

# Nutritional Mobile Applications for CKD Patients: Systematic Review



Sarah Daisy Kosa<sup>1,2,3</sup>, Jillian Monize<sup>1</sup>, Mitchell D'Souza<sup>1</sup>, Arundhati Joshi<sup>1</sup>, Kaylyssa Philip<sup>1</sup>, Samiha Reza<sup>1</sup>, Simranjit Samra<sup>1,4</sup>, Bridgette Serrago<sup>1,5</sup>, Lehana Thabane<sup>3,6</sup>, Amiram Gafni<sup>3</sup> and Charmaine E. Lok<sup>1,2,3</sup>

<sup>1</sup>Research, Kidney CARE Network International, Toronto, Ontario, Canada; <sup>2</sup>Toronto General Hospital Research Institute, Toronto, Ontario, Canada; <sup>3</sup>Department of Health Research, Evidence, and Impact, McMaster University, Hamilton, Ontario, Canada; <sup>4</sup>School of Nutrition, Faculty of Community Services, Ryerson University, Toronto, Ontario, Canada; <sup>5</sup>School of Food & Nutritional Sciences, Brescia University College, London, Ontario, Canada; and <sup>6</sup>Biostatistics Unit, Research Administration, St Joseph's Healthcare—Hamilton, Hamilton, Ontario, Canada

**Introduction:** Mobile health applications offer the potential to help people living with chronic kidney disease (CKD) manage diet-related challenges. This systematic review examined CKD dietary mobile app interventions; specifically, app characteristics, feasibility, and effectiveness in changing user behavior, as well as user satisfaction.

**Methods:** This review was reported in accordance with PRISMA guidelines. We searched scholarly databases, as well as the gray literature, for all randomized controlled trials, observational studies, needs assessments, and pilot testing/studies/trials focused on the development or evaluation of CKD dietary mobile app interventions. The characteristics, user satisfaction with, usability/feasibility, and effectiveness in changing dietary behavior of the mobile application were summarized using descriptive statistics and in a narrative manner.

**Results:** Thirteen full-text studies were included, of which 11 were single center, with a mean sample size of 23. Of the 7 studies that measured usability/feasibility, all found at least some aspects of the application feasible/useful. Of the 5 studies that reported an evaluation of changes in behavior/diet related to self-management, all reported some positive change.

**Conclusion:** According to current studies, nutritional apps show promise in CKD self-management.

*Kidney Int Rep* (2019) 4, 399–407; <https://doi.org/10.1016/j.ekir.2018.11.016>

**KEYWORDS:** application; chronic kidney disease; mobile app; nutritional; patient-centered care; systematic review

© 2018 International Society of Nephrology. Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

CKD prevalence is on the rise and is a complex condition to manage for patients, families, and providers.<sup>1</sup> Dietary monitoring and modification are vital components of treatment for individuals living with CKD to prevent disease progression and to manage symptoms. Generally, nutritional management of CKD requires balancing the intake of energy, protein, sodium, potassium, phosphorus, and fluid with biochemical markers and weight changes.<sup>2</sup> Because of complex nutrition guidelines and consideration of coexisting conditions, dietary monitoring and modification can be significant and present daily challenges for people living with CKD.

It has been suggested in the literature that mobile health applications (apps) are promising vehicles to deliver health information and interventions to people living with chronic health conditions. By 2020, it is estimated that 6.1 billion people around the world will own a mobile phone,<sup>3</sup> and as of 2017, 79,298 health and fitness apps were available on iTunes.<sup>4</sup> Apps are accessible, convenient, and customizable.<sup>3,5</sup> Other reported advantages of mobile health apps include affordability, ability to reach traditionally hard-to-reach groups and overcome geographical barriers,<sup>3</sup> improved treatment compliance,<sup>6</sup> increased access to care,<sup>3</sup> increased accuracy of data collection due to built-in features such as global positioning systems and image recognition,<sup>7</sup> and potential to reduce barriers to seeking health care, such as stigma and discomfort.<sup>3</sup>

Mobile apps offer the particular potential to assist individuals living with CKD address unique challenges related to their individual diet. For example, to monitor and adhere to the nutritional recommendations

**Correspondence:** Sarah Daisy Kosa, Division of Nephrology, Department of Internal Medicine, University Health Network, Toronto General Hospital, 200 Elizabeth Street 8N844, Toronto, Ontario, Canada, M5G 2C4. E-mail: [sarah.kosa@uhnresearch.ca](mailto:sarah.kosa@uhnresearch.ca)

