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Utilization of Mobile Health Technologies in Chronic Kidney Disease Management: A Scoping Review

Angger Anugerah Hadi Sulistyo[1], Ikha Ardianti[1], Errix Kristian Julianto[1], Ferawati Ferawati[1], Haris Suhamdani[2]

[1] Nursing Department, Faculty of Health, ISTeK Insan Cendekia Husada Bojonegoro, Indonesia
[2] Nursing Department, Faculty of Medicine, Universitas Mulawarman, Samarinda, Indonesia

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CORRESPONDING AUTHOR
Angger Anugerah Hadi Sulistyo
angger.anugerah@gmail.com
Nursing Department, Faculty of health, ISTeK Insan Cendekia Husada Bojonegoro, Indonesia

ABSTRACT

Introduction: The increasing prevalence of chronic kidney disease (CKD) necessitates innovative approaches to enhance patient care and management. Mobile health (mHealth) technologies have emerged as promising tools for improving health outcomes through remote monitoring, patient engagement, and data-driven decision-making. This scoping review aims to explore the utilization of mHealth technologies in the management of CKD.

Methods: A comprehensive literature search was conducted across multiple databases, including PubMed/Medline, ProQuest, and DOAJ, focusing on studies published in the last decade. The inclusion criteria encompassed articles that evaluated mHealth interventions specifically designed for CKD management. Key outcomes were categorized into patient adherence, clinical outcomes, patient satisfaction, and cost-effectiveness.

Results: The review identified diverse mHealth applications, including mobile apps, wearable devices, and telehealth platforms, demonstrating potential benefits in improving medication adherence, monitoring disease progression, and enhancing patient-provider communication. Despite promising results, challenges such as data privacy, technological literacy, and integration with existing healthcare systems were noted.

Conclusion: This review underscores the need for further research to optimize mHealth interventions and address barriers to widespread implementation in CKD management.

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1. INTRODUCTION

Chronic kidney disease (CKD) is defined as kidney damage or a glomerular filtration rate (GFR) of less than 60 ml/min/1.73 m^2 for more than three months, regardless of the cause (Vaidya & Aeddula, 2024). CKD is a condition in which kidney function gradually declines, eventually requiring renal replacement therapy such as dialysis or transplantation. Kidney damage can be in the form of abnormalities detected by imaging or kidney biopsy, abnormalities in the urine sediment, or increased urinary albumin excretion (Kalantar-Zadeh et al., 2021). The 2012 KDIGO classification divides CKD into six stages based on GFR and three levels of albuminuria based on the urinary albumin-creatinine ratio (KDGIO, 2024). The main causes of CKD include type 2 diabetes, hypertension, glomerulonephritis, and polycystic kidney disease (Kakitapalli et al., 2020; Kovesdy, 2022; Siddiqui et al., 2022). There has been an increase in the prevalence of CKD globally (Liyanage et al., 2022).

Globally, the prevalence of chronic kidney failure is estimated to be more than 10% of the general population, which is equivalent to approximately 843.6 million individuals diagnosed with various stages. The global prevalence of CKD ranges from 7.0% to 34.3%, with significant variation across countries. These data indicate that up to approximately 434.3 million adults in Asia suffer from CKD, with the majority of cases found in China and India (Liyanage et al., 2022). Basic Health Research (Riskesdas) data in 2018 showed that the prevalence of Indonesian people suffering from Chronic Kidney Failure was 0.38% (Kemenkes, 2021). Meanwhile, the prevalence of CKD in East Java is higher than the national average, reaching around 14.3%. This high figure is largely due to risk factors such as diabetes and hypertension which are quite high. According to data from Riskesdas, there are around 23,688 cases of kidney failure in South Sumatra, with 17.79% of these patients undergoing hemodialysis (Riskesdas Sumatera Selatan, 2020).

