Smartphone and application use in self-management of chronic kidney disease: a cross-sectional feasibility study

Christielle Lidianne Alencar Marinho, Orlando Vieira Gomes, Geraldo Bezerra da Silva Junior, Paulo Adriano Schwingel

Universidade de Pernambuco (UPE), Recife (PE), Brazil

ABSTRACT

INTRODUCTION: Smartphone and application use can improve communication and monitoring of chronic diseases, including chronic kidney disease, through self-management and increased adherence to treatment.

OBJECTIVE: To assess smartphone use in patients with chronic kidney disease on dialysis and their willingness to use mobile applications as a disease self-management strategy.

DESIGN AND SETTING: This was a cross-sectional study of chronic kidney disease patients on hemodialysis in the São Francisco Valley in the Northeast Region, Brazil.

METHODS: The questionnaire developed by the authors was administered between April and June 2021. Cronbach's alpha coefficient for the construct was 0.69. Associations between the dependent and independent variables were determined using univariate analysis. Multivariate analysis with logistic regression analysis was also performed.

RESULTS: A total of 381 patients were included, of whom 64% had a smartphone, although only 3.1% knew of a kidney disease-related application. However, 59.3% believed that using an application could help them manage their disease. Having a smartphone was associated with treatment adherence, higher educational attainment, and higher per capita income. Educational attainment remained an independent factor in multivariate analysis.

CONCLUSION: More than 64% of patients had a smartphone, although few knew of applications developed for kidney disease. More than half of the population believed that technology use could benefit chronic kidney disease treatment. Smartphone ownership was more common among the younger population, with higher educational attainment and income, and was associated with greater adherence to hemodialysis sessions.
Even though health technology is used in high-income countries, the widespread use and accessibility of mobile phones have enabled its proliferation in low- and medium-income countries, thereby reaching more people in limited-resource settings. Recent studies show that mobile devices have improved regular communication and monitoring between health professionals and their patients, as well as adherence to medication use and lifestyle changes.11-13

The coronavirus disease 2019 (COVID-19) pandemic has caused rapid unprecedented growth in the use of technology in the health field. However, barriers and challenges—such as patients’ lack of knowledge and Internet connectivity, health professionals’ limited competence in mHealth, and financial challenges—can hinder the adoption of such interventions.14

Thus, to obtain optimal results with this tool, it is important to know the target population of the technology, understand the current limitations, and assess the individuals’ knowledge of this resource and willingness to use it.

**OBJECTIVE**
The objective of this study was to assess the use of smartphones by CKD patients on dialysis and their willingness to use mobile applications as a strategy for disease self-management.

**METHODS**
This was an analytical cross-sectional quantitative study of CKD patients on hemodialysis at a renal treatment reference service in the São Francisco Valley, in the Northeast Region of Brazil.

The eligibility criteria were as follows: age ≥ 18 years and undergoing treatment for > 3 months. Individuals who reported cognitive deficits in their medical records or self-reported disabilities that prevented them from answering the research questions were excluded. A total of 443 patients were registered at the dialysis center, 401 of whom were eligible to participate in the study. Twenty individuals did not agree to participate; therefore, the sample included 381 subjects.

Data were collected using a questionnaire developed by the authors regarding sex, age, marital status, religion, skin color/race, educational attainment, per capita income, hemodialysis time in treatment, kidney disease etiology, associated diseases, use of smartphones, use of applications, use and knowledge of applications for CKD, use of additional tools to cope with and manage the disease, and non-attendance at dialysis sessions in the previous month (https://doi.org/10.6084/m9.figshare.20051600). The instrument to assess the use of mobile technologies in the treatment of CKD was evaluated three times. Research on reliability and reproducibility involved 10 patients, aged 40 to 75 years, undergoing hemodialysis. The instrument items were assessed using Cronbach’s alpha for internal consistency. The instrument’s reliability was measured by calculating the agreement and estimating kappa coefficients. The Cronbach’s alpha coefficient for the construct was 0.687, demonstrating moderate reliability in the three small-group assessments. The supplementary material available at https://doi.org/10.6084/m9.figshare.20051600 analyzes the individual questions and demonstrates maximum agreement values (1.00) for 10 of the 15 questions. In addition, all questions in the instrument demonstrated very high reliability, with values of > 0.90.

Data were collected between April and June 2021 via interviews conducted by trained researchers. Interviews were conducted in a dialysis room while the patients were undergoing treatment. On the day of the interview, a trained researcher conducted a structured face-to-face interview using a standardized questionnaire (SM1) with suitable space for each patient. The patients were asked direct questions and the responses were classified by the interviewer according to the alternatives in the questionnaire.

