MAYO CLINIC PROCEEDINGS: DIGITAL HEALTH

REVIEW

The Effectiveness of Telehealth Intervention on Chronic Kidney Disease Management in Adults: A Systematic Review

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Abstract

Objective: To evaluate the effectiveness of telehealth programs on dietary habits, quality of life, renal function, and blood pressure in adults with chronic kidney disease (CKD).

Patients and Methods: A systematic literature review was completed according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. Using PubMed/Medline, Scopus, Embase, and ScienceDirect databases, articles published between 2012 and 2024 were selected using the following keywords: *telehealth*, *eHealth*, *mHealth*, *telemedicine*, *telenutrition*, and *chronic kidney disease*.

Results: A total of 13 studies—10 randomized controlled trials and 3 single-arm trials—were chosen for this review. In these trials, telehealth interventions were administered using mobile applications, phone calls, web-based communications, text messaging, wearable devices, or a combination of these tools to provide treatment for adults with CKD. Interdisciplinary collaboration between a dietitian and other health care team members was shown to improve renal function and dietary habits when providing telehealth interventions via mobile applications, phone calls, and text messaging. Web-based telehealth delivery that involves diverse health care personnel has been shown to improve the quality of life in adult patients with CKD.

Conclusion: Receiving treatment using telehealth communication methods may be a beneficial option for adult patients with CKD by enhancing accessibility, promoting multidisciplinary collaboration, and effectively managing blood pressure and dietary habits, leading to improved quality of life for patients. Future research administering homogeneous and rigorously controlled experimental methods with larger and more diverse populations, as well as longer study durations, is necessary to further elucidate the effectiveness of CKD treatment delivery via telehealth for adult patients.

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Chronic kidney disease (CKD) is one of the leading causes of death worldwide.[1] Chronic kidney disease affects more than 800 million individuals globally and has an estimated all-age mortality rate of 1.2 million, a 41.5% increase since 1990.[2] The growing prevalence of CKD leaves patients at greater risk for comorbidities.[3]

Diabetes and high blood pressure are the 2 most common causes of CKD.[4] Additional risk factors for CKD include obesity, heart disease, smoking, a family history of kidney disease, abnormal kidney structure, and older age.[5] The essential functions of the kidneys include controlling the amount of water, solutes, and electrolytes in the blood to regulate plasma osmolarity; managing long-term acid-base balance; supporting the production of red blood cells; and producing renin for blood pressure regulation.[6] Patients with CKD require monitoring for complications such as hyperkalemia, metabolic acidosis, hyperphosphatemia, vitamin D deficiency, hypertension, secondary hyperparathyroidism, and anemia.[7]

Biometrics play a crucial role in assessing the health status and progression of CKD. Key metrics, including 24-hour urine sodium, serum creatinine, serum potassium, serum phosphorus, and proteinuria, provide valuable insights into dietary habits, kidney function, and overall patient health. For instance, measuring 24-hour urine sodium is essential for estimating sodium intake and managing hypertension, a common comorbidity in CKD.[8,9] Serum creatinine serves as a primary indicator of renal function, whereas serum potassium and phosphorus levels are critical for monitoring electrolyte balance and preventing complications. Additionally, proteinuria is a significant marker of kidney damage and disease progression.[10] Collectively, these biometrics are integral to evaluating the effectiveness of telehealth interventions aimed at improving dietary habits, quality of life, and clinical outcomes for individuals with CKD.

Medical nutrition therapy is a critical intervention for slowing CKD progression and complications, including end-stage renal disease (ESRD),[4] through careful monitoring of protein, calcium, phosphorus, potassium, and sodium.[11] Currently, the potential roles of diets such as the Dietary Approaches to Stop Hypertension, Mediterranean diet, and whole foods plant-based diet in delaying CKD progression are undergoing investigation.[11] Nutrition interventions have reported efficacy in improving blood pressure and glucose control in adults, thereby slowing CKD progression and postponing the need for dialysis.[4]

Although medical nutrition therapy has been shown to improve biochemical markers in adults with CKD, it continues to be underused due to low awareness of benefits by patients and health care workers, lack of availability of services, and inconsistent coverage for CKD treatment services.[4] Successful management of CKD typically involves interventions for blood pressure control, glycemic control in diabetic patients, and reduced proteinuria as well as lifestyle adjustments such as dietary changes, increased physical activity, and smoking cessation.[12] A multidisciplinary health care team consisting of nephrologists, registered nurses, primary care physicians, pharmacists, registered dietitian nutritionists (RDNs), and social workers has been associated with improved patient outcomes when compared with traditional nephrology care delivery models.[13] Patients with CKD who live far from their nephrology care team experience lower rates of clinic visit adherence, limited access to treatment, and higher rates of hospitalization and mortality than patients who live near their care team.[14]

Telehealth, also referred to as telemedicine, eHealth, eMedicine, virtual health care, and distance health,[14] is the use of telecommunications technology to deliver health care, information, and education.[15] Telehealth provides access to resources and care for patients in rural areas or areas with provider shortages, reduces patient travel and wait times, and improves efficiency without higher net costs.[15] Traditional nutrition counseling and therapy can be provided through telenutrition via remote electronic communication applications and may be as useful and more cost effective compared with standard care.[16]

According to the Academy of Nutrition and Dietetics, telenutrition involves the interactive use of electronic information and telecommunication technologies by an RDN to implement the nutrition care process with patients or clients at a remote location within the procession of the state licensure.[17] Registered dietitian nutritionists have begun using telenutrition as an efficient approach over traditional in-person visits as remote devices provide biometric data that are useful for nutrition interventions, and data from dialysis machines inform renal dietitians' individual care plans.[14] A meta-analysis of 126 randomized controlled trials (RCTs) found that telehealth reduces the risk and mean occurrence of all-cause or condition-related hospitalizations in patients with chronic diseases.[18]

Demand for quality health care in a post-COVID-19 environment, particularly in rural areas without local medical access, has accelerated the use of telehealth services and highlighted its potential benefits.[19] Although previous systematic reviews have explored specific aspects of telehealth for CKD, this study offers a novel contribution by comprehensively evaluating a broader range of outcomes, particularly in the context of increased telehealth utilization after the COVID-19 pandemic. Furthermore, the benefits and effectiveness of telehealth communication tools on the improvement of diet-related renal function and quality of life remain unknown in patients with CKD. Therefore, we conducted a systematic review to evaluate whether telehealth interventions, including mHealth, web-based applications, and telephone and video consultations, may help improve kidney function/damage parameters,

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healthy eating habits, and quality of life in adults with CKD.

MATERIALS AND METHODS

Systematic Search Strategy

The systematic search for this study followed Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[20] A systematic review, following methodologies outlined by the Population, Intervention, Comparison, Outcomes, and Study Design (PICOS) model, was conducted in February 2024. The following online databases were consulted: PubMed/MEDLINE, Scopus, Embase, and ScienceDirect. Titles/abstracts/keywords were identified using the following keywords: ("*telehealth*" OR "*ehealth*" OR "*mhealth*" OR "*telenutrition*" OR "*telemedicine*" OR "*telenutrition*") AND ("*chronic kidney disease*" OR "*renal disease*"). The systematic search and article selection process is outlined in Figure.

After preliminary articles were selected, they were exported into EndNote (Clarivate Analytics Version 20) and Zotero program for management.[21] Zotero automatically identified duplicates, and those studies were removed. For transparency and rigor, this review was registered with the International Platform of Registered Systematic Review and Meta-analysis Protocols (INPLASY). The registration number is INPLASY2024100095, and the DOI number is 10.37766/inplasy2024.10.0095. This ensures adherence to preestablished protocols and allows for external verification.