The main cause of CKD is diabetes mellitus, especially type 2 diabetes, which damages the small blood vessels in the kidneys, thereby disrupting their ability to filter blood effectively (Hussain et al., 2021). In addition, hypertension or high blood pressure is also a major risk factor, because it can damage blood vessels in the kidneys and accelerate the decline in kidney function. Glomerulonephritis, which is inflammation of the glomeruli (small filtering units in the kidneys), also contributes significantly to the development of CKD. Polycystic kidney disease, a genetic condition that causes cysts to form in the kidneys, can damage kidney tissue and reduce its function (Casarella et al., 2022; Walther et al., 2020; Yarlioglu et al., 2023; Zhang et al., 2022). In addition, several other chronic kidney diseases, such as chronic interstitial nephritis and reflux nephropathy, also play a role in the development of CKD. Additional risk factors include advanced age, obesity, smoking, family history of kidney disease, recurrent kidney infections, and autoimmune diseases such as lupus (Kalantar-Zadeh et al., 2021).

There are various approaches to monitoring CKD patients. Monitoring of CKD patients can be done through manual and digital methods, each with its own advantages and challenges. Manual monitoring involves regular visits to a health facility for physical examinations and laboratory tests, where patients undergo blood tests to monitor creatinine levels, electrolytes, and overall kidney function (Rossing et al., 2022). On the other hand, digital monitoring utilizes technology such as health applications and wearable devices to monitor patient conditions in real-time, allowing patients to track symptoms, remind them when to take their medication, and send health data to doctors without having to make a physical visit (Li et al., 2020).

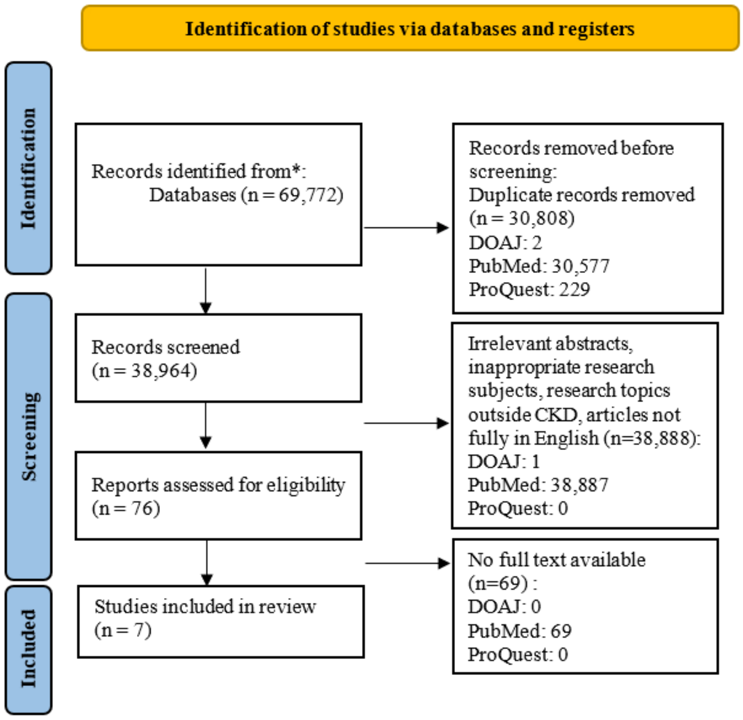

Figure 1: PRISMA flow diagram. PRISMA, Preferred Reporting Items for Systematic Review and Meta-Analysis

The high rate of chronic kidney failure in the world has caused multidisciplinary sciences to prepare a monitoring system that makes it easier for patients. The use of Application-Based Health Technology is considered necessary to improve monitoring of CKD patients. Health Technology in the current era may have been widely used. However, literature studies related to its utilization need to be studied more deeply. Therefore, researchers are interested in studying literature related to Health technology in the form of applications used in CKD patients.

2. METHODS

Study Design

A comprehensive scoping review to Utilization of Mobile Health Technologies in Chronic Kidney Disease Management

Population, Samples, and Sampling

Table 1. Literature found on Database

Database	Keyword	Articles found	Eligible articles forwarded to review process
ProQuest	smartphone application OR mobile application AND management OR monitoring AND chronic kidney failure OR chronic kidney disease	230	1
PubMed	smartphone application OR mobile application AND management OR monitoring AND chronic kidney failure OR chronic kidney disease	69.539	6
DOAJ	smartphone application OR mobile application AND management OR monitoring AND chronic kidney failure OR chronic kidney disease	3	0
Total		69.772	7

An initial search found a total of 69.772 articles. However, 30.808 articles were removed from the records due to duplication. Based on checking the suitability of the titles and abstracts, 38.888 articles were removed from the data record. As shown in Table 1, the total number of articles excluded from the review was 69.765 articles.

