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Effects of gamified versus pedometer-based walking intervention on physical activity, fatigue, and sleep quality among hemodialysis patients: a quasi-experimental study

Mohamed E. H. Elzeky[1], Rash Hafez Ramadan El-Shaboury[2], Basma Salameh[3*], Emad Samaan[4], Noha F.M.Shahine[5] and Awatef abdelhamid[2]

Abstract

Objectives Exercise is a promising approach for symptom management in hemodialysis patients who are typically very sedentary. This study evaluated the effects of gamified versus pedometer-based walking interventions on these patients' physical activity, physical function, fatigue, sleep quality, and hemodynamics.

Methods A quasi-experimental single-blind study was conducted in three groups (two intervention and one control groups). It was carried out at the hemodialysis department in Mansoura University Hospital, Egypt, from October 2022 to 2023. A total of 94 patients were divided randomly into gamified ($n=31$), pedometer ($n=31$), and control ($n=32$) groups. Randomization was done by dialysis scheduled time (first shift: pedometer group, second shift: gamified group, and third shift control group) rather than at the individual level, and the allocation ratio was approximately 1:1:1. The gamified group received a twelve-week smartphone-based gamified walking intervention, while the pedometer group received a twelve-week pedometer-based walking intervention. The control group did not receive any intervention. Step count, fatigue, sleep quality, physical function, and hemodynamic parameters were evaluated at baseline and after 12 weeks of intervention.

Result Post-intervention results indicated that patients in the gamified group significantly improved their step count, fatigue, and sleep levels compared to both the pedometer and control groups ($P<0.001$). However, the groups had no statistically significant differences in physical function or hemodynamics.

Conclusion Hemodialysis patients who participated in a short-term, smartphone-based gamified walking intervention experienced increased step counts, reduced fatigue, and improved sleep quality.

Trial Registration Prospectively registered with ClinicalTrials.gov on 28/10/2022; registration number NCT05599646.

Keywords Gamification, Fitness Trackers, Fatigue, Sleep Quality, Hemodialysis

*Correspondence:
Basma Salameh
basma.salameh@aaup.edu
Full list of author information is available at the end of the article

Introduction

Hemodialysis (HD) is the most common renal replacement therapy for patients with end-stage renal disease (ESRD); however, they suffer from multiple complications and a heavy burden of symptoms due to either ESRD or HD therapy, which lowers their quality of life [1]. The most common symptoms in HD patients are fatigue, with a prevalence ranging from 60 to 97% [2], trouble falling asleep, which was reported by a significant portion (23%–85%) [1], and poor physical functioning, which is the most pervasive and disabling disturbance [3]. There are no specific pharmaceutical guidelines to treat or prevent fatigue or sleep problems in HD patients, and nonpharmacological approaches are the cornerstone for their management [4].

Higher Physical activity (PA) as a nonpharmacological lifestyle was reported to be associated with lower levels of fatigue and insomnia [5] and higher physical function among HD patients [6]. However, HD patients are very sedentary, with activity levels that are lower than those of healthy sedentary people and those with other chronic conditions [5, 7, 8]

Intradialytic exercises have shown significant results in reducing fatigue [9], improving daily PA and sleep quality [10], and improving physical function among HD patients [11]. Despite this, these exercise interventions were performed under supervision, and only a small percentage of patients are able and willing to engage in these therapies.

Home-based exercises, such as walking, could be more accessible to a more significant percentage of HD patients [8]. However, few studies have investigated their effect on fatigue, sleep quality, and physical performance among HD patients, with conflicting results. Manfredini et al. (2017) [3] reported that low-intensity walking interventions improve physical performance, while Sheshadri et al. (2020) [8] reported a non-significant improvement in fatigue and physical performance after a pedometer-based walking intervention, and the increase in steps was not sustained during follow-up. This raises the concern that the effect of walking on HD patients' outcomes is still uncertain, and finding novel approaches to increase HD patients' motivation and adherence to PA and studying its impact on patient outcomes is necessary.

Gamification uses game design elements (such as leaderboards, points, badges, and progress bars) in non-game contexts to foster motivation and engagement [12]. Self-determination theory helps us understand how gamification elements of smartphone pedometer applications and motivations are interrelated [13]. The sense of competence (experiencing mastery), relatedness (feeling socially connected to others), and autonomy (sense of control over behavior) that users get from interacting with various gamification elements encourages them to keep using mobile health applications [14]. A recent systemic review reported that gamified interventions are promising for increasing PA in different populations and that their effect is sustained after the follow-up period [15]. In addition, adding financial incentives to gamification significantly increased PA compared to gamification without financial incentives [16]. Moreover, those using smartphones alone, without a wearable fitness device, were more likely to stick to PA [17].

Evidence of the efficacy of gamification-based walking as a behavioral change intervention among HD patients is still unclear. Therefore, In the present study, we examined if using smartphone-based gamified elements (goal setting, progress bars, rewards, feedback, badges, leaderboards, competition, social relatedness, and financial incentives) would increase HD patients PA compared to conventional pedometers and affect their fatigue, sleep quality, physical function, and hemodynamics.

