, which could mean that relevant research published in other languages was excluded. This introduces a potential language bias, where the findings of this review might not fully represent the global body of research on telemonitoring in CVD management. Important studies conducted in non-English-speaking regions could have provided additional insights or even challenged the results observed in the English-language studies. As a result, the conclusions of this review may be somewhat skewed or incomplete, reflecting only a portion of the available evidence.

A significant limitation of the reviewed studies is the lack of detailed data on security measures for the telemonitoring systems. These systems handle sensitive patient information, making robust data protection essential for maintaining confidentiality and trust. The omission of data security protocols is a critical oversight. Effective telemonitoring requires accurate health data management and stringent safeguards against unauthorized access. Future research should include evaluations of data security practices, ensuring compliance with regulations like GDPR or HIPAA and implementing necessary encryption and access controls. Addressing these aspects is crucial for developing secure and trustworthy telemonitoring solutions.

Another challenge involves the difficulty in fully adjusting for all potential confounders, such as patient age and gender, disease severity, or concurrent treatments. The studies included in this review varied widely in these aspects and did not employ consistent methods to handle these factors or statistically adjust for them. This inconsistency in approach makes it challenging to account for how these confounders might have influenced the results. For instance, younger and generally healthier patients in one study versus older, more severely ill patients in another could lead to variations in outcomes that are not solely attributable to telemonitoring. This variability, combined with the noted risk of bias in many of the included studies, complicates the ability to draw definitive conclusions and limits the generalizability of the findings.

Furthermore, the potential impact of participants' educational levels was not consistently reported across studies. Lower educational backgrounds could limit the efficacy of telemonitoring due to challenges in using technology or interpreting health data. Future research should consider controlling for educational levels or offering additional support to ensure impartial outcomes.

Additionally, the review does not address health disparities that could affect the overall impact of telemonitoring. Specifically, telemonitoring may influence patients in low-income or rural areas with less access to technology. There is a need to consider how telemonitoring could either reduce or exacerbate health disparities, particularly for populations with limited access to technological resources. Understanding these disparities is crucial for evaluating the true public health impact of telemonitoring interventions and ensuring that benefits are equally distributed across different socio-economic groups.

Another limitation of this review is the lack of detailed information on the technical reliability and accuracy of the telemonitoring devices used in the studies. Only three of the 22 reviewed studies [44,46,50] provided specifics on the performance and consistency of these devices. Without comprehensive data on device reliability, it is challenging to assess the overall trustworthiness of the telemonitoring systems and their impact on the quality of care. Future research should include thorough device accuracy and reliability evaluations to ensure that telemonitoring systems deliver dependable and high-quality data.

Moreover, while many studies focused on clinical outcomes, there was a limited exploration of the psychological impacts of telemonitoring. Only two of the 22 studies [35,40] considered aspects such as anxiety and emotional well-being. Understanding patients' psychological responses, whether telemonitoring provides a sense of control or induces anxiety, is crucial for a holistic evaluation of its effectiveness. The absence of these aspects in most studies highlights a significant gap. Future research should address these psychological factors to provide a more complete picture of how telemonitoring affects overall patient well-being.

Publication bias also presents a potential limitation of this review. While we employed a comprehensive literature search strategy across major databases (PubMed, Scopus, and Web of Science) to include a wide range of studies, the possibility remains that studies with negative or null results may be underrepresented. The tendency to publish studies with positive findings could skew the overall assessment of telemonitoring's effectiveness. To mitigate this, future reviews should consider strategies like searching grey literature and unpublished studies to ensure a more balanced representation of evidence.

Finally, it's important to consider non-key factors that were anticipated to play a significant role in telemonitoring's success but were found to be less critical based on the literature reviewed. For instance, while the ease of use of mobile applications and the frequency of data transmission were initially expected to have a major impact, they did not consistently show a significant effect on patient outcomes. This suggests that while these factors might be important for patient engagement, they are not as crucial as initially thought for the overall success of telemonitoring interventions. Understanding which factors are truly key versus those that are less influential will help refine future telemonitoring strategies and research.