Instruments

Instruments used for this research was the scoping review guideline developed by Mak and Thomas (Mak & Thomas, 2022). Additionally, databases such as PubMed, ProQuest, and DOAJ used to identify relevant studies.

Procedure

Step 1: Identifying the research question

The review aimed to answer the following question: "What evidence is available regarding utilization of mobile health technologies in chronic kidney disease management"?

Step 2: Identifying Relevant Studies

The following databases were used in the search: PubMed/Medline, ProQuest, and DOAJ. MeSH (Medical Subject Heading) was used to determine the vocabulary used. The following search terms were used: smartphone application OR mobile application AND management OR monitoring AND chronic kidney failure OR chronic kidney disease. In addition, only articles available and published after January 1, 2018 were included. Only articles published in English and were potentially relevant to the topic were reviewed. Figure 1 summarizes the literature search and study selection process. In July 2023, researchers conducted a literature search and found 7 RCT articles (Table 1).

STEP 3: Selecting Studies to Be Included in the Review

The inclusion criteria were 1) clinical trial published between 2018 to 2024; 2) mobile application program; 3) population of patients with CKD; and 4) articles published in English language. The articles that did not mention about CKD and the utilization of mobile application.

Step 4: Charting the Data

The information derived from the studies included in the analysis was organized into a Table following the guidelines outlined in scoping review steps developed by Mak and Thomas(Mak & Thomas, 2022). This table encompasses details from each article, including author, title, methodology, outcome measured and main finding (Table 1).

Step 5: Collating, Summarizing, and Reporting the Results

3. RESULTS AND DISCUSSION

The methodologies used in the studies in this document vary, but generally involve randomized controlled trials and smartphone app-based approaches to support self-management in patients with chronic kidney disease (CKD). For example, a study by Pack & Lee, (2021) used a single-blind randomized controlled trial with 75 hemodialysis patients, who followed an app-based dietary self-management program for 8 weeks. The study measured biochemical indicators such as serum phosphorus and potassium, as well as patients' quality of life using the KDQOL-SF instrument. In addition, Li et al., (2020) adopted a similar approach with a health mobile app integrated with social media to support self-management, with measurements of kidney function through serum creatinine levels and eGFR. A study by Khoury et al used a prospective pilot approach with the KELA.AE app, which provided educational materials and self-monitoring features (Khoury et al., 2020), while Chang et al. combined remote dietary counseling via a smartphone app with weekly phone calls from a dietitian (Chang et al., 2020).

Other studies, such as that by Nuala Doyle and colleagues, used a single-group pre-post design to evaluate the effects of the MiKidney app on physical activity and physiological parameters. These studies suggest that a smartphone app-based intervention can improve self-management, quality of life, and other health parameters in patients with CKD. The studies discussed in the document used a variety of samples that included populations with chronic kidney disease (CKD) and hemodialysis patients. The study by Chang et al. involved 16 patients with CKD stages 1-3a from central/northeast Pennsylvania. Pack & Lee used a larger sample size of 75 hemodialysis patients who met inclusion criteria in a randomized controlled trial (Pack & Lee, 2021). The MiKidney study by Nuala Doyle and colleagues used 23 participants in a single-group pre-post design,