**Received 5 October 2018; revised 14 November 2018; accepted 26 November 2018; published online 29 November 2018**

provided by a health care professional, it is often advised to keep a food diary. This tool has its challenges; patients may forget to record a meal, have difficulty estimating serving sizes, or lack the time or ability to keep a diary. A study by Franco *et al.*<sup>7</sup> identified 9 existing apps that provide a food diary feature to record food intake. They report that patients prefer digital recording of food intake over using pen and paper, as it saves time and resources.<sup>7</sup> The authors also discuss the potential of technology to simplify food and portion selection processes. Some existing apps have features such as text search and a barcode scanner for data input, as well as a camera feature for taking pictures of meals. This could be useful for recognizing food items and estimating portion sizes for more accurate data collection and monitoring.<sup>7</sup> Although a mobile app would not replace the role of the dietician in helping patients with CKD manage their nutritional needs, the app offers potential to help health care providers overcome some of the potential barriers to consistent and optimal nutritional management, such as cost of dietician appointments, if not covered by insurance plans, and availability of dietitians and patients for frequent follow-up. Given the suggested promise of mobile applications in addressing some of these issues in nutritional management, this systematic review aims to examine mobile app types, characteristics, feasibility, and effectiveness in changing behavior, as well as user satisfaction with dietary mobile apps, specifically in both adult and pediatric CKD populations.

## METHODS

This systematic review was reported in accordance with PRISMA guidelines (see [Supplementary Material PRISMA Checklist](#)), and the protocol, although pre-specified, was not published in advance of this review.<sup>8</sup>

### Search Strategy

#### Scholarly Literature

To retrieve scholarly articles examining mobile app types, characteristics, feasibility, and effectiveness in changing behavior, as well as user satisfaction with dietary mobile apps, in both adult and pediatric populations living with CKD, the scholarly databases PubMed, Embase, and Google Scholar were searched in July 2017 using search terms related to nutrition [i.e., dietary OR nutritional], mobile application [i.e., mobile applications, mobile apps, OR smartphone apps], AND Chronic Kidney Disease [i.e., Renal failure—chronic, Chronic renal insufficiency, Chronic kidney failure, Chronic renal failure, OR Chronic Kidney Disease].

#### Gray Literature

The gray literature was searched by entering keywords in the search bar on multiple general and targeted Web

sites. The first 100 records retrieved were reviewed. The search terms for the gray literature included the following: “kidney disease” AND eHealth, mobile health, health information technology, mobile health apps, telemedicine, mHealth, mobile health apps for patients, apps, applications, OR mobile health technology. The Web sites searched included Google, iMedical Apps (using the Web site search bar to enter the search term “kidney” for information on kidney apps currently available), Canadian Medical Association, National Kidney Foundation, Nephcure Kidney International, MyHealthApps, Athena Health, and Mobi Health News.

### Types of Participants

Patients of any age diagnosed with any stage of CKD who are able to use the mobile application (patients with end-stage renal disease on any form of renal replacement therapy were included).

### Types of Interventions

Mobile application designed to assist individuals living with CKD manage their nutritional intake.

### Types of Records

This systematic review includes randomized control trials, observational studies, and pilot testing/studies/trials focused on the development or evaluation of all types of mobile applications designed to assist individuals living with CKD manage their nutritional intake.

### Article Selection

Title and abstract screening was performed in duplicate (MD, AJ, KP, SR, SS, BS), and disagreements were resolved by a third reviewer (SK) using predefined inclusion and exclusion criteria.

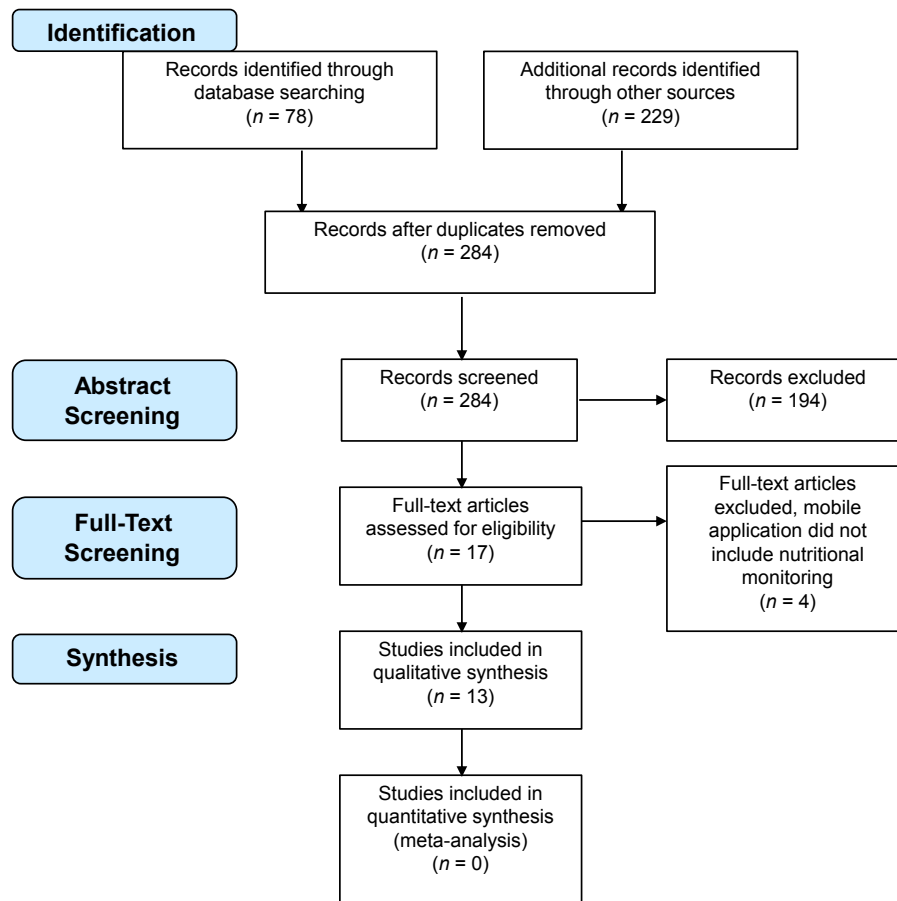
### Criteria for Considering Studies for This Review