4.4. Practical Implications and Future Developments

Our findings indicate that integrating telemonitoring systems into routine care for patients with CVD could improve disease management and patient outcomes. Healthcare providers should consider adopting telemonitoring technologies to empower patients to manage their conditions more effectively. Policymakers should support the inclusion of telemonitoring into healthcare policies and funding models in order to ensure that patients have access to these beneficial interventions.

When considering the implementation of telemonitoring for patients with CVD, it is also important to take into account the presence of multiple comorbidities. The management of cardiovascular conditions can become more complex in patients with additional health issues, which might affect the efficacy of telemonitoring. While some comorbid conditions might require more personalized approaches, telemonitoring can still be valuable in providing continuous monitoring and early intervention. Therefore, the presence of comorbidities should not be seen as a contraindication but rather as a factor that necessitates careful planning and adaptation of telemonitoring protocols.

Future research should aim to standardize telemonitoring intervention and outcome measures to facilitate meta-analyses and more robust conclusions. It is necessary to lead long-term studies to assess the sustained impact of telemonitoring on patient outcomes. Furthermore, the next studies should focus on the cost-effectiveness of telemonitoring systems to inform policy decisions and healthcare funding allocations, and they could include other RCTs that may have been published after our article's research.

Further research should ensure greater blindness among healthcare practitioners to reduce bias and improve the reliability of the results. The absence of a substantial number of papers on atrial fibrillation highlights the need for more RCTs focused on this condition to provide a clearer understanding of the benefits and limitations of telemonitoring in this specific patient group.

5. Conclusions

In summary, the findings from this systematic review highlight the considerable benefits of using telemonitoring systems in managing chronic cardiovascular conditions. The evidence points towards notable improvements in patients' ability to manage their disease, including better control of disease-specific parameters, enhanced quality of life, and stronger self-care practices. Integrating telemonitoring into routine care practices can enhance patient outcomes and support chronic disease management significantly. It is essential for future research to explore further and leverage the full potential of these technologies to maximize their benefits for patients and the healthcare system at large.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app14177633/s1, File S1: Search strategy; Table S1: PRISMA checklist.

Author Contributions: Conceptualization, G.F.R. and S.S.; methodology, G.F.R.; validation, G.F.R., S.S. and M.C.; formal analysis, G.F.R.; investigation, G.F.R. and I.B.; resources, G.F.R., I.B. and S.S.; data curation, G.F.R., I.B. and S.S.; writing—original draft preparation, G.F.R., I.B. and S.S.; writing—review and editing, G.F.R., I.B., M.C. and S.S.; visualization, G.F.R. and S.S.; supervision, S.S. and M.C.; project administration, S.S.; funding acquisition, S.S. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the European Union—NextGenerationEU—National Recovery and Resilience Plan (Piano Nazionale di Ripresa e Resilienza, PNRR)—Project: "SoBigData.it—Strengthening the Italian RI for Social Mining and Big Data Analytics"—Prot. IR0000013—Avviso n. 3264 del 28 December 2021.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Acknowledgments: We thank Simona Sada and Giuseppe Trerotola for the administrative and technical support they provided.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

AF	Atrial fibrillation
AFEQT	Atrial Fibrillation Effect on Quality-of-Life
BMI	Body-mass index
BP	Blood pressure
CVD	Cardiovascular disease
DBP	Diastolic blood pressure
DOAJ	Directory of open access journals
ECG	Electrocardiogram
EQ-5D-5L	5-level EuroQol EQ-5D
HF	Heart failure
HT	Hypertension
HRQoL	Health-related Quality-of-life
MCS	Mental component summary
MDPI	Multidisciplinary Digital Publishing Institute
MLHFQ	Minnesota Living with Heart Failure Questionnaire
NYHA	New York Heart Association
PCS	Physical component summary
PPG	Photoplethysmography
RCT	Randomized controlled trial
QoL	Quality-of-Life
SBP	Systolic blood pressure
SF-12	12-item Short-Form
SF-36	36-item Short-Form
TM	Telemonitoring
TTE	Transthoracic echocardiogram
UC	Usual care