Table 2. Intervention using mobile application on CKD patients

Authors	Title	Methodology	Intervention	Outcome measured	Main findings
(Pack & Lee, 2021)	Randomised controlled trial of a smartphone application-based dietary self-management program on haemodialysis patients	1) Prospective, single-blind, randomized controlled trial with repeated measures 2) 75 haemodialysis patients meeting inclusion criteria	The intervention in this study is an 8-week smartphone application-based dietary self-management program for haemodialysis patients. The program included an introduction phase (week 1), a practice phase (weeks 2-4), and a maintenance phase (weeks 5-8). Participants received 30-minute training sessions 3 days per week, including both face-to-face training at the haemodialysis center and online counseling using smartphones. The program provided real-time feedback on simulated biochemical values based on the participants' food selections, and participants received feedback on their diet plans based on regular blood tests.	1) Biochemical indicators: serum phosphorus (mg/ml), serum potassium (mEq/L), and serum albumin (mg/ml) 2) Self-efficacy, measured using a 15-item dietary self-efficacy questionnaire for haemodialysis patients 3) Quality of life, measured using the Kidney Disease Quality of Life-Short Form (KDQOL-SF) instrument	1) The smartphone application-based dietary self-management program lowered serum potassium and phosphorus and improved self-efficacy and quality of life in haemodialysis patients over time. 2) The program assists effective dietary self-management from the patient's side and aids provision of high-quality nursing care based on individual lifelog data from the medical team's side, thereby contributing to improving overall health and quality of life of haemodialysis patients.
(Li et al., 2020)	Mobile Health App With Social Media to Support Self-Management for Patients With Chronic Kidney Disease: Prospective Randomized Controlled Study	The methodology of this study involved a randomized controlled trial with an intervention group and a control group.	1) Wearable devices (Heart Rate Smart Wristband) that collected exercise-related data such as steps, calories, and sleep 2) A smartphone app (WowGoHealth) to connect with a health management platform (GSH AI health platform) where participants' exercise data was uploaded 3) A social media platform (LINE app) where a group was created to deliver medical knowledge	1) Self-efficacy scores 2) Self-management scores 3) Quality of life as measured by the Kidney Disease Quality of Life survey (KDQOL-SF) 4) Renal function as measured by serum creatinine and estimated glomerular filtration rate (eGFR)	1) The intervention group showed significantly higher self-efficacy and self-management scores compared to the control group after the 90-day intervention. 2) The intervention group had a significantly slower decline in estimated glomerular filtration rate

Authors	Title	Methodology	Intervention	Outcome measured	Main findings
			about diet and exercise 4) Dietary and exercise suggestions provided to the intervention group only This intervention was provided to the intervention group over a 90-day period.		(eGFR) compared to the control group.
(Khoury et al., 2020)	A Dietary Mobile App for Patients Undergoing Hemodialysis: Prospective Pilot Study to Improve Dietary Intakes	Prospective pilot study conducted at a hemodialysis unit in Sharjah, UAE	1) The intervention in this study was the use of the KELA.AE mobile app, which provided educational materials and self-monitoring features, along with weekly meetings with a dietitian for 2 weeks. 2) All eligible patients at the unit were considered for enrollment - Inclusion criteria included being on hemodialysis for ≥3 months, free of life-threatening conditions, able to use a smartphone, and not recently hospitalized 3) Participants used a dietary mobile app called KELA.AE that was developed using a person-centered, theory-based approach - Participants met with a dietitian once a week for 2 weeks - Outcomes were measured at baseline (T0) and 2 weeks post-app usage (T1)	1) Dietary intakes of energy (kcal/kg/day), carbohydrates, proteins (g/kg/day), high biological value (HBV) proteins (%), total fat, potassium (mg/day), phosphorus (mg/day), and sodium (mg/day) 2) Serum levels of phosphorus (mg/dL), potassium (mEq/L), and iron (mg/dL)	1) The dietary intervention using the KELA.AE app had the potential to improve dietary intakes of energy and protein among patients undergoing hemodialysis. 2) The intervention also improved the intake of high biological value (HBV) proteins. 3) Sodium intake decreased during the intervention.
(Chang et al., 2020)	Remote Dietary Counseling Using Smartphone Applications in Patients With Stages 1-3a Chronic Kidney Disease: A Mixed Methods Feasibility Study	The methodology of this study was a pre-post, mixed methods feasibility study of 16 patients with Stage 1-3a chronic kidney disease (CKD) in central/northeast Pennsylvania.	1) Weekly 15-20 minute telephone counseling sessions with a registered dietitian nutritionist (RDN) who used motivational interviewing for 8 weeks. 2) Daily dietary data entry using either a customized study-specific smartphone application or the commercially available	1) Difference in sodium intake (mg/day) from baseline to end of intervention 2) Difference in sodium excretion (mg/day) from baseline to end of intervention	1) The remote dietary counseling program using smartphone apps and weekly calls with a registered dietitian was feasible and well-accepted by patients with early chronic kidney disease. 2) The program was associated