Records were included if (i) the publication date was available; (ii) available in English; (iii) available free of charge; (iv) focused on apps used by patients, not medical professionals; (v) focused on a randomized controlled trial, observational study, or pilot testing/studies/trials, or needs assessment/design of a nutritional application in patients with CKD; and (vi) not a review/systematic review of other studies.

### Types of Outcome Measures

The types of outcomes collected included the following:

(i) Dietary behavior: Immediate changes in dietary behavior, nutritional markers (e.g., sodium, glucose, and cholesterol levels), and fluid intake of the patient with CKD using the app



**Figure 1.** PRISMA 2009 flow diagram.

(ii) Mobile application feasibility: Feasibility of application to use for patients and sustainability of use

(iii) User satisfaction: Satisfaction with the content/functionality of the application, suggestions/feedback for improvements

### Data Extraction

Data extraction was performed in duplicate (MD, AJ, KP, SR, SS, BS), with all data entries reviewed by a third reviewer (JM), and disagreements resolved through consultation with the study lead (SDK). A standardized data extraction spreadsheet was created and piloted by the review team. After piloting and further revision of the data extraction sheet, the following items were extracted: author; title; year of publication; journal in which the study was published; reviewer who extracted data; link from which the record was retrieved; intervention under study; sample size; number of sites; start date of the study; primary completion date of the study; study type; study design; study arms paper; primary objective/goals; secondary objectives/goals; whether the app provides dietary recommendations regarding carbohydrates, protein, fat, vitamins (A, D, E, K, B-complex), or minerals; whether the app provides a calorie-counting function;

whether the app provides personalized Dietary Reference Intake (DRI) values for users based on age; whether the app allows users to track their food intake (e.g., food diary); whether the app contains a section for healthy recipes; whether users found the app user-friendly; whether the app has been evaluated; how long the app has been in use; use of a data-monitoring committee; study sponsor; and clinical trial registry number. Although risk of bias assessment was planned, given the variable and largely exploratory nature of the study designs, no risk of bias assessment was conducted.

### Analysis

The level of agreement between reviewers was estimated using the kappa statistic. The characteristics, user satisfaction with, usability/feasibility, and effectiveness in changing dietary behavior of the mobile application were summarized using descriptive statistics and in a narrative manner.

## RESULTS

Of the 284 records retrieved, 13 full-text studies were admissible for the purposes of this evaluation based on

**Table 1.** Features of nutritional mobile applications for people living with chronic kidney disease ( $n = 9$ )

Features	<i>n</i>
Recommendations on macronutrients:	
Carbohydrates	0
Protein	7
Fat	0
Recommendations on micronutrients:	
Vitamins (e.g., A, D, E, K, B-complex)	0
Minerals (e.g., sodium, potassium, phosphorus, copper, zinc, iodine, selenium, fluoride)	8
Calorie-counting function	8
Personalized Dietary Reference Intake	7
Allows users to track their food intake (e.g., food diary)	9
Provides examples of healthy recipes	0

the inclusion criteria (see Figure 1 for PRISMA diagram).

### Characteristics of Included Studies

Eleven of the 13 included studies were single center. The mean sample size was 22.7 and ranged from 1 to 48 participants. Two of the 13 studies were industry funded, and 2 reported having a data-monitoring committee. Four of the included studies were needs assessment/design studies, 2 were case studies, 5 were nonrandomized pilot studies, and 2 were randomized pilot studies.

### Summary of Key Features of Mobile Applications

Reported features of the 9 studies testing a developed app varied widely: 8 allowed patients to track their food intake like a food diary, 7 had a calorie-counting function, 7 provided dietary recommendations regarding minerals, 6 provided dietary recommendations regarding protein, and 6 provided personalized DRIs. No apps contained a feature that recommended CKD-friendly recipes (see Table 1).

### Studies Focused on the Design of a Mobile Application for Patients With CKD to Monitor Their Own Dietary Intake

Of the 13 full-text articles included, 4 were design studies (i.e., did not evaluate an already developed app) (see Table 2).