References

1. Kuan, P.X.; Chan, W.K.; Ying, D.K.F.; Rahman, M.A.A.; Peariasamy, K.M.; Lai, N.M.; Mills, N.L.; Anand, A. Efficacy of telemedicine for the management of cardiovascular disease: A systematic review and meta-analysis. *Lancet Digit. Health* **2022**, *4*, e676–e691. [CrossRef]
2. Bashshur, R.L. On the definition and evaluation of telemedicine. *Telemed. J.* **1995**, *1*, 19–30. [CrossRef]
3. Rebolledo Del Toro, M.; Herrera Leaño, N.M.; Barahona-Correa, J.E.; Muñoz Velandia, O.M.; Fernández Ávila, D.G.; García Peña, Á.A. Effectiveness of mobile telemonitoring applications in heart failure patients: Systematic review of literature and meta-analysis. *Heart Fail. Rev.* **2023**, *28*, 431–452. [CrossRef] [PubMed]
4. Leo, D.G.; Buckley, B.J.R.; Chowdhury, M.; Harrison, S.L.; Isanejad, M.; Lip, G.Y.H.; Wright, D.J.; Lane, D.A. Interactive Remote Patient Monitoring Devices for Managing Chronic Health Conditions: Systematic Review and Meta-analysis. *J. Med. Internet Res.* **2022**, *24*, e35508. [CrossRef]
5. Giles, T.D.; Berk, B.C.; Black, H.R.; Cohn, J.N.; Kostis, J.B.; Izzo, J.L., Jr.; Weber, M.A. Expanding the definition and classification of hypertension. *J. Clin. Hypertens.* **2005**, *7*, 505–512. [CrossRef]
6. Bozkurt, B.; Coats, A.J.; Tsutsui, H.; Abdelhamid, C.M.; Adamopoulos, S.; Albert, N.; Anker, S.D.; Atherton, J.; Böhm, M.; Butler, J.; et al. Universal definition and classification of heart failure: A report of the Heart Failure Society of America, Heart Failure Association of the European Society of Cardiology, Japanese Heart Failure Society and Writing Committee of the Universal Definition of Heart Failure. *Eur. J. Heart Fail.* **2021**, *23*, 352–380. [CrossRef] [PubMed]
7. McDonagh, T.A.; Metra, M.; Adamo, M.; Gardner, R.S.; Baumbach, A.; Böhm, M.; Burri, H.; Butler, J.; Čelutkienė, J.; Chioncel, O.; et al. 2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure: Developed by the Task Force for the diagnosis and treatment of acute and chronic heart failure of the European Society of Cardiology (ESC) With the special contribution of the Heart Failure Association (HFA) of the ESC. *Eur. Heart J.* **2021**, *42*, 3599–3726. [CrossRef] [PubMed]
8. Hindricks, G.; Potpara, T.; Dagres, N.; Arbelo, E.; Bax, J.J.; Blomström-Lundqvist, C.; Boriani, G.; Castella, M.; Dan, G.A.; Dilaveris, P.E.; et al. 2020 ESC Guidelines for the diagnosis and management of atrial fibrillation developed in collaboration with the European Association for Cardio-Thoracic Surgery (EACTS): The Task Force for the diagnosis and management of atrial fibrillation of the European Society of Cardiology (ESC) Developed with the special contribution of the European Heart Rhythm Association (EHRA) of the ESC. *Eur. Heart J.* **2021**, *42*, 373–498.
9. Kędzierski, K.; Radziejewska, J.; Sławuta, A.; Wawrzyńska, M.; Arkowski, J. Telemedicine in Cardiology: Modern Technologies to Improve Cardiovascular Patients' Outcomes—A Narrative Review. *Medicina* **2022**, *58*, 210. [CrossRef]
10. Colbert, G.B.; Venegas-Vera, A.V.; Lerma, E.V. Utility of telemedicine in the COVID-19 era. *Rev. Cardiovasc. Med.* **2020**, *21*, 583–587.
11. Alvarez, P.; Sianis, A.; Brown, J.; Ali, A.; Briasoulis, A. Chronic disease management in heart failure: Focus on telemedicine and remote monitoring. *Rev. Cardiovasc. Med.* **2021**, *22*, 403–413. [CrossRef] [PubMed]