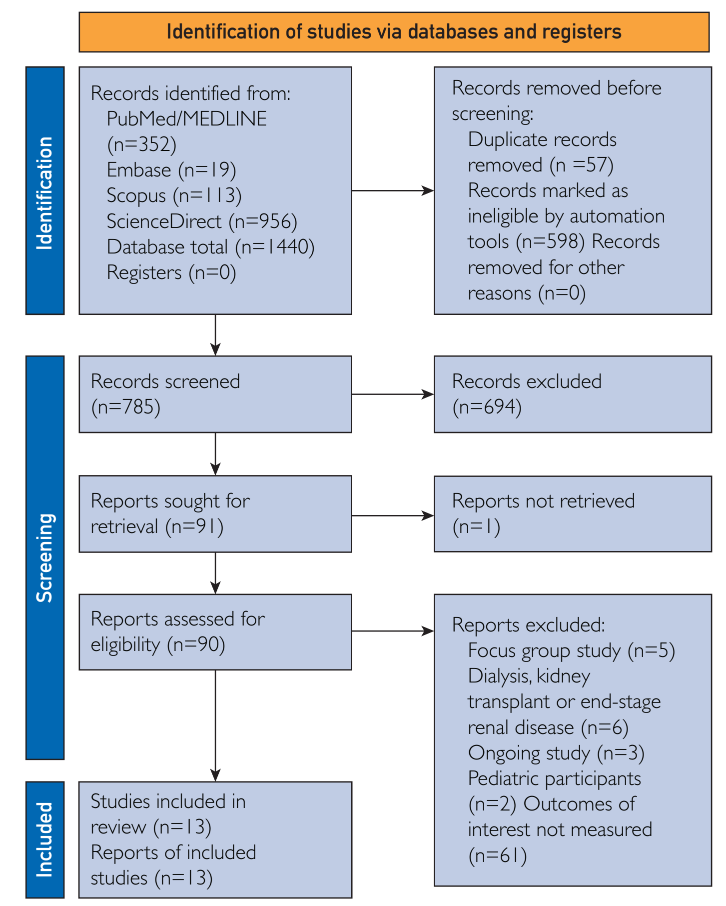

FIGURE. PRISMA article selection flowchart using the PRISMA 2020 flow diagram.

Eligibility Criteria

Studies were included if they met the following criteria: (1) RCT or single-arm study, as RCTs provide high-quality evidence of causality, whereas single-arm studies offer insight when control groups are not feasible; (2) a sample of adult individuals (18 years or older), ensuring homogeneity in physiology and treatment protocols as CKD management differs between children and adults; (3) diagnosis of chronic kidney disease stage 1 to 4 (glomerular filtration rate [GFR]: ≥90 to <15 mg/mmol, respectively), focusing on telehealth's potential to manage complications and delay progression before dialysis or kidney transplant; (4) use of telehealth communications, and (5) assessment of the effect of telehealth on dietary habits, quality of life, blood pressure, or renal function via GFR, as these outcomes are critical for monitoring CKD progression and management.

The exclusion criteria were (1) adults on hemodialysis or dialysis, as these patients have different health care needs that could obscure the specific benefits of telehealth for earlier CKD stages; (2) ESRD, which introduces confounding variables from dialysis or transplant interventions; and (3) reviews, as they do not contribute original data for analysis.

Screening Process

The screening process involved 2 reviewers (T.E., A.J.K.) who independently evaluated the titles and abstracts of the identified studies. Both reviewers screened each title and abstract, and any discrepancies were resolved through discussion and consensus. This dual-review process ensured a high level of agreement and reliability, with an agreement rate of approximately 90%. Subsequently, both reviewers participated in the full-text screening. The selection process is summarized in the PRISMA flow diagram (Figure), which outlines the number of studies identified, screened, assessed for eligibility, and included in the final review.

RESULTS

Systematic Search and Study Selection

The preliminary search identified 1440 articles across 4 databases. After removing duplicates, 785 unique articles published between 2012 and 2024 remained. Articles were then selected using the inclusion criteria, which eliminated 694 articles and left 91 for screening. One report could not be retrieved due to an unavailable abstract, leaving 90 articles to be assessed for eligibility. Excluded reports, including focus group studies, studies not meeting the present research review outcomes, and those involving dialysis, kidney transplant, ESRD, or pediatric participants, are indicated in Figure.

TABLE 1. PICOS (Population, Intervention, Comparison, Outcome, Study Design) Criteria for Inclusion of Studies

Category	Result
Population	Adults (18 y or older) with chronic kidney disease stage 1 to 4 (glomerular filtration rate [GFR]: ≥ 90 to <15 mg/mmol, respectively) without renal replacement therapy (eg, dialysis) or end-stage renal disease
Intervention/ exposure	Telehealth communications (mobile applications, web-based applications, self-monitoring device, telephone, text messaging, and monitoring device)
Comparison	Control group (eg, usual care as part of randomized controlled trial) or control group not applicable for single-arm studies
Outcomes	GFR, estimated glomerular filtration rate, Healthy Eating Index, Alternate Healthy Eating Index, health-related quality of life, personalized priority and progress, kidney disease quality of life, blood pressure, serum potassium, 24-h sodium excretion, serum phosphorus, and urine or serum albumin/protein
Study designs	Randomized controlled trials, single-arm trials, clinical trials

Descriptive Data and Characteristics

The main characteristics of the 13 selected studies in this systematic review are listed in Table 1. Ten are RCTs and 3 are single-arm trials. Interventions involved home visits and various telehealth communication methods including mobile applications, phone, websites, email, text messaging, and telemonitoring blood pressure devices. Interventions were led by physicians, pharmacists, RDNs, health care workers, student researchers, and nephrologists, as indicated in Table 2.[22−34]

Biochemical Results

24-Hour Urine Sodium. Measuring 24-hour urinary sodium excretion is the gold standard for estimating daily sodium intake. This method is on the basis of the premise that most (90%-95%) ingested sodium is excreted through urine.[35] Past studies have shown that elevated urinary excretion of sodium (as a surrogate for sodium intake) is associated with an increased risk of CKD progression compared with reference ranges.[8,9] High sodium intake and water retention lead to increased blood pressure, which not only is a frequent complication of CKD but can also act as the cause of CKD.[36] The National Kidney Foundation Kidney Disease Outcomes Quality Initiative advises nondialysis patients with CKD to restrict their daily dietary sodium intake to less than 2400 mg.[10]

Three studies in this review measured 24-hour urine sodium excretion after implementing telehealth interventions.[25,29,30] In an 8-week, single-arm study examining the effects of a dietary application-supported telecounseling intervention, there was no significant decline in 24-hour urine sodium over the study period. However, participants who completed the 12-month follow-up reported

TABLE 2. Results on the Use of Telehealth Measuring eGFR, QoL, Dietary Habits, and BP in Adults with CKD (*N*=13)

Study	Study type, population	CKD stage (GFR)	Telehealth type, hardware used, and team	Measurements taken at home vs by physician/nurse	Objective	Intervention vs control.	Design concepts for interventions	Results
Greenwood et al,[22] 2023	Single-blind, randomized controlled trial Location: United Kingdom Setting: Outpatient Intervention: *n*=173; control: *n*=167 Mean age: 53.9 y (intervention); 53.8 y (control) sex/race: 45% female, 12% Black, 73% White, 13% Asian (intervention); 47% female, 11% Black, 77% White, 10% Asian (control) Duration: 3-mo intervention	CKD stages 2-5 (GFR 27-42 mL/min/1.73 m^2)	Live and prerecorded sessions of an on-demand physical activity and emotional well-being self-management intervention (Kidney BEAM) Hardware used: devices such as computers, smartphones, and tablets to access the web-based program Team: Specialist kidney physical therapists	At home with wearable device: physical activity levels, heart rate; quality-of-life questionnaires were completed at home By professional: BP, BMI, laboratory tests	To evaluate the clinical effect of a 12-wk physical activity digital health intervention on HRQoL in patients with CKD	Intervention: the Kidney BEAM intervention, which is a digital physical activity program codesigned with individuals living with CKD, consisting of live and prerecorded sessions of kidney rehabilitation exercises (moderate-intensity and resistance) delivered by kidney physical therapist specialists over a 12-wk period. Control: no participation in any structured exercise program during the trial period. Received usual care without any additional physical activity interventions. Invited to use Kidney BEAM after trial completion.	1. User-centered design (codesigned with input from people with CKD) 2. Behavior change techniques (on the basis of the behavior change wheel method) 3. Digital delivery (live and prerecorded sessions) 4. Integration of multimedia components (combination of visual, audio, and interactive elements)	At 12 wk, there was a significant improvement in KDQoL-SF1.3 MCS score in the Kidney BEAM group at baseline compared with the waiting list control group.
Cardol et al,[23] 2023	Two-arm, parallel randomized controlled trial Country: Netherlands Setting: Outpatient Intervention: *n*=60;	CKD stages 2-4 (eGFR 20-89 mL/min/1.73 m^2)	Therapist-guided iCBT Hardware used: computers or tablets with internet access by patients to complete online	At home with wearable device: dietary adherence, physical activity levels; HRQoL	To investigate the effectiveness of the E-GOAL personalized iCBT intervention in	Intervention: Tailored and therapist-guided eHealth pathway that included guided internet-delivered iCBT adapted for	1. Cocreation and stakeholder involvement (frequent feedback and prototype testing	There were no significant effects for psychological distress, HRQoL, self-efficacy, and