Huby *et al.*<sup>9</sup> developed an online resource to provide reliable information and support to parents of children with CKD stages 3–5. Interviews were conducted for the purposed online application, and confirmed that such an application is needed and would be useful, especially if easily accessible (i.e., can be accessed on different platforms, regardless of device and location).

The objective of the study by Lin *et al.*<sup>10</sup> was to understand the needs of the CKD population they were working with to inform the creation of a personal mobile health diary using a simulated prototype. The primary goal of the mobile health diary was to improve communication channels between the patients and members of the health care team. Although all of the participants found the prototype easy to learn, they felt that if errors or system malfunctions arose, this might reduce the utility of the app.

Nightingale *et al.*<sup>11</sup> conducted a study in the pediatric population and facilitated interactive child-led interviews to gather user input to inform the development of a child-focused, efficient, cost-effective digital application that provides safe, supportive, and timely care management to children with CKD. According to their findings, gaps exist with current online information and support, and there is a need for reliable sources of CKD information tailored to engage and empower pediatric patients. Participant suggestions for an app included diverse colors and interactive games, as well as a decision-making tool for food/meal selection tailored to children.

**Table 2.** Studies focused on the design of a mobile application for patients with chronic kidney disease to monitor their own dietary intake

Author (yr) sample size	Primary goal of study	Main findings including desired features
Huby <i>et al.</i> <sup>9</sup> (2017) $n = 26$	Develop an online parent information and support internet application for parents of children with chronic kidney disease (CKD) stages 3–5 that is a trustworthy source of information; also provide support to children living with CKD	Participants indicated that an application would be useful if it can be accessed across many platforms regardless of where users were and on any device they choose to use.
Lin <i>et al.</i> <sup>10</sup> (2014) $n = 20$	Develop a mobile application to increase communication channels between patient and case management health care teams	All participants found the system prototype (paper-based) potentially easy to understand; however, participants were concerned about errors arising from system malfunctions.
Nightingale <i>et al.</i> <sup>11</sup> (2017) $n = 37$	To determine the desirable components for a child-focused and interactive child-led application to support home-based CKD management	Participants suggested an app that made use of colors and includes interactive games and a decision-making tool for food/meal selection, which may be more accessible and usable for children and young people, than an online resource.
Welch <i>et al.</i> <sup>12</sup> (2010) $n = 40$	Develop a Dietary Intake Monitoring Application for adults receiving hemodialysis to self-manage dietary intake regardless of health literacy levels	Participants indicated that a word associated with food icons helped to confirm dietary selections for the day. They also suggested that the use of more than 1 application/device, such as a scanner, would complicate the use of dietary self-management. Overall, participants indicated that the Dietary Intake Monitoring Application could be helpful and usable.

Welch *et al.*<sup>12</sup> described the computer, informational, numerical, and visual literacy considerations relevant to the development of a Dietary Intake Monitoring Application to facilitate self-management and improve clinical outcomes regardless of literacy levels. Forty participants of an urban inner-city hemodialysis facility were recruited to take part in this iterative participatory design approach. Participants were approached during scheduled dialysis appointments to discuss computer literacy for using an interactive app. In particular, items discussed included the ability to read and interpret informational, graphical, and numerical data within the app, and visual screenshots of these proposed components were shared with participants. The study found that having words associated with food icons helped patients confirm dietary selections for the day. They also found that the use of more than 1 application/device (such as a scanner) would complicate dietary self-management. Overall, participants indicated that the Dietary Intake Monitoring Application could be helpful and usable.

### Studies Focused on the Evaluation of a Mobile Application for Patients With CKD to Monitor Their Own Dietary Intake

Of the 9 studies noted that evaluated the mobile app in some way, 7 measured usability/feasibility, and all found some aspect of the applications feasible/useful. Among the 5 studies that measured changes in dietary behavior, all reported some positive change, although different measures were used (see Table 3).

### Case Studies

Examples of the impact of nutritional-based apps on CKD patient care and outcomes are reviewed. Sevick *et al.*<sup>13</sup> described a case study of one patient's self-monitoring using a Personal Dietary Assistant programmed with a software called BalanceLog. This was paired with dietary counseling based on social cognitive theory over the 16 weeks of intervention. This hemodialysis patient saw reductions in interdialytic weight gain, as well as intake of sodium, phosphorus, and potassium.

In an earlier study, Sevick *et al.*<sup>14</sup> conducted a case study in 5 hemodialysis patients to determine whether BalanceWise, an individualized dietary adherence enhancement program, could improve patients' adherence to CKD diet and reduce information burden associated with adhering to the hemodialysis dietary regimen. For a 4-month period, 5 patients received dietary counseling sessions based on social cognitive theory, as well as training on using Personal Dietary Assistants with BalanceWise. Serum albumin levels, phosphorus, and potassium levels and average monthly interdialytic weight gain were successfully monitored.