Authors	Title	Methodology	Intervention	Outcome measured	Main findings
			MyFitnessPal application. 3) Incentives in the form of weekly virtual lottery tickets for two $100 gift certificates for entering at least 5 days of dietary data per week. Patients recorded and shared dietary data via smartphone applications, with registered dietitians providing weekly telephone counseling using motivational interviewing for 8 weeks. Seven patients used a customized study-specific application, while nine used the commercially available MyFitnessPal app. Participant satisfaction was assessed via survey and semistructured interviews. The outcomes evaluated included sodium intake, Healthy Eating Index 2015 score, weight, and 24-hour blood pressure.		with improvements in dietary sodium intake, dietary quality, blood pressure, and weight.
(Doyle et al., 2019)	The "Mikidney" Smartphone App Pilot Study: Empowering Patients With Chronic Kidney Disease	1) Single-group pre-post study design - 12-week intervention using the MiKidney app 2) Sample size of 23, with 3 withdrawals	The intervention in this study was the use of the MiKidney smartphone app over a 12-week period. All participants received the app, which included features like recording personal/medical details, providing information on CKD, an exercise tracker, reminder alerts, a note-taking section, and a feedback/scoring system. Participants were also provided with a smartphone and instructions on how to use the app.	1) Physical activity, measured using the International Physical Activity Questionnaire (long form) (IPAQ-LF) and reported as MET-min/week 2) Functional exercise capacity, measured using the six-minute walking test (6MWT) 3) Body measurements including weight, waist	1) There was significant improvement in physical activity, cholesterol levels, and body composition measures among participants using the MiKidney app. 2) The majority of participants found the MiKidney app easy to navigate, suggesting good usability and acceptability. 3) Using the MiKidney app was a positive experience, with participants

Authors	Title	Methodology	Intervention	Outcome measured	Main findings
				circumference, and body fat 4) Blood parameters including total cholesterol and LDL cholesterol	more likely to adhere to a renal diet, take medication as prescribed, exercise regularly, and have a better understanding of their condition.
(Sobrinho et al., 2018)	Design and evaluation of a mobile application to assist the self-monitoring of the chronic kidney disease in developing countries	- In-depth interviews and prototyping with healthcare professionals to elicit requirements	Not mentioned (the paper does not describe any specific intervention that participants received)	1) The agreement between the app and three nephrologists in evaluating the CKD stage and renal damage risk of patients 2) The usability and user perceptions of the app	A mobile health app was designed to assist the early diagnosis and self-monitoring of chronic kidney disease, with a substantial degree of agreement with nephrologists in evaluating CKD stage and risk. The app showed good user satisfaction in usability testing, though some users had difficulty understanding the meaning of specific biomarkers like creatinine.
(Min & Park, 2020)	Effects of a Mobile-App-Based Self-Management Support Program For Elderly Hemodialysis Patients	1) Nonequivalent control-group non-synchronized design 2) Sample size calculated using G*Power 3.1 program, with 40 total participants (20 per group) and additional 10 per group for potential dropouts	1) A mobile app with a feedback system for blood test results, dry weight, and weight gain visualization 2) Standardized messaging service with templates developed in consultation with medical experts 3) Appointment reminders for regular blood tests 4) Weekly entry of interdialytic weight gain with feedback messages on test results, complications, and dietary restrictions 5) Sending blood test results via smartphone with graphical display of changes	1) Sick-role behavior adherence 2) Basic psychological needs 3) Self-efficacy 4) Physiological parameters: - Serum phosphate level - Serum potassium level - Interdialytic weight gain rate (IWGR)	1) The mobile-app-based self-management support program significantly improved the sick-role behavior adherence, basic psychological needs, and self-efficacy of elderly hemodialysis patients. 2) However, the program did not significantly improve the physiological parameters (serum phosphate, serum potassium, and interdialytic weight gain rate) of the elderly hemodialysis patients.

with three participants dropping out before completion.

Meanwhile, the study by Li et al. involved participants using a mobile health app with social media to support self-management, although the specific sample size was not mentioned. These studies showed variation in sample size and type, covering different stages of CKD and different healthcare settings.