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TABLE 2. Continued

Study	Study type, population	CKD stage (GFR)	Telehealth type, hardware used, and team	Measurements taken at home vs by physician/nurse	Objective	Intervention vs control.	Design concepts for interventions	Results
	control: n=61 Mean age: 57.2 y (intervention); 54.8 y (control) sex/race: 53.3% male (intervention); 59% male (control) Duration: 15-mo intervention and 3-mo follow-up		screening questionnaires via the secured eHealth application "PatientCoach" Team: Health psychologists who received specific training for the trial, a skilled cognitive-behavioral therapy supervisor, and registered clinical psychologists	questionnaires were completed at home By professional: laboratory tests, 24-h urine samples, waist circumference, BP, initial psychological screening	reducing psychological distress at posttest directly after the intervention and at 3-mo follow-up among patients with CKD not on dialysis	patients with lifestyle related diseases including CKD. Patients received weekly or biweekly feedback from therapists via a secure message box within the eHealth application "E-coach" for up to 4 mo. Control: Standard medical care provided by their health care centers. Did not include the personalized components of the eHealth intervention.	from health professionals and patients with CKD) 2. Personalized screening and feedback 3. Tailored eHealth modules (covered topics such as mood improvement, social functioning, coping with fatigue, and behavior change) 4. Therapist-guided iCBT 5. Personalized outcome measures	chronic condition self-management.
Sarker et al,[24] 2022	Parallel randomized controlled trial Country: Bangladesh Setting: Community-based, single-center Intervention: n=63; control: n=63 Mean age: 57.32 y (intervention); 57.97 y (control) sex/race: 60% female (intervention); 71% female (control) Duration: 6-mo intervention	CKD stages 1-3 (eGFR 30-59 mL/min/1.73 m^2)	Health education provided over mobile phone call using mHealth technology every 2 wk, which included diet and exercise Hardware used: mobile phones used by CHWs to conduct mHealth education Team: Nephrologist and CHWs in public-sector health facilities	At home with wearable device: BP By professional: laboratory tests, QoL measurements	To evaluate the outcome of a health education intervention designed to enhance HRQoL and motivation about healthy lifestyle in adults with CKD	Intervention: Health education provided through a CKD awareness campaign and mHealth technologies facilitated by CHWs, including phone-based sessions every 2 wk Control: Received standard treatment without these additional interventions.	1. The PHC box, which facilitated the collection and analysis of various health parameters including BP, blood sugar, and kidney function indicators. 2. Use of mHealth technology (to conduct health education over mobile phone calls)	Patients' intention-to-treat analysis found a significant improvement in knowledge score. The intervention group exhibited lower DBP, SBP, waist circumference, and BMI compared with the control group. There were no significant differences on QoL.

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TABLE 2. Continued

Study	Study type, population	CKD stage (GFR)	Telehealth type, hardware used, and team	Measurements taken at home vs by physician/nurse	Objective	Intervention vs control.	Design concepts for interventions	Results
Schrauben et al,[25] 2022	Single-center, single-arm study Country: United States Setting: Outpatient Completers: n=23 Mean age: 67 y (completers) sex/race: 35% female, 96% non-Hispanic White, 4% Hispanic, 0% African American (completers); 52% female, 81% non-Hispanic White, 10% Hispanic, 10% African American (noncompleters) Duration: 8-wk intervention Follow-up: 6-12 mo	CKD stages 1-3a	MyFitnessPal Application for web-based self-monitoring diet, telephone counseling, and motivational interviewing Hardware used: smartphones used by participants to access the MyFitnessPal application for self-monitoring their diet; Spacelabs Ontrak ambulatory BP monitoring device (Snoqualmie, WA) for 24-h BP monitoring Team: Dietitian	At home with wearable device: 24-h ambulatory BP monitoring By professional: laboratory tests, 24-h urine collection, physical examinations, and clinical evaluations	To examine the effect of a telehealth intervention that used a dietary application, educational website, and weekly dietitian telecounseling on sodium intake, diet quality, BP, and albuminuria among individuals with diabetes and early-stage CKD	Intervention: Weekly telecounseling sessions with a dietitian, daily emails with nutrition tips, and weekly summaries of nutrition intake with tailored messages. A nutritionist-led grocery store tour was offered. Participants used MyFitnessPal for daily self-monitoring, with dietitians reviewing data to inform telecounseling sessions focusing on goals such as reducing sodium intake, supported by motivational interviewing techniques. Participants received access to a study-developed educational website with various dietary and health topics. No control (single-arm study).	1. User-centered design (informed by situated learning and control theories, discussions with advisory councils, and a prior feasibility study) 2. Technology integration (MyFitnessPal) 3. Remote monitoring and feedback with dietitian 4. Educational platform (website) 5. Behavioral change techniques (motivational interviewing) 6. Feasibility and adherence tracking	HEI 2015 score in the completer group improved at 12 mo, whereas 24-h DBP declined at 12 mo from baseline. 24-h urine sodium found no decrease during the study period.

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TABLE 2. Continued

Study	Study type, population	CKD stage (GFR)	Telehealth type, hardware used, and team	Measurements taken at home vs by physician/nurse	Objective	Intervention vs control.	Design concepts for interventions	Results
Chan et al,[26] 2021	Single-arm secondary analysis of intervention participants recruited from the previous ENTICE-CKD trial, which was a pilot RCT. Country: Australia Setting: Outpatient Participants: *n*=41 Mean age: 63 y sex/race: 63% male, 85% Caucasian, 5% Asian, 5% European, 2.5 % Indigenous, 2.5% other race Duration: 6-mo intervention	CKD stages 3-4 (eGFR <60 mL/min/1.73 m^2	Dietitian-led telehealth intervention that combined coaching calls and text messages Hardware used: mobiles phones used by participants to receive calls and text messages Team: Dietitian	At home with wearable device: BP, weight, dietary intake; AHEI surveys were completed at home By professional: laboratory tests, BP validation, physical examinations	To evaluate the effects of goal setting on improving diet quality in stages 3-4 CKD using telehealth coaching	Intervention: Dietitian-led coaching calls and tailored text messages for 2 wk to support improving diet quality. Participants set SMART goals and received weekly goal tracking text messages No control (single-arm study).	1. Systematic approach (study divided into phases with specific goals, monitoring, and feedback mechanisms) 2. User-centered design (patients set SMART goals) 3. Feedback loops (through coaching calls and text messages) 4. Technology (semiautomated text message management platform)	There were significant improvements in the AHEI, vegetable intake, and fiber intake observed at 3 mo in participants who set a fruit and/or vegetable goal compared with those who did not. There were no differences in body weight or SBP.
Li et al,[27] 2020	Two-arm randomized controlled trial with a pretest-posttest design Country: Taiwan Setting: Outpatient Intervention: *n*=25; control: *n*=24 Mean age: 50.6 y (intervention); 51.87 y (control) sex/race: 68% male (intervention); 79% male (control)	CKD stages 1-4 (eGFR >90 to 15-29 mL/min/1.73 m^2)	Wearable devices and smartphone applications to record diet and exercise; social media support and health management platform Hardware used: Heart Rate Smart Wristband (GSH405-B6, Golden Smart Home Technology) used by participants	At home with wearable device: physical activity, dietary adherence; QoL questionnaires were completed at home By professional: BMI, BP, laboratory	To evaluate the effectiveness of wearable devices, a health management platform, and social media at improving the self-management of CKD, with the goal of establishing a new self-	Intervention: 90-d intervention involved using wearable devices to document exercise, a smartphone application (WowGoHealth) to record dietary diaries, and a health management platform (LINE application) where participants received	1. Integration of wearable devices (tracked exercise-related data) 2. Health management platform (data from wearable devices and dietary diaries were uploaded and personalized diet and exercise	The intervention group found higher scores for self-efficacy, self-management, and KDQoL and an increase in the number of steps per day, a higher eGFR, and a significantly slower decline in eGFR compared with the control group.