### Nonrandomized Pilot Studies

Connelly *et al.*<sup>15</sup> conducted a pilot study of 18 hemodialysis patients to assess the usability of a Dietary Intake Monitoring Application to assist with self-management of prescribed dietary regimens. Interdialytic weight gain was recorded 3 times per week and at study completion, 2 face-to-face questionnaires were administered to assess usability. All participants used a Dietary Intake Monitoring Application and agreed that the food icons were helpful in monitoring their dietary intake; however, 1 participant noted that feedback from the app was not easy to understand.

The pilot study by Cueto-Manzano *et al.*<sup>16</sup> aimed to determine whether mobile phone text messages would improve lifestyle, adherence, and clinical outcomes in 23 patients with CKD. When evaluated, users rated the usefulness of the text messaging application as 9.6 on a scale of 0 to 10.

Dowell and Welch<sup>17</sup> conducted a pilot study in 4 hemodialysis patients to record intake patterns of fluid, sodium, potassium, phosphorus, protein, and calories over a 3-month period using a Palm Pilot Zire 31 Personal Dietary Assistant, programmed with an application designed by Diet Mate Pro. Patients in this pilot study were compliant with their recommended dietary regimen. The fluid, sodium, potassium, and phosphorus intakes of these patients fell within the recommended intakes, whereas 3 of the 4 patients fell below the suggested intake for calories and protein.

Welch *et al.*<sup>18</sup> conducted a pilot study among 4 patients with CKD to test the feasibility of a Palm Personal Dietary Assistant programmed with software DietMate Pro to electronically self-monitor fluid and dietary intake (calories, sodium, phosphorus, potassium, and protein) over 3 months. Although participants found the Personal Dietary Assistant to be helpful in creating shopping lists and developing weekly menus, they had navigation difficulties 33% of the time, especially when trying to find specific food items. Participants also found the font to be too small, and had difficulties in using the stylus pen of the Palm Personal Dietary Assistant. Compliance for capturing each meal after eating ranged from 22% to 31%.

Welch *et al.*<sup>19</sup> conducted a pilot study of 44 hemodialysis patients to examine the feasibility of using the Dietary Intake Monitoring Application to help design a randomized trial with sufficient power to assess changes in intradialytic weight gain, changes in self-efficacy, perceived benefits, and perceived control. Twenty-four participants were assigned to the Dietary Intake Monitoring Application and 20 were assigned to a Daily Activity Monitoring Application (i.e., does not monitor dietary intake). Data collection in both the

**Table 3.** Studies focused on the evaluation of a mobile application for patients with CKD to monitor their own dietary intake