The answers were typed and stored in regular Excel spreadsheets (Microsoft Corporation, Redmond, Washington, United States, Release 12.0.6662, 2012) and exported to the SPSS computer program (SPSS Inc., Chicago, Illinois, United States, Release 16.0.2, 2008). Descriptive statistical analysis was performed with categorical variables presented as absolute and relative frequencies. Continuous variables were reported as mean ± standard deviation (SD) after data normality was determined using the Kolmogorov-Smirnov test. For inferential analysis, continuous data were analyzed using the Student’s t-test for independent samples or one-way analysis of variance. Age and mobile phone use were correlated using Pearson’s correlation coefficient. In the univariate analysis, the association between the dependent variable (having a smartphone) and each independent variable (sex, marital status, age group, religion, skin color/race, educational attainment, income, time in treatment, and non-attendance to dialysis) was calculated using Pearson’s chi-square test or Fisher’s exact test. Variables with $P ≤ 0.20$ in these analyses were selected for multivariate analysis with logistic regression, performed with the stepwise technique. Unadjusted and adjusted odds ratios (OR) and 95% confidence intervals (95% CI) were calculated. Statistical analyses were two-tailed, and statistical significance was set at $P < 0.05$.

The Research Ethics Committee of the Amaury de Medeiros Integrated Health Center (CISAM, in Portuguese) approved this research on May 20, 2020, under register number 4.044.382 (CAAE:31246220.1.0000.5191). The participants were informed of the study objective and the procedures they would undergo. Participants then signed an informed consent form agreeing to their voluntary participation in the research.

**RESULTS**
The patients’ ages ranged from 19 to 92 years, with a mean age ($± SD$) of 50.8 ($± 16.0$) years. Most participants were male ($n = 240; 63.0%$), had completed middle school ($n = 129; 33.3%$), and earned
an income ranging from one to two times the minimum wage (n = 286; 75.1%). The minimum wage at the time was R$ 1,100.00 (US$ 202.00). The sample characteristics are listed in Table 1.

Although more than 64% of participants had smartphones, only 12 (3.1%) knew about kidney disease-related applications (Table 2). The proportion of kidney patients on hemodialysis who used additional treatment strategies was 14.4% (95% CI: 11.1–18.4). However, approximately 60% of the patients considered that using a mobile application could help manage kidney disease.

Having a smartphone was associated with adherence to treatment, higher educational attainment, and higher per capita income (Table 3). The mean age of the patients who had a smartphone (44.7 ± 13.5 years) was statistically lower (P < 0.001) than that of the patients who did not have one (61.7 ± 14.2 years).

Moreover, according to the OR calculated for the association of baseline characteristics with mobile phone use, only educational attainment remained an independent factor in smartphone

Table 1. Sample characterization. São Francisco Valley, Brazil, 2021 (n = 381)