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TABLE 2. Continued

Study	Study type, population	CKD stage (GFR)	Telehealth type, hardware used, and team	Measurements taken at home vs by physician/nurse	Objective	Intervention vs control.	Design concepts for interventions	Results
	Duration: 3-mo intervention		to detect steps, calories consumed, and sleep; smartphones to use the WowGoHealth application and record dietary diaries; Omron HBF-701 to assess body composition Team: Researchers trained by a dietitian	tests, urine tests	management intervention model	personalized diet and exercise suggestions on the basis of their data. Included social media support to enhance self-management of patients with CKD Control: Received routine care (health education provided by case managers according to patient's renal function and blood test results) and were provided a diet manual for kidney disease at the end of the study. Not invited to join the LINE group, nor were they provided individualized dietary suggestions.	suggestions were provided) 3. Use of mobile applications (WowGoHealth for dietary diaries) 4. Social media integration (LINE application to deliver medical knowledge, reminders, and inspiration)	
Kelly et al,[28] 2020	Pilot, parallel group, randomized controlled trial Country: Australia Setting: Tertiary hospitals Intervention: *n*=41; Control: *n*=39 Mean age: 63 y (intervention); 61 y	CKD stages 3-4 (eGFR 15-59 mL/min per 1.73 m^2)	Telephone-based coaching and text messaging Hardware used: mobiles phones used by participants to receive calls and text messages; calibrated digital BP monitor	At home with wearable device: BP, weight By professional: laboratory tests, in-clinic BP for validation, BMI	To test the feasibility and acceptability of the telehealth program to improve diet quality	Intervention: Dietitian-led telehealth coaching intervention to improve diet quality in people with CKD. In the first phase, participants received individualized telephone coaching	1. Personalized and tailored text messages and telephone coaching sessions 2. Phased implementations (2 distinct phases) 3. Use of mHealth	Individual measures of diet quality improved after the intervention, including increased energy intake from core food groups, vegetables, and dietary fiber, although these

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TABLE 2. Continued

Study	Study type, population	CKD stage (GFR)	Telehealth type, hardware used, and team	Measurements taken at home vs by physician/nurse	Objective	Intervention vs control.	Design concepts for interventions	Results
	(control) sex/race: 63% male, 5% Asian, 85% White, 5% European, 2.5% Indigenous, 2.5% other (intervention); 64% man, 3% Asian, 74% White, 8% European, 0% Indigenous, 15% other (control) Duration: 6-mo intervention		used at in-clinic visits Team: Dietitians			from a dietitian every 2 wk for 3 mo, along with weekly tailored text messages. The second phase consisted of continued receipt of tailored text messages without further telephone coaching for 3 mo. All participants received the ENTICE-CKD workbook, designed by dietitians specialized in kidney disease. Control: All participants received the ENTICE-CKD workbook. Received usual care for 3 mo supplemented with educational materials followed by nontailored, educational text messages for follow-up.	technology (to deliver text messages and conduct telephone coaching sessions) 4. Pilot design (to test feasibility and acceptability of telehealth program) 5. Cost-effectiveness analysis (compared costs of the tailored telehealth program with usual care)	improvements were not sustained after 6 mo. There were no significant changes in BP, serum electrolytes, AHEI or QoL between groups.
Humalda et al,[29] 2020	Randomized controlled trial Country: Netherlands Setting: Outpatient Intervention: *n*=50;	CKD stages 1-4 (eGFR ≥25 mL/min/1.73 m^2)	Web-based self-management program, coaching by telephone or email (e-coaching)	At home with wearable device: ambulatory BP monitoring,	To evaluate a self-management approach for dietary sodium restriction in	Intervention: The SUBLIME intervention involved a 3-mo phase where	1. Intervention on the basis of self-regulation theory (emphasizes goal setting, self-	Sodium excretion and SBP decreased significantly in the intervention group. During the

Continued on next page

TABLE 2. Continued

Study	Study type, population	CKD stage (GFR)	Telehealth type, hardware used, and team	Measurements taken at home vs by physician/nurse	Objective	Intervention vs control.	Design concepts for interventions	Results
	Control: n=44 Mean age: 55.1 y (intervention); 58.2 y (control) sex/race: 14% female, 98% White (intervention); 18% female, 91% White (control) Duration: 3-mo intervention (6-mo maintenance phase)		Hardware used: devices such as computers, smartphones, and tablets to access the web-based program and receive e-coaching Team: Dietitians, lifestyle coaches, and research nurses who were trained by certified lifestyle professionals	weight measurements By professionals: 24-h urine collection, 24-h dietary recalls	patients with CKD	participants received coaching from trained professionals and accessed a web-based self-management program focusing on sodium restriction, supported by motivational interviewing techniques. Received group coaching sessions and individual coaching via telephone or email during this phase. In the 6-mo maintenance phase, participants continued with the self-management modules and received additional e-coaching sessions Control: Received routine care without these additional telehealth supports.	monitoring, and feedback) 2. E-coaching and group meetings (provided personalized support and a sense of community) 3. Web-based self-management program (included modules for self-regulation, motivation, and self-monitoring) 4. Focus on barriers and facilitators	maintenance phase, sodium excretion increased in the intervention group but remained lower than baseline, whereas it increased in the control group.
Chang et al,[30] 2020	Single-arm pre-post, mixed methods feasibility study Country: United States Setting: Single-center study	CKD stages 1-3a (eGFR > 45 mL/min/1.73 m^2)	Smartphone applications used to record and share dietary data with dietitians, who provided weekly	At home with wearable device: heart rate, physical activity levels, BP	To test the feasibility and acceptability of a 2-mo remote dietary counseling	Intervention: An educational website covering topics like food label reading and sodium reduction strategies,	1. User-centered design (informed by situated learning and control theories, discussions with	Excellent adherence to the intervention was reported, with high satisfaction among participants. Dietary applications were