Author (yr) sample size	Description of mobile application	Goal of the application	Feasibility/user satisfaction	Dietary/behavioral change
<b>Case study</b>				
Sevick <i>et al.</i> <sup>14</sup> (2005) <i>n</i> = 5 Adult hemodialysis (HD) patients	A behavioral intervention based on social cognitive theory to enhance self-efficacy, paired with a dietary self-monitoring PDA with BalanceWise software	To improve patients' adherence to chronic kidney disease (CKD) diet and reduce information burden associated with adhering to the HD dietary regimen	Not reported	<ul style="list-style-type: none"> <li>• 4/5 study participants had an increase in serum albumin level.</li> <li>• 4/5 participants experienced a small increase in serum phosphorus level.</li> <li>• Mixed results with regard to serum potassium and average monthly interdialytic weight gain</li> </ul>
Sevick <i>et al.</i> <sup>13</sup> (2008) <i>n</i> = 1 Adult HD patient	A PDA programmed with BalanceLog software for self-monitoring paired with dietary counseling based on social cognitive theory	To help patients evaluate content of foods, track their dietary intake, and evaluate the percentage of dietary targets achieved by meal; ultimately to reduce interdialytic weight gain and increase adherence to a complex kidney diet	<ul style="list-style-type: none"> <li>• The participant was highly compliant.</li> <li>• The intervention did not place a high burden on the participant.</li> </ul>	<ul style="list-style-type: none"> <li>• Reduction in sodium intake</li> <li>• Reduction in interdialytic weight gain</li> <li>• Alleviation of hyperphosphatemia</li> <li>• Alleviation of hyperkalemia</li> </ul>
<b>Pilot study (nonrandomized)</b>				
Connelly <i>et al.</i> <sup>15</sup> (2012) <i>n</i> = 18 Adult HD patients	Dietary Intake Monitoring Application is a mobile application that uses touch-screen, visual interfaces, barcode scanning, and voice recording.	To help patients self-manage dietary intake regardless of health literacy levels	<ul style="list-style-type: none"> <li>• 14/18 users reported ease of finding food using icon interface.</li> <li>• 6/18 used voice recordings.</li> <li>• 15/18 used disease-specific interface components.</li> <li>• 18/18 reported that feedback icons were useful in monitoring dietary intake.</li> <li>• 10/18 reported difficulty finding a food the first time using the scanning feature.</li> <li>• 15/18 reported it easier to find the same item the next time.</li> </ul>	Not reported
Cueto-Manzano <i>et al.</i> <sup>16</sup> (2015) <i>n</i> = 23 CKD patients older than 14	Mobile phone text messages generated by a multidisciplinary group of experts in nephrology, internal medicine, family medicine, general medicine, and nutrition about kidney disease risk factors, medical alert information, healthy diet and lifestyle, as well as recommendations to improve adherence to treatment and attendance of follow-up appointments	To improve lifestyle, treatment adherence, and clinical outcomes in patients with kidney disease	<ul style="list-style-type: none"> <li>• Participants rated the usefulness of the text messages (on a 0–10 scale) as 9.6 (SD 0.7).</li> <li>• Medication reminders as 9.8 (SD 0.5)</li> <li>• Appointment reminders as 9.8 (SD 0.6) <ul style="list-style-type: none"> <li>• Perceived the tool as helpful</li> <li>• Considered that it could be implemented widely</li> </ul> </li> </ul>	Not reported
Dowell <i>et al.</i> <sup>17</sup> (2006) <i>n</i> = 4 Adult HD patients	PDA, Palm Pilot Zire 31, with application designed by Diet Mate Pro in which participant inputted dietary and fluid intake	To test the feasibility of the intervention to electronically self-monitor dietary (calories, sodium, phosphorus, potassium, and protein) and fluid intake over 3 months	Not reported	<ul style="list-style-type: none"> <li>• Participants were fairly adherent to their dietary intake of measured micronutrients and fluid.</li> <li>• Reduced intake of protein and calories <ul style="list-style-type: none"> <li>• Dietary and fluid intake varied considerably over 3 months.</li> </ul> </li> </ul>
Welch <i>et al.</i> <sup>18</sup> (2007) <i>n</i> = 4 Adult HD patients	Electronic self-monitoring diary, Palm PDAs (Zire 31) that were programmed with software designed to collect diet and fluid information (DietMate Pro)	To collect diet and fluid information	<ul style="list-style-type: none"> <li>• Participants found the PDA to be helpful in making shopping lists and developing weekly menus.</li> <li>• A total of 33% had navigation difficulties, especially in trying to find specific food items.</li> <li>• Found the font to be too small</li> <li>• Had difficulties in using the stylus pen part of the Palm hardware</li> <li>• Actual compliance for capturing each meal after eating ranged from 22% to 31%</li> </ul>	Not reported

**Table 3.** (Continued)

Author (yr) sample size	Description of mobile application	Goal of the application	Feasibility/user satisfaction	Dietary/behavioral change
Welch <i>et al.</i> <sup>19</sup> (2013) <i>n</i> = 44 Adult HD patients	The Dietary Intake Monitoring Application based on mobile technology to facilitate self-monitoring for patients	To assess changes in intra-dialytic weight gain and self-efficacy, perceived benefits, and perceived control	<ul style="list-style-type: none"> <li>• Patients using Dietary Intake Monitoring Application had higher perceived control than participants assigned to Daily Activity Monitoring Application.</li> <li>• On a scale of 1–5, the mean acceptability score in the Dietary Intake Monitoring Application group was 3.93.</li> </ul>	<ul style="list-style-type: none"> <li>• No changes in interdialytic weight gain</li> <li>• Decrease in calories, sodium intake, and protein using Dietary Intake Monitoring Application</li> </ul>
Pilot studies (randomized)				
Koprucki <i>et al.</i> <sup>20</sup> (2010) <i>n</i> = 26 PD patients	An individualized PDA with BalanceLog software which delivers counseling and feedback based on the daily dietary targets	To determine if adhering to an individualized PDA dietary program would reduce sodium intake	<ul style="list-style-type: none"> <li>• A total of 86.7% of intervention participants said they would use the PDA with BalanceLog to self-monitor their diets.</li> </ul>	<ul style="list-style-type: none"> <li>• Reduction in sodium (187 mg in intervention vs. 44 mg in control)</li> </ul>
Stark <i>et al.</i> <sup>21</sup> (2011) <i>n</i> = 48 HD and PD patients	PDA, PalmOne Tungsten/e2 PDAs programmed with BalanceLog software by MicroLife	To determine whether a PDA, PalmOne Tungsten/e2 PDAs programmed with BalanceLog software by MicroLife can moderate sodium intake in patients over a 16-week period	<ul style="list-style-type: none"> <li>• On average, HD patients entered 244.9 meals.</li> <li>• PD patients averaged 212.1 meals.</li> <li>• The intervention is feasible and may be useful for assisting dialysis patients in adhering to a complex dietary regimen.</li> </ul>	Not reported

CKD, chronic kidney disease; HD, hemodialysis; PD, peritoneal dialysis; PDA, Personal Dietary Assistant.

control and intervention groups occurred during patient visits at 2 urban outpatient dialysis units at baseline, 6 weeks, and 8 weeks after study completion (14 weeks after baseline). No changes in interdialytic weight gain were seen in either group, but users of the Dietary Intake Monitoring Application did see a decrease in calories, sodium intake, and protein. At the end of the self-monitoring period, patients using Dietary Intake Monitoring Application were found to have higher perceived control than participants assigned to Daily Activity Monitoring Application. On a scale of 1 to 5, the mean acceptability score in the Dietary Intake Monitoring Application group was 3.93.