| Variables                              | n  | %    | 95% CI  |
|----------------------------------------|----|------|---------|
| Sex                                    |    |      |         |
| Female                                 | 141| 37.0%| 32.2–42.1|
| Male                                   | 240| 63.0%| 58.0–67.7|
| Age                                    |    |      |         |
| ≤ 44 years                             | 143| 37.5%| 32.8–42.5|
| 45–64 years                            | 157| 41.2%| 36.4–46.2|
| 65–74 years                            | 48 | 12.6%| 9.6–16.3 |
| ≥ 75 years                             | 33 | 8.7% | 6.2–11.9 |
| Marital status                         |    |      |         |
| Single                                 | 102| 26.8%| 22.4–31.5|
| Married                                | 206| 54.1%| 48.9–59.2|
| Divorced                               | 39 | 10.2%| 7.4–13.7 |
| Widow(er)                              | 34 | 8.9% | 6.3–12.3 |
| Religion                               |    |      |         |
| Catholic                               | 244| 64.0%| 59.0–68.9|
| Evangelical                            | 110| 28.9%| 24.4–33.7|
| Others                                 | 13 | 3.4% | 1.8–5.8  |
| No religion                            | 14 | 3.7% | 2.0–6.1  |
| Race/skin color                        |    |      |         |
| Multiracial                            | 256| 67.2%| 62.2–71.9|
| Black                                  | 53 | 13.9%| 10.6–17.8|
| White                                  | 72 | 18.9%| 15.1–23.2|
| Educational attainment                 |    |      |         |
| Illiterate, or elementary school not completed | 82 | 21.5%| 17.5–26.0|
| Elementary school completed and/or middle school not completed | 129 | 33.9%| 29.1–38.9|
| Middle school completed and/or high school not completed | 58 | 15.2%| 11.8–19.2|
| High school completed and/or higher education not completed | 94 | 24.7%| 20.4–29.3|
| Higher education completed             | 18 | 4.7% | 2.8–7.4  |
| Per capita income                      |    |      |         |
| Less than 1 time the minimum wage (< US$ 200.00) | 58 | 15.2%| 11.8–19.2|
| From 1 to 2 times the minimum wage (from US$ 200.00 to 400.00) | 286 | 75.1%| 70.4–79.3|
| From 3 to 5 times the minimum wage (> US 400.00 to 1,000.00) | 25 | 6.6% | 4.3–9.5  |
| More than 5 times the minimum wage (> US 1,000.00) | 12 | 3.1% | 1.6–5.4  |
| Time in treatment                      |    |      |         |
| Less than 1 year                       | 77 | 20.2%| 16.2–24.6|
| From 1 to 2 years                      | 88 | 23.1%| 19.0–27.7|
| From 3 to 5 years                      | 101| 26.5%| 22.1–31.2|
| From 5 to 10 years                     | 69 | 18.1%| 14.4–22.4|
| More than 10 years                     | 46 | 12.1%| 9.0–15.8 |
| Non-attendance to treatment sessions in the previous month |    |      |         |
| Yes                                    | 72 | 18.9%| 15.1–23.2|
| No                                     | 309| 81.1%| 76.8–84.9|

CI = confidence interval.
acquisition (Table 4). In addition, the other clinical variables analyzed were not related to mobile phone use nor to kidney disease-related mobile applications.

DISCUSSION
Few studies have assessed the use of innovative technologies, including smartphones and applications, as auxiliary methods for treating CKD patients to increase their treatment adherence. Low adherence to CKD treatment has been associated with a greater probability of disease progression and higher mortality.15 The study participants were predominantly male, multi-racial, married, catholic, with low educational attainment and low income. This reflects the epidemiological profile of the Brazilian population on dialysis. Approximately 65% of the studied patients had a smartphone, and more than half of them used applications in their daily routine. The most used applications were social media, such as WhatsApp, Facebook, and Instagram. Few participants knew of an application to help with kidney treatment. However, more than half of the participants still considered it important and believed it could help them to manage their health conditions. Moreover, smartphone use was associated with income, educational attainment, and adherence to hemodialysis treatment.

A global study investigated CKD epidemiology in 2017 and found a higher prevalence of women in the initial stages of CKD, whereas there were more men in the final stages; moreover, the mortality rates were higher among men.16 This may be explained by the harmful effects of testosterone combined with unhealthy lifestyles among men, accelerating their decline in kidney function.

The mean age of the study population was 50.8 years, corroborating other studies conducted in Brazil, wherein the most prevalent age range was from 50 to 60 years.17 In a study conducted in Iceland, the mean age of patients with terminal CKD was 63 years, while in another study of 1,174 individuals from Sri Lanka, the mean age was 58.7 years.18,19

Studies on CKD conducted both within Brazil and in other countries found similar economic profiles and educational attainments to the present study population. Socially disadvantaged people worldwide face a disproportionate kidney disease burden.2,6,20,21 It is important to understand the educational and economic situation of patients who are receiving care to provide them with effective treatment.

Recent technological advancements, combined with the COVID-19 pandemic, have led more people to embrace the alternatives offered by virtual media. Hence, technology that was exclusive to developed countries and economically advantaged people