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TABLE 2. Continued

Study	Study type, population	CKD stage (GFR)	Telehealth type, hardware used, and team	Measurements taken at home vs by physician/nurse	Objective	Intervention vs control.	Design concepts for interventions	Results
	Participants: $n=16$ Mean age: 64.7 y sex/race: 31% female, 100% non-Hispanic White Duration: 2-mo intervention		telephone counseling sessions Hardware used: smartphones to access the Vibrent Health and MyFitnessPal applications; devices such as computers, smartphones, and tablets to access the educational website; mobile phones used to receive telephone counseling sessions, text messages, and emails Team: Dietitian	By professional: laboratory tests, cardiovascular assessments, physical examinations, specialized tests	program that consisted of weekly telephone calls with a licensed RDN and daily dietary entry using smartphone application technology	weekly telephone counseling sessions with RDNs using motivational interviewing techniques for goal setting, smartphone apps (Vibrent and MyFitnessPal) for dietary monitoring shared with the RDN, daily or weekly educational messages on healthy lifestyles, sodium and fruit/vegetable intake No control (single-arm study).	advisory councils, and a prior feasibility study) 2. Technology integration (Vibrent and MyFitnessPal) 3. Remote monitoring and feedback with an RDN 4. Educational platform (website) 5. Behavioral change techniques (motivational interviewing) 6. Phased intervention design (8-wk intensive phase followed by maintenance phase) 7. Feasibility and adherence tracking	positively viewed. Improvements were observed in several key outcomes, including reduced sodium intake, increased HEI-2015 score, weight loss, and improvements in daytime SBP and DBP.
Cooney et al,[31] 2015	Randomized controlled trial Country: United States Setting: Outpatient Intervention: $n=1070$; Control: $n=1129$ Mean age: 75.6 y	CKD stages 3-5 (eGFR <45 mL/min/1.73 m^2)	Pharmacists interacted with patients and collaborated with PCPs electronically Hardware used: mobile phones used by participants to	At home with wearable devices: NA By professional: BP, laboratory tests, QoL, and medication	To evaluate the effect of a pharmacist-based quality improvement program on outcomes for	Intervention: phone-based pharmacist intervention that included delivery system redesign, self-management support in the form	1. Use of EMR-based CKD registry 2. Phone script with branching logic (embedded within the CKD	Among those with poorly controlled baseline BP, there was no difference in the past recorded BP or the % at goal BP during the study

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TABLE 2. Continued

Study	Study type, population	CKD stage (GFR)	Telehealth type, hardware used, and team	Measurements taken at home vs by physician/nurse	Objective	Intervention vs control.	Design concepts for interventions	Results
	(intervention); 75.7 y (control) sex/race: 98.5% male, 5.8% Black (intervention); 98% man, 5% Black (control) Duration: 12-mo intervention		receive calls Team: Clinical pharmacists	adherence questionnaires	patients with CKD and adherence to CKD guidelines in the primary care setting	of an informational pamphlet about CKD, and utilization of a CKD registry to identify patients not receiving guideline-adherent care and to support decision-making. Pharmacists interacted with patients before primary care appointments to discuss CKD and hypertension management, review medications and lifestyle modifications, and order recommended laboratories. Control: Received usual care from their PCPs without the additional pharmacist-based intervention or patient education components.	registry) on the basis of patients' responses 3. Automated documentation and note generation (generated by the registry to reduce the administrative burden on pharmacists and ensure PCPs had access to updated information) 4. Pharmacist-physician electronic collaboration	period. However, the intervention group was more likely to have PTH measured during the study and were prescribed more antihypertensive medications compared with the control group. There were no differences in QoL between the intervention and control arms.
Blakeman et al,[32] 2014	Randomized controlled trial Country: United Kingdom Setting: Outpatient Intervention: n=215;	CKD stages 3a-3b	Interactive website, guidebooks, and telephone-guided help Hardware used: mobile phones used by	At home with wearable device: physical activity levels; QoL questionnaires	To determine the effectiveness of an intervention to provide information and telephone-	Intervention: involved 2 telephone calls from a lay health worker trained to facilitate appropriate referrals to local resources.	1. "Keeping Your Kidneys Healthy" guidebook (developed with input from patients with	Mean HRQoL was significantly higher in the intervention group and BP was controlled for in a significantly greater

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TABLE 2. Continued

Study	Study type, population	CKD stage (GFR)	Telehealth type, hardware used, and team	Measurements taken at home vs by physician/nurse	Objective	Intervention vs control.	Design concepts for interventions	Results
	control: n=221 Mean age: 72.4 y (intervention); 71.8 y (control) sex/race: 41.9% male, 98.1% White (intervention); 41.2% male, 99.1% White (control) Duration: 6-mo intervention		participants to receive telephone-guided help; computers and/or mobile devices to access the interactive website Team: Lay health workers who received a 3-h training session (included 3 staff members, 4 postgraduate students, 1 undergraduate student)	were completed at home By professional: BP	guided access to community support vs usual care in patients with stage 3 CKD using the BRIGHT intervention	During the calls, patients were guided through the PLANS booklet and website, which serves as a self-assessment tool including vascular health and offers links to relevant community resources and local support services. Also received the "Keeping Your Kidneys Healthy" guidebook. Control: Received access to primary care without additional interventions provided to the intervention group. At the end of the trial, participants were sent the kidney information guidebook and PLANS booklet with links to the website.	stage 3 CKD and provided tailored information) 2. PLANS booklet and interactive website (for self-assessment of health and social needs) 3. Telephone-guided support (helped patients navigate the resources and implement the information provided) 4. Integration with routine care	proportion of patients in the intervention group. Reduction in costs was reported by the intervention group compared with the control.
Rifkin et al,[33] 2014	Randomized controlled trial Country: United States Setting: Outpatient Intervention group: n=28; control:	CKD stages 3-5	Bluetooth-enabled BP cuff with an internet-enabled hub, which wirelessly transmitted readings Hardware used: a fully	At home with wearable device: BP By professionals: laboratory tests,	To test the feasibility and acceptability of a novel home-based, Bluetooth-	Intervention: Received a novel telemonitoring device pairing a Bluetooth-enabled BP cuff with an	1. Integration of a Bluetooth-enabled BP cuff integrated with an internet-enabled hub	In the intervention arm, 78% of participants continued to use the device regularly vs 20% in the control group. Both groups

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TABLE 2. Continued

Study	Study type, population	CKD stage (GFR)	Telehealth type, hardware used, and team	Measurements taken at home vs by physician/nurse	Objective	Intervention vs control.	Design concepts for interventions	Results
	n=15 Mean age: 67.9 y (intervention); 67.9 y (control) sex/race: 93% male, 25% African American (intervention); 100% male, 27% African American (control) Duration: 6-mo intervention		automatic oscillometric BP unit and Home Health Hub were used to monitor and receive BP data via Bluetooth Team: Pharmacists and physicians	medication adjustments, in-clinic BP measurements for validation	enabled BP monitoring device and intervention protocol requiring minimal effort or technological in older adults with CKD	internet-enabled hub, which wirelessly transmitted readings. Home BP recordings were reviewed weekly by study personnel and participants were contacted by telephone if BP readings were above the general range. Control: Received usual care, which included using their own home BP cuff as recommended by their physician, no study-specific instructions for frequency of BP measurements, and were checked in by personnel at the end of 6 mo for an end-of-study visit related to BP.	2. Wireless data transmission to a secure website via a cellular modem 3. User-friendly interface of device 4. Automated monitoring system 5. Remote monitoring and feedback loop (allowed for timely adjustments to treatment without the need for in-person visits)	significantly improved in SBP, but SBP was lower in monitored participants vs the control group. No eGFR change in the intervention group at the end of the study was observed, and the control group found a decreasing trend in kidney function.
Lin et al,[34] 2013	Randomized controlled trial Country: Taiwan Setting: Outpatient Intervention: *n*=18 control: *n*=18 Mean age, 65 y (intervention); 69 y (control) sex/race:	CKD stages 3-5	Cloud-based manometers integrated with physician order entry system Hardware used: cloud-based manometers, integrated with physical order entry	At home with wearable device: BP By professionals: laboratory tests	To investigate how integrating cloud-based manometers with physician order entry systems benefits outpatient	Intervention: Used cloud-based manometers integrated with physician order entry systems to track BP. Daily recording and integration were	1. Integration of cloud-based manometers (designed to be user-friendly and provide a feedback loop for physicians and patients)	Nighttime SBP and DBP significantly decreased in the intervention group. Serum creatinine levels significantly improved, and proteinuria found a nonsignificant

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TABLE 2. Continued

Study	Study type, population	CKD stage (GFR)	Telehealth type, hardware used, and team	Measurements taken at home vs by physician/nurse	Objective	Intervention vs control.	Design concepts for interventions	Results
	40.9% male, 63.3% female (intervention); 59.1% male, 35.7% female (control) Duration: 6-mo intervention		systems for daily BP recordings; clinic sphygmomanometer used during outpatient clinic visits to obtain seated BP measurements Team: Physician		patients with CKD compared with typical BP tracking systems	performed in the integrated cloud-based manometer recording system group. Physicians verified patient BPs in their order entry system weekly, and more frequently if required as per the study group. Control: Received routine care, conducting BP tracking using traditional methods (readings taken at outpatient clinic every 3 mo). Regular medication adjustments were conducted with every outpatient clinic visit on the basis of BP record sheet.	2. Data accessibility and monitoring (integration of physician order entry systems allowed for seamless transfer of BP data from patient's homes to health care providers' systems)	improvement in the intervention group compared with the control group at 6 mo.