### Randomized Pilot Studies

Koprucki *et al.*<sup>20</sup> conducted a randomized controlled trial of 26 peritoneal dialysis patients over 4 months to determine if adhering to an individualized Personal Dietary Assistant dietary program with BalanceLog software would reduce sodium intake. Participants in both groups received computer-based, dietary education. Participants in the intervention arm also received counseling and feedback based on the daily dietary targets from the Personal Dietary Assistant dietary program. Outcomes were measured at baseline and at 4 months. Those using the Personal Dietary Assistant were able to reduce their sodium intake by 187 mg, whereas patients assigned to the control group saw an increase in sodium intake of 44 mg. Most (86.7%) participants in the intervention group said they would use the Personal Dietary Assistant to self-monitor their diets.

Stark *et al.*<sup>21</sup> conducted 2 randomized trials of 48 patients, 22 hemodialysis patients, and 30 peritoneal dialysis patients to determine whether a Personal Dietary Assistant, PalmOne Tungsten/e2 Personal Dietary Assistant, programmed with BalanceLog software by MicroLife could moderate sodium intake in hemodialysis and peritoneal dialysis patients over a 16-week period. On average, hemodialysis patients entered 244.9 meals, whereas peritoneal dialysis patients inputted an average of 212.1 meals during the intervention period. Study findings suggest that the intervention is feasible and may be useful for assisting dialysis patients in adhering to a complex dietary regimen.

## DISCUSSION

Given the complexity of managing diet in CKD, there is a need for interventions that can not only help patients navigate daily challenges but that could also be integrated into clinical practice to support the work of dietitians and other health care providers. This systematic review aimed to examine the characteristics, user satisfaction with, feasibility of, and effectiveness in changing dietary behavior of mobile app interventions in patients with CKD. Eleven of the 13 included studies were single center and all were relatively small, with a mean sample size of approximately 23. The most common mobile application feature was allowing patients to track their food intake like a food diary. Interventions varied from more general text messaging applications to specialized applications, such

as Dietary Intake Monitoring Applications and Personal Dietary Applications. In the 7 studies that measured app usability/feasibility, all found at least some aspects of the application feasible/useful; however, a few studies noted the difficulty some end-users experienced with using their assigned application/device. Noncompliance was a commonly reported issue. Of the 5 studies that evaluated changes in behavior/diet related to self-management, all reported some positive change, particularly with respect to sodium intake.

Our findings indicate that a mobile application focused on engaging patients and encouraging healthy self-management of CKD may be helpful in improving adherence to dietary restrictions pertaining to sodium, potassium, phosphorus, protein, calories, and fluid. Our findings are consistent with those of Campbell and Porter,<sup>2(p750)</sup> who found in their systematic review of 5 studies that there is “potential for clinical benefits of dietary mobile app interventions in a CKD population.” In addition to helping individuals living with CKD, mobile apps also can serve as a knowledge translation tool to provide friends and family members with trustworthy information about CKD, particularly with respect to pediatric populations, as identified by Nightingale *et al.*<sup>11</sup>

This systematic review has several limitations that are important to acknowledge. The search was restricted to English-language studies and some relevant studies therefore may not have been found. Among included studies, there was a lack of randomized controlled trials. Most included studies were pilot studies, which are largely exploratory in nature. The time frame of included studies was often short (less than 6 months). Some of the apps used are not currently available (e.g., were used on Palm Pilots), so although proof of concept was demonstrated, those apps evaluated in the study are out of date. Because of the wide range of study designs and outcome measures, a meta-analysis could not be conducted. Therefore, definitive conclusion of the efficacy of mobile apps for CKD dietary management cannot be drawn. Finally, although reporting quality of included pilot trials was assessed, the quality of the study conduct itself could not be evaluated due to a lack of validated measures for this purpose.

## CONCLUSION

This systematic review found that development and testing of apps was often informed by not only behavioral/dietary outcomes, but also patient-reported usability/feasibility. Future research is required to study apps in pediatric and adolescent populations, how to address different types of learning styles to

effectively use apps, and how (and to what extent) apps can complement the work of health care provider teams to optimize dietary adherence. The results of the included pilot studies provide a foundation for future research, which should use more rigorous study design and study larger and more diverse samples.

## DISCLOSURE

All the authors declared no competing interests.