12. Choi, W.S.; Kim, N.S.; Kim, A.Y.; Woo, H.S. Nurse-Coordinated Blood Pressure Telemonitoring for Urban Hypertensive Patients: A Systematic Review and Meta-Analysis. *Int. J. Environ. Res. Public Health* **2021**, *18*, 6892. [CrossRef]
13. AbuDagga, A.; Resnick, H.E.; Alwan, M. Impact of blood pressure telemonitoring on hypertension outcomes: A literature review. *Telemed. J. e-Health* **2010**, *16*, 830–838. [CrossRef] [PubMed]
14. Duan, Y.; Xie, Z.; Dong, F.; Wu, Z.; Lin, Z.; Sun, N.; Xu, J. Effectiveness of home blood pressure telemonitoring: A systematic review and meta-analysis of randomised controlled studies. *J. Hum. Hypertens.* **2017**, *31*, 427–437. [CrossRef]
15. Nick, J.M.; Roberts, L.R.; Petersen, A.B. Effectiveness of telemonitoring on self-care behaviors among community-dwelling adults with heart failure: A quantitative systematic review. *JBI Evid. Synth.* **2021**, *19*, 2659–2694. [CrossRef] [PubMed]
16. Strandberg, S.; Backåberg, S.; Fagerström, C.; Ekstedt, M. Self-care management and experiences of using telemonitoring as support when living with hypertension or heart failure: A descriptive qualitative study. *Int. J. Nurs. Stud. Adv.* **2023**, *5*, 100149. [CrossRef]
17. Haleem, A.; Javaid, M.; Singh, R.P.; Suman, R. Telemedicine for healthcare: Capabilities, features, barriers, and applications. *Sensors Int.* **2021**, *2*, 100117. [CrossRef]
18. Ciampi, M.; Sicuranza, M.; Silvestri, S. A Privacy-Preserving and Standard-Based Architecture for Secondary Use of Clinical Data. *Information* **2022**, *13*, 87. [CrossRef]
19. Silvestri, S.; Islam, S.; Amelin, D.; Weiler, G.; Papastergiou, S.; Ciampi, M. Cyber threat assessment and management for securing healthcare ecosystems using natural language processing. *Int. J. Inf. Secur.* **2024**, *23*, 31–50. [CrossRef]
20. Moher, D.; Liberati, A.; Tetzlaff, J.; Altman, D.G.; Group, T.P. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Med.* **2009**, *6*, e1000097. [CrossRef]
21. Page, M.J.; McKenzie, J.E.; Bossuyt, P.M.; Boutron, I.; Hoffmann, T.C.; Mulrow, C.D.; Shamseer, L.; Tetzlaff, J.M.; Akl, E.A.; Brennan, S.E.; et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ* **2021**, *372*, n71. [CrossRef]
22. Muka, T.; Glisic, M.; Milic, J.; Verhoog, S.; Bohlius, J.; Bramer, W.; Chowdhury, R.; Franco, O.H. A 24-step guide on how to design, conduct, and successfully publish a systematic review and meta-analysis in medical research. *Eur. J. Epidemiol.* **2020**, *35*, 49–60. [CrossRef]
23. Álvarez Hernández, S.; Castillo, D.; Villa-Vicente, J.G.; Yanci, J.; Marqués-Jiménez, D.; Rodríguez-Fernández, A. Analyses of Physical and Physiological Responses during Competition in Para-Footballers with Cerebral Palsy: A Systematic Review. *Appl. Sci.* **2024**, *14*, 3812. [CrossRef]
24. Schardt, C.; Adams, M.B.; Owens, T.; Keitz, S.; Fontelo, P. Utilization of the PICO framework to improve searching PubMed for clinical questions. *BMC Med. Inform. Decis. Mak.* **2007**, *7*, 16. [CrossRef]