AHEI, Alternative Healthy Eating Index; BEAM, Building Exercise and Active Management; BMI, body mass index; BP, blood pressure; BRIGHT, Bringing Information and Guided Help Together; CHW, community health worker; CKD, chronic kidney disease; DBP, diastolic blood pressure; eGFR, estimated glomerular filtration rate; eHealth, electronic health; EMR, electronic medical record; ENTICE-CKD, Evaluation of Individualized Telehealth Intensive Coaching to Promote Healthy Eating and Lifestyle in chronic kidney disease; GFR, glomerular filtration rate; HEI, Healthy Eating Index; HRQoL, health-related quality of life; iCBT, internet-based cognitive-behavioral therapy; KDQoL, kidney disease quality of life; KDQoL-SF, kidney disease quality of life short-form; LINE, leading innovation network experience; MCS, mental component summary; mHealth, mobile health; NA, not applicable or reported; PCP, primary care physician; PHC, portable health clinic; PLANS, Patient-Led Assessment for Network Support; PTH, parathyroid hormone; QoL, quality of life; SBP, systolic blood pressure; RDN, registered dietitian nutritionist; SUBLIME, Sodium Burden Lowered by Lifestyle Intervention: Self-Management and E-coaching.

a decrease in daily sodium intake by 638 mg from a baseline of 2919 mg.[25] Similarly, another 8-week program led by an RDN using application-supported telecounseling did not result in a significant change in 24-hour urine sodium among participants.[30] Contrary to these results, Humalda et al[29] found that a 3-month web-based self-management intervention, including individual e-coaching and group meetings, resulted in lower mean sodium excretion in the intervention group compared with that in the control group, which received only routine care without telecommunication methods.

Serum Creatinine. Four studies measured serum creatinine levels in adult patients with CKD.[24,27,33,34] In a 6-month study, patients in an experimental group that received regular blood pressure monitoring through cloud-based manometers integrated with physician order entry systems found a significant decrease in serum creatinine levels compared with those in the control group that used typical blood pressure tracking systems.[34] Furthermore, Li et al[27] found that serum creatinine levels were lower in the intervention group that received diet and exercise suggestions as well as support from a social media group compared with those in the control group that received routine care, although the difference was not significant. Conversely, Rifkin et al[33] reported that after a 6-month intervention, the intervention group receiving wirelessly transmitted readings through a novel telemonitoring device did not show a significant difference in creatinine levels compared with the control group receiving usual care. However, there was an increasing trend of 0.28 mg/dL in creatinine levels in the usual care group compared with an increasing trend of 0.04 mg/dL in the intervention group.[33] In another 6-month RCT where the intervention group received health education through mobile health technologies and the control group received standard treatment, no change was observed in serum creatinine levels between participants in either group.[24]

Serum Potassium. Serum potassium levels were assessed in only 1 study after a 6-month intervention that used dietitian-led telehealth coaching, incorporating phone calls and tailored text messages to promote a diet consistent with CKD guidelines. The results indicated no significant difference in serum potassium levels between the intervention group and the control group, which received usual care and nontailored text messaging, at both 3 and 6 months.[28]

Serum Phosphorus. One study in this review measured serum phosphate levels after a 6-month intervention using dietitian-led telehealth coaching. At 3 and 6 months, the intervention group that received phone calls and tailored text messages found no significant difference in serum phosphorus levels compared with the control group that received usual care.[28]

Serum Albumin. Studies have indicated that patients with CKD and low serum albumin face an increased risk of kidney failure compared with those with normal serum albumin.[37] A 6-month intervention providing health education via phone calls and in-person visits to individuals with CKD did not result in statistically different serum albumin levels between the intervention group and the control group receiving usual care.[24]

Proteinuria. Proteinuria, also referred to as albuminuria, is a broad term indicating the presence of proteins in the urine.[38] It serves as an indicator of early renal disease, signifying an elevated risk of renal damage associated with hypertension and cardiovascular disease (CVD).[36] To effectively manage CKD, it is recommended to maintain a low-protein diet, typically ranging from 0.6 to 0.8 g/kg of body weight per day. This dietary approach plays a crucial role in controlling and reducing protein in the urine.[39]

In this review, 4 studies measured proteinuria.[25,29,30,34] In an RCT, Lin et al[34] allocated participants in the intervention group to use cloud-based manometers integrated with physician order entry systems, whereas those in the control group were assigned to use conventional blood pressure recording sheets over a 6-month period. The results indicated a nonsignificant improvement in proteinuria in the intervention group compared with the control group by the end of month 6.[34] Conversely, a single-arm study investigating the effects of a dietary application-supported telecounseling intervention found no significant improvement in proteinuria between the intervention and control groups.[25] A more extensive study, which included a 3-month intervention and 6-month maintenance period and compared routine care with routine care plus a web-based self-management intervention involving e-coaching and group meetings, reported that median proteinuria did not change from baseline in either the intervention group or the control group after the intervention phase.[29] Chang et al[30] further observed that participants, after receiving motivational interviews and sharing dietary data via smartphone applications with RDNs for 8 weeks, found no significant changes in proteinuria.

Healthy Eating Index

The Healthy Eating Index (HEI), a measure of diet quality, is administered and used to assess alignment of dietary patterns with recommendations from the Dietary Guidelines for Americans.[40] The HEI scores range from 0 to 100, with higher scores indicating better diet quality.[41] The HEI has been used to document the diet quality of the US population, assess differences in diet quality among population subgroups, identify influences on diet quality, evaluate associations between diet quality and disease risk/mortality, and examine the effect of interventions on diet quality.[40]

An intervention lasting 8 weeks involved RDNs who used motivational interviewing and telephone counseling for individuals with type 2 diabetes and stage 1-3a CKD. Participants shared their recorded dietary data with the RDNs through the MyFitnessPal application. After 12 months, there was a notable 7.76-point improvement in the HEI-2015 score, compared with the baseline score of 54.6.[25] In a separate study lasting 8 weeks and using a pre-post mixed-method approach, patients with stage 1-3a CKD used smartphone applications and recorded and shared their dietary information with RDNs, who used motivational interviewing techniques during telephone counseling sessions. The intervention resulted in a significant improvement in the HEI-2015 score.[30]

Alternative Healthy Eating Index

The Alternative Healthy Eating Index (AHEI) was created as an alternative to the HEI to identify foods and nutrients predictive of chronic disease risk. Higher scores on the AHEI are significantly associated with a lower risk of major chronic disease. Research has shown that participants with higher scores on the AHEI had a 19% lower risk of chronic disease, 31% lower risk of coronary heart disease, and 33% lower risk of diabetes when compared with participants with lower AHEI scores.[42]

In a 6-month, dietitian-led telehealth coaching intervention, patient-centered goal setting significantly improved diet quality (AHEI), vegetable intake, and fiber intake at 3 months among participants who set a fruit and/or vegetable intake goal, but no significant changes were observed at 6 months.[26] Contrarily, AHEI did not show improvement after a separate 3-month dietitian-led telehealth coaching intervention aiming to enhance diet quality in individuals with stage 3-4 CKD. However, individual measures of diet quality found significant improvement at 3 months, including a 5.8% increase in energy intake from core food groups, an increase of 1.5 servings in daily vegetable consumption, and an increase of 6.1 g in daily fiber intake. These improvements were notably not sustained at 6 months.[28]