### Table 2. Use and knowledge of mobile phones. São Francisco Valley, Brazil, 2021 (n = 381)

| Variables                                              | n   | %   | 95% CI        |
|--------------------------------------------------------|-----|-----|---------------|
| **Have a smartphone**                                  |     |     |               |
| Yes                                                    | 245 | 64.3%| 59.3–69.1     |
| No                                                     | 136 | 35.7%| 30.1–40.7     |
| **Applications installed**                             |     |     |               |
| Yes                                                    | 209 | 54.9%| 49.7–59.9     |
| No                                                     | 25  | 6.6% | 4.3–9.5       |
| Do not know what an application is                     | 11  | 2.9% | 1.5–5.1       |
| Do not have a smartphone                               | 136 | 35.7%| 30.9–40.7     |
| **Knows of kidney disease-related applications**       |     |     |               |
| Yes                                                    | 12  | 3.1% | 1.6–5.4       |
| No                                                     | 369 | 96.9%| 94.6–98.4     |
| **Believes that mobile applications may help manage the kidney disease** |     |     |               |
| Yes                                                    | 226 | 59.3%| 54.2–64.3     |
| No                                                     | 55  | 14.4%| 11.1–18.4     |
| Do not know                                           | 100 | 26.2%| 21.9–31.0     |
| **Uses treatment strategies other than dialysis**      |     |     |               |
| Yes                                                    | 55  | 14.4%| 11.1–18.4     |
| No                                                     | 326 | 85.6%| 81.6–88.9     |
| **Additional strategies used**                         |     |     |               |
| Physical activity                                      | 18  | 4.7% | 2.8–7.4       |
| Physical therapy                                       | 7   | 1.8% | 0.7–3.8       |
| Nutritional therapy                                    | 4   | 1.0% | 0.3–2.7       |
| Psychological therapy                                  | 15  | 3.9% | 2.2–6.4       |
| Religion/Spirituality                                  | 4   | 1.0% | 0.3–2.7       |
| Various therapies                                      | 7   | 1.8% | 0.7–3.8       |
| Does not use additional strategies                     | 326 | 85.6%| 81.6–88.9     |

CI = confidence interval.
Table 3. Relationship between sociodemographic characteristics, clinical variables, and mobile phone use. São Francisco Valley, Brazil, 2021 (n = 381)

| Variables                        | Has a smartphone |       |       | P       |
|----------------------------------|------------------|-------|-------|---------|
|                                  | Yes (n = 245)    | No (n = 136) |       |         |
|                                  | n   | %    | n   | %    |         |
| Sex                              |     |      |     |      |         |
| Female                           | 95  | 38.8%| 46  | 33.8%| 0.337  |
| Male                             | 150 | 61.2%| 90  | 66.2%|         |
| Marital status                   |     |      |     |      | < 0.001|
| Single                           | 74  | 30.2%| 28  | 20.6%|         |
| Married                          | 138 | 56.3%| 68  | 50.0%|         |
| Divorced                         | 22  | 9.0% | 17  | 12.5%|         |
| Widowed                          | 11  | 4.5% | 23  | 16.9%|         |
| Religion                         |     |      |     |      |         |
| Catholic                         | 150 | 61.2%| 94  | 69.1%| 0.104  |
| Evangelical                      | 73  | 29.8%| 37  | 27.2%|         |
| Others                           | 9   | 3.7% | 4   | 2.9% |         |
| No religion                      | 13  | 5.3% | 1   | 0.7% |         |
| Race/skin color                  |     |      |     |      | 0.896  |
| Multiracial                      | 163 | 66.5%| 93  | 68.4%|         |
| Black                            | 34  | 13.9%| 19  | 14.0%|         |
| White                            | 48  | 19.6%| 24  | 17.6%|         |
| Educational attainment           |     |      |     |      | < 0.001|
| Illiterate, or elementary school not completed | 24 | 9.8% | 58 | 42.6% |         |
| Elementary school completed and/or middle school not completed | 77 | 31.4% | 52 | 38.2% |         |
| Middle school completed and/or high school not completed | 43 | 17.6% | 15 | 11.0% |         |
| High school completed and/or higher education not completed | 84 | 34.3% | 10 | 7.4% |         |
| Higher education completed       | 17  | 6.9% | 1   | 0.7% |         |
| Per capita income                |     |      |     |      | 0.043  |
| Less than 1 time the minimum wage (< U$ 200.00) | 40 | 16.3% | 18 | 13.2% |         |
| From 1 to 2 times the minimum wage (from U$ 200.00 to 400.00) | 174 | 71.0% | 112 | 82.4% |         |
| From 3 to 5 times the minimum wage (> U$ 400.00 to 1,000.00) | 21 | 8.6% | 4 | 2.9% |         |
| More than 5 times the minimum wage (> U$ 1,000.00) | 10 | 4.1% | 2 | 1.5% |         |
| Time in treatment                |     |      |     |      | 0.830  |
| Less than 1 year                 | 48  | 19.6%| 29  | 21.3%|         |
| From 1 to 2 years                | 60  | 24.5%| 28  | 20.6%|         |
| From 3 to 5 years                | 67  | 27.3%| 34  | 25.0%| 0.830  |
| From 5 to 10 years               | 42  | 17.1%| 27  | 19.9%|         |
| More than 10 years               | 28  | 11.4%| 18  | 13.2%|         |
| Non-attendance to treatment sessions in the previous month |     |      |     |      | 0.011  |
| Yes                              | 37  | 15.1%| 35  | 25.7%|         |
| No                               | 208 | 84.9%| 101 | 74.3%|         |