25. Mann, D.M.; Chen, J.; Chunara, R.; Testa, P.A.; Nov, O. COVID-19 transforms health care through telemedicine: Evidence from the field. *J. Am. Med. Inform. Assoc.* **2020**, *27*, 1132–1135. [CrossRef]
26. Omboni, S.; Padwal, R.S.; Alessa, T.; Benczúr, B.; Green, B.B.; Hubbard, I.; Kario, K.; Khan, N.A.; Konradi, A.; Logan, A.G.; et al. The worldwide impact of telemedicine during COVID-19: Current evidence and recommendations for the future. *Connect Health* **2022**, *1*, 7–35. [CrossRef]
27. Hincapié, M.A.; Gallego, J.C.; Gempeler, A.; Piñeros, J.A.; Nasner, D.; Escobar, M.F. Implementation and Usefulness of Telemedicine During the COVID-19 Pandemic: A Scoping Review. *J. Prim. Care Community Health* **2020**, *11*, 2150132720980612. [CrossRef] [PubMed]
28. Cochrane Methods Bias. RoB 2: A Revised Cochrane Risk-of-Bias Tool for Randomized Trials. Available online: https://methods.cochrane.org/bias/resources/rob-2-revised-cochrane-risk-bias-tool-randomized-trials (accessed on 21 August 2024).
29. Sterne, J.A.C.; Savović, J.; Page, M.J.; Elbers, R.G.; Blencowe, N.S.; Boutron, I.; Cates, C.J.; Cheng, H.Y.; Corbett, M.S.; Eldridge, S.M.; et al. RoB 2: A revised tool for assessing risk of bias in randomised trials. *BMJ* **2019**, *366*, l4898. [CrossRef]
30. Di Francesco, F.; Lanza, A.; Di Blasio, M.; Vaienti, B.; Cafferata, E.A.; Cervino, G.; Cicciù, M.; Minervini, G. Application of Botulinum Toxin in Temporomandibular Disorders: A Systematic Review of Randomized Controlled Trials (RCTs). *Appl. Sci.* **2022**, *12*, 12409. [CrossRef]
31. Andersson, U.; Nilsson, P.M.; Kjellgren, K.; Hoffmann, M.; Wennersten, A.; Midlöv, P. PERson-centredness in Hypertension management using Information Technology: A randomized controlled trial in primary care. *J. Hypertens.* **2023**, *41*, 246–253. [CrossRef]
32. Bozorgi, A.; Hosseini, H.; Eftekhar, H.; Majdzadeh, R.; Yoonessi, A.; Ramezankhani, A.; Mansouri, M.; Ashoorkhani, M. The effect of the mobile "blood pressure management application" on hypertension self-management enhancement: A randomized controlled trial. *Trials* **2021**, *22*, 413. [CrossRef]
33. Choi, E.Y.; Park, J.S.; Min, D.L.; Ahn, S.; Ahn, J.A. Heart Failure-Smart Life: A randomized controlled trial of a mobile app for self-management in patients with heart failure. *BMC Cardiovasc. Disord.* **2023**, *23*, 7. [CrossRef]
34. Cichosz, S.L.; Udsen, F.W.; Hejlesen, O. The impact of telehealth care on health-related quality of life of patients with heart failure: Results from the Danish TeleCare North heart failure trial. *J. Telemed. Telecare* **2020**, *26*, 452–461. [CrossRef] [PubMed]
35. Clays, E.; Puddu, P.E.; Luštrek, M.; Pioggia, G.; Derboven, J.; Vrana, M.; De Sutter, J.; Le Donne, R.; Baert, A.; Bohanec, M.; et al. Proof-of-concept trial results of the HeartMan mobile personal health system for self-management in congestive heart failure. *Sci. Rep.* **2021**, *11*, 5663. [CrossRef] [PubMed]