Quality of Life Measurements

Chronic kidney disease adversely affects quality of life (QoL) by increasing the risk of mortality during its progression.[43] Therefore, it is essential to enhance QoL scores in both physical and mental health for individuals living with CKD. The Kidney Disease Quality of Life Short-Form (KDQoL-SF) was developed as a self-report measure for individuals with kidney disease and on dialysis. The KDQoL-SF encompasses 43 kidney disease—specific items and evaluates factors such as daily activities, work status, and social interactions to measure physical and mental health on a scale of 0-10, where a higher score indicates better health.[44] An additional measure of QoL is the health-related quality of life (HRQoL), which focuses on the impact of health status on QoL.[45] Measuring HRQoL, with higher scores indicating a better QoL, can help determine the burden of preventable disease, injuries, and disabilities and may also provide valuable information for health and risk factors.[46] Finally, the Personalized Priority and Progress Questionnaire assesses personalized outcomes in 7 areas of functioning (ie, fatigue, pain, itch, anxiety, depression, social environment, and daily activities) and 5 areas of self-management (ie, medication adherence, healthy diet, physical activity, weight management, and nonsmoking).[23]

In a 3-month, 2-arm RCT, control participants received routine care, whereas those in the intervention group received personalized suggestions for diet and exercise as well as support from a social media group. The results found that utilization of social media and a health management platform contributed to higher scores in self-efficacy, self-management, and KDQoL-SF within the intervention group compared with those in the control group.[27] Similarly, the Kidney BEAM trial, which evaluated the clinical effect of a 12-week physical activity digital health intervention in adults with CKD, found that there were significant improvements in KDQoL-SF scores in the intervention group compared with those in the waiting list control group.[22] In contrast, another trial in which patients were randomized to usual care or a multifactorial intervention that included a phone-based pharmacist intervention, pharmacist-physician collaboration, and patient education found no significant difference in KDQoL-SF scores between the control and intervention groups.[31]

A 6-month Bringing Information and Guided Help Together intervention that provided tailored information and telephone-facilitated help to enhance self-management in patients with stage 3 CKD revealed significantly higher mean HRQoL scores in the intervention group than those in the control group receiving usual care. However, there were no significant differences in positive and active engagement in life among patients.[32] In a separate RCT, HRQoL was assessed using the Short Form (SF)-12, one of the most widely used instruments for assessing self-reported HRQoL,[47] comparing routine care with routine care plus a web-based self-management intervention.[29] The results indicated higher scores in both the Physical Health Summary and Mental Health Summary for the intervention group compared with those in the control that received routine care.[29] Conversely, Kelly et al[28] found that dietitian-led telehealth coaching resulted in no significant differences in Assessment of QoL questionnaire scores between the intervention group that received phone calls every 2 weeks for 3 months, followed by 3 months of tailored text messages, and the control group that received usual care. Furthermore, in a 2-arm parallel RCT that evaluated the effectiveness of a personalized E-GOAL electronic health care intervention, including cognitive-behavioral therapy and self-management support, no significant time-by-group interaction effects were found for HRQoL. However, at posttest, the intervention group found significantly greater progress in personally prioritized areas of functioning and self-management, as measured by the Personalized Priority and Progress Questionnaire, compared with the control group. These positive effects on personalized outcomes were sustained at the follow-up assessment.[23]

Blood Pressure

The American College of Cardiology advises maintaining systolic blood pressure (SBP) at 130 mm Hg and diastolic blood pressure (DBP) at 80 mm Hg for adults with CKD.[7] Maintaining blood pressure control is essential as elevated blood pressure can lead to damaged blood vessels, thereby diminishing blood supply to the kidneys and damaging the filtering units known as nephrons. Lowering blood pressure slows disease progression and reduces incidents of CVDs.[7] Intensive blood pressure control is associated with lower mortality risk in adults with CKD.[48]

In an 8-week, single-arm intervention in which participants with stage 1-3a CKD recorded and shared dietary data with RDNs using a mobile application and received motivational interviewing via telephone counseling weekly, 24-hour blood pressure was measured on placement of a 24-hour ambulatory blood pressure monitoring device. In these participants, SBP and DBP declined at 12 months from baseline.[25] Chang et al[30] also reported that patients with stage 1-3a CKD experienced a significant reduction in daytime DBP after receiving telephone counseling from RDNs. This reduction was measured at month 3 of the intervention using 24-hour ambulatory blood pressure monitoring with the Spacelabs OnTrack device and an appropriately sized cuff applied at baseline and 8-week research visits.[30] Similarly, Lin et al[34] reported a significant decrease in nighttime SBP and DBP after 6 months in patients with CKD who were assigned blood pressure telemonitoring by a physician, in contrast to patients using typical blood pressure recording sheets. Blood pressure was monitored in this study by obtaining 3 consecutive seated BP measurements using a clinic sphygmomanometer during outpatient clinic visits at baseline and every 3 months for the first 6 months, with the mean of the past 2 readings recorded after patients rested for at least 5 minutes.[34]

Additionally, in another 6-month study where participants were randomized to use either a telemonitoring device for wireless blood pressure readings and alerts or to receive usual care, the intervention group exhibited a median 13-mm Hg drop in SBP, surpassing the 8.5-mm Hg reduction in the usual care participants.[33] Furthermore, DBP significantly improved among participants in a separate 6-month intervention who received health education via mobile phone calls coupled with in-home care involving weekly blood pressure monitoring compared with that in patients who received standard treatment.[24] Finally, in a 3-month program that provided individual e-coaching and group meetings, blood pressure was measured at an outpatient clinic after 5 minutes' rest with an automated oscillometric device 3 times with a 1-minute interval. Systolic blood pressure significantly decreased in the intervention group but remained unchanged in the control group that received routine care. However, there were no significant differences between groups after the 6-month maintenance period.[29]

Other studies have reported conflicting results on the effects of telehealth interventions on blood pressure management in adult patients with CKD. Two RCTs in this review, which included telehealth communication methods such as telephone, text messaging, and RDN coaching, did not show statistically significant effects on SBP. Blood pressure measurements were collected as part of usual care where possible or by a trained site investigator who was blind to the treatment allocation in both the intervention and control groups.[26,28] In a similar fashion, a 12-month phone-based pharmacist intervention that included pharmacist-physician collaboration and patient education found no significant differences between the intervention and control groups in blood pressure control among patients with poorly controlled hypertension at baseline. However, patients increased adherence to blood pressure medication by the end of the study.[31] The Bringing Information and Guided Help Together intervention, aimed to enhance health outcomes for patients with stage 3 CKD through self-management information, tailored community resource access, and telephone guidance revealed that intervention patients maintained, rather than increased, blood pressure control over the 6-month trial period. In contrast, control patients, who were provided a kidney information guidebook and booklet with website links, experienced increases in mean SBP and DBP.[32]

Estimated Glomerular Filtration Rate

According to the National Kidney Foundation, CKD is defined as either a low estimated glomerular filtration rate (eGFR) of less than 60 mL/min/1.73 m^2 or kidney damage persisting for 3 or more months. A low eGFR has been shown to increase the risk of systemic complications, such as CVD and hypertension, and the risks of mortality and progression to ESRD. An eGFR of 90 mL/min/1.73 m^2 or higher indicates kidney damage with normal kidney function, 60 to 89 mL/min/1.73 m^2 indicates stage 2 CKD, 45 to 59 mL/min/1.73 m^2 indicates stage 3a CKD, 30 to 44 mL/min/1.73 m^2 indicates stage 3 CKD, 15 to 29 mL/min/1.73 m^2 indicates stage 4 CKD, and less than 15 mL/min/1.73 m^2 indicates kidney failure or ESRD.[49]

Three studies in this review measured eGFR to evaluate kidney function.[27,33,34] In a 3-month prospective study, all participants were equipped with a wearable device that collected exercise-related data. Only the intervention group received diet and exercise suggestions, along with access to a social media support group, resulting in a significantly higher eGFR compared with the control group receiving routine care.[27] In contrast, in a separate 6-month study using cloud-based manometers integrated with physician order entry systems vs typical blood pressure recording sheets, there were no significant improvements in eGFR in the intervention group compared with the control group. However, a trend of improved eGFR was observed in the intervention group.[34] Another 6-month study, incorporating telemonitoring, follow-up, and self-recorded blood pressure readings, found no statistically significant improvement in eGFR for the intervention group compared with that in the control group, which received standard care without telemonitoring.[33]

DISCUSSION

This review assessed the effectiveness of telehealth interventions on dietary habits, nutritional status, biochemical markers, QoL, and kidney function in adults with CKD. The primary findings suggest that telehealth interventions effectively improve blood pressure, QoL scores, and dietary habits in patients with CKD. However, it is important to note that serum albumin, serum potassium, and serum phosphorus did not show significant improvements in the presence of telehealth coaching, indicating that although telehealth can enhance certain health metrics, it may not be universally effective across all biochemical markers. This discrepancy suggests the need for further exploration into which telehealth interventions yield the most beneficial outcomes and whether certain methods or combinations of methods should be prioritized in future research to maximize improvements in CKD management.