The intervention procedures implemented in these studies included the use of smartphone applications and technology-based approaches to support self-management in patients with chronic kidney disease (CKD). The study by Pack & Lee used an 8-week app-based dietary self-management program, which involved intensive training in the first week and the use of an app to monitor food intake and provide feedback based on blood test results (Pack & Lee, 2021). Li et al. implemented a mobile health application integrated with social media and wearable devices to monitor physical activity, provide diet and exercise advice for 90 days, and measure the effectiveness of the intervention through self-efficacy, self-management, and kidney function scores (Li et al., 2020). Khoury et al. tested the KELA.AE mobile application that provides educational materials and self-monitoring features, accompanied by weekly meetings with a dietitian for 2 weeks for hemodialysis patients (Khoury et al., 2020).

Meanwhile, Chang et al. utilized remote dietary counseling via a smartphone application, combined with motivational interviews by a registered dietitian every week for 8 weeks (Chang et al., 2020). The MiKidney study by Nuala Doyle et al. added features such as physical activity logging, medication reminders, and diet tracking, with results showing improvements in physical activity and patient knowledge of CKD (Doyle et al., 2019). This intervention suggests that the use of mobile technology can provide significant support in CKD patient self-management, improving quality of life, and reducing kidney function decline.

Utilization of application-based health technology in chronic kidney disease management. Based on the 7 articles that have been analyzed, all of them show the effect of intervention using mobile applications for the outcomes that researchers expect. However, there is 1 outcome that does not show a change (Min & Park, 2020). The studies in this document show that the use of smartphone-based applications has a significant effect on various outcomes in patients with chronic kidney disease (CKD) and hemodialysis patients. For example, a study by Pack & Lee found that a diet self-management application significantly reduced serum potassium and phosphorus levels, and increased self-efficacy and quality of life in patients(Pack & Lee, 2021). In addition, a study by Li et al. showed that a mobile health application integrated with social media not only increased self-efficacy and self-management scores, but also slowed the decline in kidney function as measured by the estimated glomerular filtration rate (eGFR)(Li et al., 2020). These findings suggest that technology-based applications can provide effective support in the management of chronic diseases.

Several types of interventions that have been shown to have a significant impact on outcomes include dietary self-management apps, mobile health apps equipped with social media, the KELA.AE app, and the MiKidney app. For example, the KELA.AE app used in a study by Khoury et al. successfully increased energy and protein intake, and reduced sodium intake in hemodialysis patients (Khoury et al., 2020). Similarly, the MiKidney app helped increase physical activity, reduce total and LDL cholesterol levels, and improve body composition in patients. Of the seven studies discussed, four showed a significant positive impact on the outcomes measured, demonstrating the effectiveness of app-based interventions in managing CKD. Outcomes that experienced significant changes included biochemical indicators such as decreased serum potassium and phosphorus levels, increased self-efficacy and self-management scores, and improved kidney function such as a slower decline in eGFR. In addition, positive changes were also seen in dietary intake patterns, with increased energy and protein consumption, and reduced sodium intake. Improvements in physical activity and body composition were also noted, with decreased cholesterol levels and increased physical activity levels. Overall, these findings highlight the great potential of mobile technologies in supporting self-management and improving quality of life in patients with chronic kidney disease.

Technology-based interventions, such as smartphone apps, have been shown to be effective in supporting self-management in patients with chronic kidney disease (CKD) and hemodialysis patients. The studies analyzed showed that these apps can provide significant benefits, including increased self-efficacy, self-management, and quality of life, as well as improvements in biochemical parameters and kidney function. The use of mobile apps also helped improve patients' dietary patterns and physical activity. Thus, mobile technologies offer innovative solutions that can improve chronic disease care and management, as well as improve patients' health and quality of life.

Limitations such as small sample sizes and short intervention durations reduce the generalizability and long-term reliability of these findings. Additionally, usability challenges and the absence of control groups in some studies further limit the strength of conclusions drawn. While the interventions are generally well-received, the limited physiological improvements suggest that mobile apps may need to be combined with other strategies for a more comprehensive impact.

4. CONCLUSION

From the 7 journals found, all of them used pre-experimental, qualitative and RCT conducted with human respondents. RCT is a method often used in research. Analysis of 7 articles indicated that the use of health applications can improve patient self-management, monitoring of physiological parameters, and compliance with medical recommendations. The 7 articles that have been analyzed, all showed the effect of intervention using mobile applications for the outcomes that researchers expected. However, there was 1 outcome that did not show any change. Future research with larger, diverse samples and extended study periods is needed to validate these preliminary benefits.

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