## ACKNOWLEDGMENTS

The publication fee for this study was funded by Kidney CARE Network International.

The first 8 listed authors, SDK, JM, MD, AJ, KP, SR, SS, and BS, as well as the senior author, CEL, are all members of the research arm of a volunteer organization, Kidney CARE Network International. With the exception of the aforementioned support received for the publication fee, no direct funding was received for this study. No funding bodies had any role in the study design, data collection, analysis, decision to publish, or preparation of the published paper.

## SUPPLEMENTARY MATERIAL

### PRISMA 2009 checklist.

Supplementary material is linked to the online version of the paper at [www.kireports.org](http://www.kireports.org).

## REFERENCES

1. Arora P, Vasa P, Brenner D, et al. Prevalence estimates of chronic kidney disease in Canada: results of a nationally representative survey. *CMAJ*. 2008;185:E417–E423.
2. Campbell J, Porter J. Dietary mobile apps and their effect on nutritional indicators in chronic renal disease: a systematic review. *Nephrology*. 2015;20:744–751.
3. Grist R, Porter J, Stallard P. Mental health mobile apps for preadolescents and adolescents: a systematic review. *J Med Internet Res*. 2017;19:e176.
4. De Cock N, Vangeel J, Lachat C, et al. Use of fitness and nutrition apps: associations with body mass index, snacking, and drinking habits in adolescents. *JMIR Mhealth Uhealth*. 2017;5:e58.
5. Majeed-Ariss R, Baildam E, Campbell M, et al. Apps and adolescents: a systematic review of adolescents' use of mobile phone and tablet apps that support personal management of their chronic or long-term physical conditions. *J Med Internet Res*. 2015;17:e287.
6. Donker T, Petrie K, Proudfoot J, et al. Smartphones for smarter delivery of mental health programs: a systematic review. *J Med Internet Res*. 2013;15:e247.
7. Franco RZ, Fallaize R, Lovegrove JA, Hwang F. Popular nutrition-related mobile apps: a feature assessment. *JMIR Mhealth Uhealth*. 2016;4:e85.
8. Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med*. 2009;6:e1000097.



9. Huby K, Swallow V, Smith T, Carolan I. Children and young people's views on access to a web-based application to support personal management of long-term conditions: a qualitative study. *Child Care Health Dev.* 2017;43:126–132.
10. Lin HW, Wang YJ, Jing LF, Chang P. Mockup design of personal health diary app for patients with chronic kidney disease. *Stud Health Technol Inform.* 2014;201:124–132.
11. Nightingale R, Hall A, Gelder C, et al. Desirable components for a customized, home-based, digital care-management app for children and young people with long-term, chronic conditions: a qualitative exploration. *J Med Internet Res.* 2017;19:e235.
12. Welch JL, Siek KA, Connelly KH, et al. Merging health literacy with computer technology: self-managing diet and fluid intake among adult hemodialysis patients. *Patient Educ Couns.* 2010;79:192–198.
13. Sevick MA, Stone RA, Novak M, et al. A PDA-based dietary self-monitoring intervention to reduce sodium intake in an in-center hemodialysis patient. *Patient Prefer Adherence.* 2008;2:177–184.
14. Sevick MA, Piraino B, Sereika S, et al. A preliminary study of PDA-based dietary self-monitoring in hemodialysis patients. *J Ren Nutr.* 2005;15:304–311.
15. Connelly K, Siek KA, Chaudry B, et al. An offline mobile nutrition monitoring intervention for varying-literacy patients receiving hemodialysis: a pilot study examining usage and usability. *J Am Med Inform Assoc.* 2012;19:705–712.
16. Cueto-Manzano AM, Gallardo-Rincón H, Martínez-Ramírez HR, et al. A pilot study of a mobile phone application to improve lifestyle and adherence of patients with kidney disease. *J Telemed Telecare.* 2015;21:119–120.
17. Dowell SA, Welch JL. Use of electronic self-monitoring for food and fluid intake: a pilot study. *Nephrol Nurs J.* 2006;33:271.
18. Welch J, Dowell S, Johnson CS. Feasibility of using a personal digital assistant to self-monitor diet and fluid intake: a pilot study. *Nephrol Nurs J.* 2007;34:43.
19. Welch JL, Astroth KS, Perkins SM, et al. Using a mobile application to self-monitor diet and fluid intake among adults receiving hemodialysis. *Res Nurs Health.* 2013;36:284–298.
20. Koprucki M, Piraino B, Bender F, et al. 162: RCT of personal digital assistant supported dietary intervention to reduce sodium intake in PD. *Am J Kidney Dis.* 2014;55:B72.
21. Stark S, Snetselaar L, Piraino B, et al. Personal digital assistant-based self-monitoring adherence rates in 2 dialysis dietary intervention pilot studies: BalanceWise-HD and BalanceWise-PD. *J Ren Nutr.* 2011;21:492–498.