Significant improvements in SBP and/or DBP were observed after using a combination of telephone counseling by an RDN and monitoring by a physician, web-based management, mobile applications, or cloud-based blood pressure monitoring.[24,25,29,33,34] However, studies in this review did not show significant differences in blood pressure between groups when the intervention only included text message-based coaching.[26,29] These results suggest that providing telehealth using a combination of technologies may help improve blood pressure and lower mortality risk in adults with CKD.

Self-management plays a crucial role in helping individuals cope with chronic diseases. Strengthening self-management skills, such as problem-solving, decision-making, resource utilization, formation of client-health care provider partnerships, and taking action, has been shown to delay the progression of CKD by improving modifiable risk factors.[27] In this review, telehealth self-management tools included telephone-delivered education and web-based or mobile applications providing dietary and exercise information, social support, and resources directly to participants. The use of these telehealth self-management tools by intervention patients resulted in improved QoL scores compared with that in control patients receiving routine care without additional support.[27,29,32] Similarly, a systematic review by He et al[50] found that remote home management resulted in higher QoL in patients with CKD than did typical care in certain dimensions. These findings underscore the potential of telehealth interventions to empower patients in managing their health more effectively and improving their overall QoL.

To enhance the dietary habits of adult patients with CKD, the provision of individualized dietary evaluation and counseling by an RDN has been shown to be cost effective, improve control of diabetes and hypertension, and even slow CKD progression and delay need for dialysis.[51] Both the Academy of Nutrition and Dietetics and National Kidney Foundation underscore the effectiveness of telehealth or telenutrition, wherein an RDN uses electronic information and telecommunication technologies to implement the Nutrition Care Process with patients or clients in remote locations. This approach has been proven to be efficient compared with traditional in-person visits, as remote devices provide valuable data for planning nutrition interventions and informing individualized care plans.[6]

Dietary modifications such as decreasing intake of sodium and increasing intake of fruits and vegetables may slow kidney disease progression.[4] In this review, interventions that included telephone counseling by and sharing of dietary data with an RDN resulted in significant improvements in HEI scores,[25,30] which measures diet quality and dietary habits, including increased vegetable and dietary fiber intake.[26,28] In addition, dietary sodium intake improved with interventions that included telephone coaching with dietitians, motivational interviewing, and SMART goal setting.[29,25,30] Kelly et al[52] also found that telehealth-delivered dietary interventions targeting whole foods and dietary patterns improved diet quality and intake habits, suggesting that integrating telehealth approaches with personalized dietary counseling can effectively support patients in making sustainable lifestyle changes that positively impact their kidney health.

Estimated glomerular filtration rate and serum creatinine are widely recognized as primary indicators of kidney function.[53] Three studies in this review assessed kidney function by measuring eGFR.[27,33,34] Improvement of eGFR was reported in only 1 study, which used a health management platform, RDN-recommended diet and exercise suggestions through text messaging, and support via a social media group. Participants received answers to inquiries regarding CKD management through the LINE text messaging application, and teleconsultations were also provided.[27] The remaining 2 studies did not use coaching with an RDN or telehealth communication tools; instead, they provided blood pressure monitoring devices to intervention participants, which may explain the absence of significant changes in eGFR in these studies.[33,34] As eGFR improved only in the study that included telehealth communication tools to provide care, the use of these tools in improving kidney function warrants further investigation.

Telehealth was initially developed to improve health care access for patients in rural and underserved areas, particularly for managing chronic diseases. Its adoption has broadened with the shift from fee-for-service to outcome-based reimbursement models, a trend that accelerated after the COVID-19 pandemic.[19] The effectiveness of telehealth lies in its ability to improve health care accessibility, enhance efficiency without escalating costs, decrease patient travel and wait times, and maintain or even elevate the quality of care. Importantly, telemedicine has been shown to save patients between $19 and $121 per visit on average.[54] This transition also leads to increased patient satisfaction, stemming from improved access, convenience, and reduced stress associated with telehealth services.[15] Current evidence suggests that virtual education delivered via telehealth to patients with chronic diseases, such as diabetes mellitus, chronic obstructive pulmonary disease, irritable bowel disease, and heart failure, is comparable with or more effective than usual care.[28] Telehealth, encompassing mobile or web-based applications and self-monitoring tools, can engage patients in managing diet, exercise, and medications for CKD, which subsequently may influence disease outcomes and result in short-term cost savings for patients.

In this review, however, 3 secondary outcomes—serum albumin,[24] potassium, and phosphorus[28]—did not show significant improvements in the presence of telehealth coaching, although these outcomes were measured in only 2 studies. Given the limited sample of research, future studies should incorporate these biochemical markers to better evaluate the potential effects of telehealth interventions on these important indicators. Moreover, our findings suggest that telehealth interventions using a combination of methods—particularly those incorporating personalized education and support from RDNs—tend to yield the most positive outcomes. Future efforts should prioritize these comprehensive telehealth strategies to optimize CKD management and avoiding reliance on interventions that lack these critical components, as such approaches have found limited efficacy in improving patient outcomes.

Methodologic limitations of the studies in this systematic review include small sample sizes and short durations. Additionally, the overrepresentation of older male participants highlights the need for more diverse research, incorporating women and wider age ranges. Future investigations should prioritize larger sample sizes, longer durations, and RCT designs. It is also crucial to examine the effectiveness of telehealth in treating CKD among populations in resource-poor countries, particularly those in rural areas with limited access to medical facilities and specialized care, where telehealth may offer a more viable solution. In-depth, long-term investigations of telehealth communication methods, such as mobile applications, are essential to fully understand telehealth's impact on kidney function, dietary habits, nutritional status, and QoL in adults with CKD.

CONCLUSION

Telehealth interventions hold promise in improving CKD management by increasing accessibility, supporting multidisciplinary care, and improving the management of blood pressure and dietary habits, ultimately leading to a better QoL for patients. Studies have found the benefits of telehealth in delivering cost effective and convenient health care, particularly in rural and underserved areas. However, its effectiveness varies on the basis of the tools and methods used, with some biochemical markers showing only limited improvement. This review suggests that interventions incorporating personalized education and support from RDNs tend to produce better outcomes. Given the rapid adoption of telehealth after the COVID-19 pandemic, future studies should use homogeneous and rigorous methods, include larger and more diverse populations, extend study durations, and assess telehealth's impact in resource-poor countries where it may provide essential support for CKD treatment in adult patients.

POTENTIAL COMPETING INTERESTS

The authors report no competing interests.

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Abbreviations and Acronyms: **AHEI,** Alternative Health Eating Index; **CKD,** chronic kidney disease; **CVD,** cardiovascular disease; **DBP,** diastolic blood pressure; **ESRD,** end-stage renal disease; **eGFR,** estimated glomerular filtration rate; **HEI,** Healthy Eating Index; **HRQoL,** health-related quality of life; **KDQoL-SF,** Kidney Disease Quality of Life Short-Form; **QoL,** quality of life; **RDN,** registered dietitian nutritionist; **SBP,** systolic blood pressure

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