36. Ding, H.; Jayasena, R.; Chen, S.H.; Maiorana, A.; Dowling, A.; Layland, J.; Good, N.; Karunanithi, M.; Edwards, I. The Effects of Telemonitoring on Patient Compliance With Self-Management Recommendations and Outcomes of the Innovative Telemonitoring Enhanced Care Program for Chronic Heart Failure: Randomized Controlled Trial. *J. Med. Internet Res.* **2020**, *22*, e17559. [CrossRef]
37. Dwairej, L.; Ahmad, M. Hypertension and mobile application for self-care, self-efficacy and related knowledge. *Health Educ. Res.* **2022**, *37*, 199–212. [CrossRef]
38. Echeazarra, L.; Pereira, J.; Saracho, R. TensioBot: A Chatbot Assistant for Self-Managed in-House Blood Pressure Checking. *J. Med. Syst.* **2021**, *45*, 54. [CrossRef]
39. Guo, Y.; Lane, D.A.; Wang, L.; Zhang, H.; Wang, H.; Zhang, W.; Wen, J.; Xing, Y.; Wu, F.; Xia, Y.; et al. Mobile Health Technology to Improve Care for Patients With Atrial Fibrillation. *J. Am. Coll. Cardiol.* **2020**, *75*, 1523–1534. [CrossRef]
40. Jiang, Y.; Koh, K.W.L.; Ramachandran, H.J.; Nguyen, H.D.; Lim, S.; Tay, Y.K.; Shorey, S.; Wang, W. The effectiveness of a nurse-led home-based heart failure self-management programme (the HOM-HEMP) for patients with chronic heart failure: A three-arm stratified randomized controlled trial. *Int. J. Nurs. Stud.* **2021**, *122*, 104026. [CrossRef] [PubMed]
41. Koehler, J.; Stengel, A.; Hofmann, T.; Wegscheider, K.; Koehler, K.; Sehner, S.; Rose, M.; Deckwart, O.; Anker, S.D.; Koehler, F.; et al. Telemonitoring in patients with chronic heart failure and moderate depressed symptoms: Results of the Telemedical Interventional Monitoring in Heart Failure (TIM-HF) study. *Eur. J. Heart Fail.* **2021**, *23*, 186–194. [CrossRef]
42. Lazaridis, C.; Bakogiannis, C.; Mouselimis, D.; Tsarouchas, A.; Antoniadis, A.P.; Triantafyllou, K.; Fragakis, N.; Vassilikos, V.P. The usability and effect of an mHealth disease management platform on the quality of life of patients with paroxysmal atrial fibrillation—The emPOWERD-AF study. *Health Inform. J.* **2022**, *28*, 14604582221139053. [CrossRef] [PubMed]
43. Leupold, F.; Karimzadeh, A.; Breitkreuz, T.; Draht, F.; Klidis, K.; Grobe, T.; Weltermann, B. Digital redesign of hypertension management with practice and patient apps for blood pressure control (PIA study): A cluster-randomised controlled trial in general practices. *Eclinicalmedicine* **2023**, *55*, 101712. [CrossRef] [PubMed]
44. Liu, F.; Song, T.; Yu, P.; Deng, N.; Guan, Y.; Yang, Y.; Ma, Y. Efficacy of an mHealth App to Support Patients' Self-Management of Hypertension: Randomized Controlled Trial. *J. Med. Internet Res.* **2023**, *25*, e43809. [CrossRef]
45. Marcus, G.M.; Modrow, M.F.; Schmid, C.H.; Sigona, K.; Nah, G.; Yang, J.; Chu, T.C.; Joyce, S.; Gettabecha, S.; Ogomori, K.; et al. Individualized Studies of Triggers of Paroxysmal Atrial Fibrillation: The I-STOP-AFib Randomized Clinical Trial. *JAMA Cardiol.* **2022**, *7*, 167–174. [CrossRef]
46. McManus, R.J.; Little, P.; Stuart, B.; Morton, K.; Raftery, J.; Kelly, J.; Bradbury, K.; Zhang, J.; Zhu, S.; Murray, E.; et al. Home and Online Management and Evaluation of Blood Pressure (HOME BP) using a digital intervention in poorly controlled hypertension: Randomised controlled trial. *BMJ* **2021**, *372*, m4858. [CrossRef]
47. Meng, W.W.; Bai, Y.Y.; Yan, L.; Zheng, W.; Zeng, Q.; Zheng, Y.S.; Zha, L.; Pi, H.Y.; Sai, X.Y. Effect of Home Blood Pressure Telemonitoring Plus Additional Support on Blood Pressure Control: A Randomized Clinical Trial. *Biomed. Environ. Sci.* **2023**, *36*, 517–526. [CrossRef]