Table 4. Odds ratios of the association between baseline characteristics and mobile phone use. São Francisco Valley, Brazil, 2021 (n = 381)

| Variables                        | Smartphone use |       |       |       |       |
|----------------------------------|----------------|-------|-------|-------|-------|
|                                  |                | Yes (n = 245) | No (n = 136) | Crude (95% CI) | Adjusted (95% CI) |
|                                  | n   | %    | n   | %    |         |         |
| Marital status                   |     |      |     |      |         |         |
| Single, divorced or widowed      | 107 | 43.7%| 68  | 50.0%| 1.00   | 1.00   |
| Married                          | 138 | 56.3%| 68  | 50.0%| 1.38 (0.88–2.17) | 1.29 (0.85–1.96) |
| Educational attainment           |     |      |     |      |         |         |
| Illiterate to middle school completed | 144 | 58.8% | 125 | 91.9% | 1.00   | 1.00   |
| High school to higher education completed | 101 | 41.2% | 11  | 8.1% | 7.97 (4.09–15.52) | 7.70 (3.80–15.01) |
| Per capita income                |     |      |     |      |         |         |
| 2 times the minimum wage or less (≤ U$ 400.00) | 214 | 87.3% | 130 | 95.6% | 1.00   | 1.00   |
| More than 2 times the minimum wage (> U$ 400.00) | 31 | 12.7% | 6 | 4.4% | 1.00 (0.36–2.80) | 1.08 (0.39–3.00) |
| Non-attendance to treatment sessions in the previous month |     |      |     |      |         |         |
| Yes                              | 37  | 15.1%| 35  | 25.7%| 1.00   | 1.00   |
| No                               | 208 | 84.9%| 101 | 74.3%| 0.65 (0.37–1.12) | 0.64 (0.36–1.11) |

CI = confidence interval.
has become accessible and desired by a larger significant portion of the population.\textsuperscript{22}

A study of 949 patients on dialysis in the United States showed that 81% of them had smartphones, 72% reported using the Internet, and 60% were interested in using mHealth to manage their health.\textsuperscript{23} Another study conducted on patients on dialysis in Australia found that 83.5% of them had mobile phones, although only 36.6% used applications.\textsuperscript{24} In the present study, this percentage was smaller, which points to the lower purchasing power of patients on dialysis in Brazil. Nevertheless, despite not knowing about any CKD applications, the patients believed that CKD applications could be effective.

One barrier to the implementation of this technology is the limited knowledge of the potential benefits of CKD applications for both users and health professionals. While health professionals recognize the potential of CKD applications, they lack the knowledge, time, and skill to search, assess, and recommend reliable applications, thus highlighting that these technologies need support policies and better publicization.\textsuperscript{25}

Health teams must be trained to both use and encourage the use of applications, as they are agents who promote health education, and whom patients trust.\textsuperscript{10} There are Portuguese applications aimed at CKD patients; for example, Renal Health, which has multiple tools such as a smart medication box with reminder alarms, monthly examination charts, liquid and diet control, and general information on kidney disease.\textsuperscript{26}

Age, marital status, educational attainment, and income were associated with smartphone use. Younger, single people with higher educational attainment and income tend to have smartphones, in contrast to older, married individuals with lower educational attainment and income. These results corroborate those of other studies in which age, educational attainment, and income were factors associated with smartphone use.\textsuperscript{23,27,28}

A primary objective of introducing mobile phone use to promote health self-management is to increase treatment adherence. Patients with CKD must adhere to four treatment pillars: hemodialysis, restricted fluid intake, diet, and medication use. Regarding hemodialysis, only 18.9% of the participants in this study were non-adherent to therapy. Smartphone use was associated with adherence to treatment; moreover, other studies identified social and family support as protective factors against non-adherence to treatment.\textsuperscript{29}

Generally, adhering to a given treatment is similar to acquiring a new habit in which information is obtained and incorporated into the routine. However, understanding the person’s perceptions and difficulties and becoming acquainted and establishing ties with them simplifies this process.\textsuperscript{31}

The possibility of introducing mobile technology into the routine of patients with CKD is very promising, as it can potentially add knowledge and empowerment to their treatment. The patients were interested in this possibility; therefore, health services that treat them should encourage application use and provide the necessary information to promote the technology, including monthly examination results, limits of the liquid they can drink, diet, and medication prescriptions.