48. Sahlin, D.; Rezanezad, B.; Edvinsson, M.L.; Bachus, E.; Melander, O.; Gerward, S. Self-care Management Intervention in Heart Failure (SMART-HF): A Multicenter Randomized Controlled Trial. *J. Card. Fail.* **2022**, *28*, 3–12. [CrossRef]
49. Upshaw, J.N.; Parker, S.; Gregory, D.; Koethe, B.; Vest, A.R.; Patel, A.R.; Kiernan, M.S.; DeNofrio, D.; Davidson, E.; Mohanty, S.; et al. The effect of tablet computer-based telemonitoring added to an established telephone disease management program on heart failure hospitalizations: The Specialized Primary and Networked Care in Heart Failure (SPAN-CHF) III Randomized Controlled Trial. *Am. Heart J.* **2023**, *260*, 90–99. [CrossRef] [PubMed]
50. Yanicelli, L.M.; Goy, C.B.; González, V.D.C.; Palacios, G.N.; Martínez, E.C.; Herrera, M.C. Non-invasive home telemonitoring system for heart failure patients: A randomized clinical trial. *J. Telemed. Telecare* **2021**, *27*, 553–561. [CrossRef]
51. Yuting, Z.; Xiaodong, T.; Qun, W. Effectiveness of a mHealth intervention on hypertension control in a low-resource rural setting: A randomized clinical trial. *Front. Public Health* **2023**, *11*, 1049396. [CrossRef]
52. Zhang, Y.; Tao, Y.; Zhong, Y.; Thompson, J.; Rahmani, J.; Bhagavathula, A.S.; Xu, X.; Luo, J. Feedback based on health advice via tracing bracelet and smartphone in the management of blood pressure among hypertensive patients: A community-based RCT trial in Chongqing, China. *Medicine* **2022**, *101*, e29346. [CrossRef]
53. Ware, J.E., Jr.; Sherbourne, C.D. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. *Med. Care* **1992**, *30*, 473–483. [CrossRef]
54. Herdman, M.; Gudex, C.; Lloyd, A.; Janssen, M.F.; Kind, P.; Parkin, D.; Bonsel, G.; Badia, X. Development and preliminary testing of the new five-level version of EQ-5D (EQ-5D-5L). *Qual. Life Res.* **2011**, *20*, 1727–1736. [CrossRef] [PubMed]
55. Rector, T.S.; Cohn, J.N. Assessment of patient outcome with the Minnesota Living with Heart Failure questionnaire: Reliability and validity during a randomized, double-blind, placebo-controlled trial of pimobendan. Pimobendan Multicenter Research Group. *Am. Heart J.* **1992**, *124*, 1017–1025. [CrossRef] [PubMed]
56. Spertus, J.; Dorian, P.; Bubien, R.; Lewis, S.; Godejohn, D.; Reynolds, M.R.; Lakkireddy, D.R.; Wimmer, A.P.; Bhandari, A.; Burk, C. Development and Validation of the Atrial Fibrillation Effect on QualiTy-of-Life (AFEQT) Questionnaire in Patients with Atrial Fibrillation. *Circ. Arrhythmia Electrophysiol.* **2011**, *4*, 15–25. [CrossRef] [PubMed]
57. Ware, J., Jr.; Kosinski, M.; Keller, S.D. A 12-Item Short-Form Health Survey: Construction of scales and preliminary tests of reliability and validity. *Med. Care* **1996**, *34*, 220–233. [CrossRef]
58. Höfer, S.; Lim, L.; Guyatt, G.; Oldridge, N. The MacNew Heart Disease health-related quality of life instrument: A summary. *Health Qual. Life Outcomes* **2004**, *2*, 3. [CrossRef]

59. Stergiou, G.S.; Palatini, P.; Parati, G.; O'Brien, E.; Januszewicz, A.; Lurbe, E.; Persu, A.; Mancia, G.; Kreutz, R.; on behalf of the European Society of Hypertension Council and the European Society of Hypertension Working Group on Blood Pressure Monitoring and Cardiovascular Variability. 2021 European Society of Hypertension practice guidelines for office and out-of-office blood pressure measurement. *J. Hypertens.* **2021**, *39*, 1293–1302. [CrossRef]
60. Russell, S.D.; Saval, M.A.; Robbins, J.L.; Ellestad, M.H.; Gottlieb, S.S.; Handberg, E.M.; Zhou, Y.; Chandler, B.; HF-ACTION Investigators. New York Heart Association functional class predicts exercise parameters in the current era. *Am. Heart J.* **2009**, *158*, S24–S30. [CrossRef]