Thus, it is important to identify individuals with greater difficulties and barriers to technological access. This will help in allowing mHealth interventions to equitably reach as many people as possible. Application developers must consider the needs of both older adults and those with low literacy to diminish the digital gap between users and non-users. Hence, campaigns to enable older adults to use mobile technologies and increase their health literacy may help to reduce the inequalities caused by technological progress.\textsuperscript{32}

Few studies have addressed CKD patients and their interest in and use of smartphones to help promote health among these individuals in Brazil, which makes this research relevant as a bridge to efficiently implementing such resources in the country. A limitation of this study is the single-period and single-service data collection. Thus, although the associations between the variables were assessed, causality between them was not.

CONCLUSION
More than 64% of CKD patients on dialysis treatment had a smartphone, and 54.9% used applications. Although few patients knew of applications aimed at kidney disease, more than half of them believed that such technology use may benefit CKD treatment. Having a smartphone was more frequent among younger patients with higher educational attainment and income and was also associated with greater adherence to hemodialysis sessions.

REFERENCES
1. Levin A, Tonelli M, Bonventre J, et al. Global kidney health 2017 and beyond: a roadmap for closing gaps in care, research, and policy. Lancet. 2017;21;390(10105):1888-1917. PMID: 28434650; https://doi.org/10.1016/S0140-6736(17)30788-2.
2. Crews DC, Bello AK, Saadi G. 2019 World Kidney Day Editorial - burden, access, and disparities in kidney disease. J Bras Nefrol. 2019;41(1):1-9. PMID: 31063178; https://doi.org/10.1590/2175-8239-JBN-2018-0224.
27. Ma Q, Chan AH, Chen K. Personal and other factors affecting acceptance of smartphone technology by older Chinese adults. Appl Ergon. 2016;54:62-71. PMID: 26851465; https://doi.org/10.1016/j.apergo.2015.11.015.

28. Sayed M, Mamun-Ur-Rashid M. Factors influencing e-Health service in regional Bangladesh. Int J Health Sci (Qassim). 2021;15(3):12-9. PMID: 34234631.

29. Oliveira JGR, Askari M, Fahd MGN, et al. Chronic Kidney Disease and the Use of Social Media as Strategy for Health Education in Brazil. Stud Health Technol Inform. 2019;264:1945-6. PMID: 31438420; https://doi.org/10.3233/SHTI190726.

30. Sousa H, Ribeiro O, Paul C, et al. Social support and treatment adherence in patients with end-stage renal disease: A systematic review. Semin Dial. 2019;32(6):562-74. PMID: 31309612; https://doi.org/10.1111/ sdi.12831.

31. Chan AHY, Honey MLL. User perceptions of mobile digital apps for mental health: Acceptability and usability - An integrative review. J Psychiatr Ment Health Nurs. 2022;29(1):147-68. PMID: 33604946; https://doi.org/10.1111/jpm.12744.

32. Ernsting C, Dombrowski S, Oedekoven M, et al. Using Smartphones and Health Apps to Change and Manage Health Behaviors: A Population-Based Survey. J Med Internet Res. 2017;19(4):e101. PMID: 28381394; https://doi.org/10.2196/jmir.6838.

Authors’ contributions: Marinho CLA: conceptualization (lead), data curation (equal), formal analysis (lead), investigation (equal), project administration (lead), writing-review and editing (equal), and final approval of the version to be published (equal); Gomes OV: conceptualization (equal), investigation (equal), resources (equal), writing-original draft (equal), and writing-review and editing (equal); Silva Junior GB: conceptualization (equal), data curation (equal), resources (equal), writing-original draft (equal), writing-review and editing (equal); and interpretation of data for the work (equal), revising it critically for important intellectual content (lead); Schwingel PA: supervision (lead), interpretation of data for the work (equal), writing-original draft (equal), and writing-review and editing (lead). All authors actively contributed to the discussion of the study results and reviewed and approved the final version of the manuscript.

Sources of funding: Fundação de Amparo à Ciência e Tecnologia do Estado de Pernambuco (FACEPE) [APQ-0246-4.06/14; APQ-1413-4.08/21; BIC-1434-4.06/21; BCT-0293-4.06/22], Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) [finance code 001].

Conflicts of interest: We declare that there were no competing interests.