Study aims

This study evaluated the effects of gamified versus pedometer-based walking interventions on hemodialysis patients' physical activity, physical function, fatigue, sleep quality, and hemodynamics.

Research hypothesis

(1) Patients in the smartphone-based gamified walking group will have a higher step count than those in the traditional pedometer-based walking and control groups. (2) Patients in the smartphone-based gamified walking group will have a lower fatigue level than those in the traditional pedometer-based walking and control groups. (3) Patients in the smartphone-based gamified walking group will have better sleep quality than those in the traditional pedometer-based walking and control groups. (4) Patients in the smartphone-based gamified walking group will have higher physical function than those in the traditional pedometer-based walking and control groups. (5) Patients in the smartphone-based gamified walking group will have lower hemodynamic readings than those in the traditional pedometer-based walking and control groups.

Theoretical framework

Self-determination theory explains how PA is initiated and maintained. The theory contends that behaviors should be self-determined, or, in other words, volitional, for people to be optimally motivated. Interventions based on self-determination theory achieve autonomous motivation by addressing individuals' basic psychological needs of autonomy, competence, and relatedness [13]. Users' sense of competence, relatedness, and independence from interacting with various gamification elements encourages them to keep using mobile health applications [14]. Through this, more self-determined forms of motivation are associated with PA adoption and adherence [18].

This study used two free smartphone applications: 1): The Fitbit application, which incorporates gamified elements, and 2) the sweat coin application, which incorporates gamified and financial incentive elements. We propose that if the gamified and financial incentive intervention meets individuals' basic psychological needs, they could actively engage in the behavior change procedure.

Autonomy can be satisfied by personalizing PA targets and choosing how to spend sweat coins. Users may change the predetermined daily step goal to suit their PA requirements and achieve the desired sweat coins [19].

Competence can be positively met by giving feedback on PA performance via prompts, badges, alerts, sweat coins (monetary rewards, one for every 1000 steps), leaderboards, and weekly challenges [20]. Relatedness can be satisfied via the app's social features. The two apps, for example, permit users to form friends, communicate with them (through emojis or text), challenge them to PA competitions, and send sweat coins to them [20].

Methods

Design, participants, and setting

This quasi-experimental single-blind study was conducted in three groups (two intervention and one control group) with two stages of pre-and post-tests and was carried out at the HD department in Mansoura University Hospital, Egypt, from October 2022 to October 2023.

The sample size for this study was determined using G*Power version 3.1 (power analysis for a one-way ANOVA with three groups). The calculation was based on two key studies:

1. *Salehi* et al*., 2020*: This study reported a partial eta squared (η^2) value of 0.15 for the effect of exercise on fatigue in HD patients. Using the formula , $F = \sqrt{\frac{\eta 2}{1-\eta 2}}$ the effect size was calculated to be 0.403. With a desired power of 0.8 and a significance level of $\alpha = 0.05$, the total sample size for the three groups was 63 (21 participants per group).
2. *Mazeas* et al*., 2022*: This meta-analysis reported an effect size of 0.42 for the impact of gamification on PA. Using G*Power, the three groups' sample size was 60 (20 participants per group).

By adding 20% for the possibility of dropout, the required sample size was 78 (26 per group). Of the total of 140 dialysis patients, 94 met the inclusion criteria. They were recruited through convenience sampling and were initially informed about the study's aims. These participants were randomly assigned to three groups based on their dialysis scheduled time: gamified (n = 31), Pedometer (n = 31), and control (n = 32). During the study, four participants were excluded due to protocol violations: two from the control group, one from the pedometer group, and one from the gamified group. As a result, the final sample included gamified (n = 30), Pedometer (n = 30), and control (n = 30) groups. The analysis was conducted on this final sample (Fig. 1). Subjects included in this study were 18 to less than 60 years of age, underwent conventional HD three times per week for three months or more, had access to smartphones and the internet, could read and write, were ambulatory, and provided written informed consent. Patients with unstable angina, lower limb amputations, or wheelchairs were excluded from the study.

Randomization and blinding

The investigators grouped patients according to their dialysis treatment times to prevent group contamination through discussion. Randomization was done by dialysis scheduled time (first shift: pedometer group, second shift: gamified group, and third shift control group) rather than at the individual level, and the allocation ratio was approximately 1:1:1. Three opaque and sealed envelopes were prepared by an independent researcher who didn't participate in the assessment or intervention procedures. Each envelope contains either the letter G (gamified group), the letter P (pedometer group), or the letter C (control group). Another independent researcher, who was not involved in the study's assessment or intervention procedures, assigned each envelope to a time (first, second, or third dialysis shift). This assignment was done randomly, ensuring that the time periods were not biased. Then, they were opened by study researchers, blinded to the dialysis scheduled time allocation until patients' recruitment. This ensured that the researchers did not know which group patients were being assigned to until the recruitment process was complete—two research assistants who were blinded to the group assignments collected data. The assistants were unaware of which participants were in which group (Pedometer, gamified, or control) throughout the study period. Patients were instructed to avoid discussing their group allocation with the blinded outcome assessor.

Interventions

The intervention was carried out by 2 of the researchers, both of whom are specialized health care professionals with extensive experience in health promotion

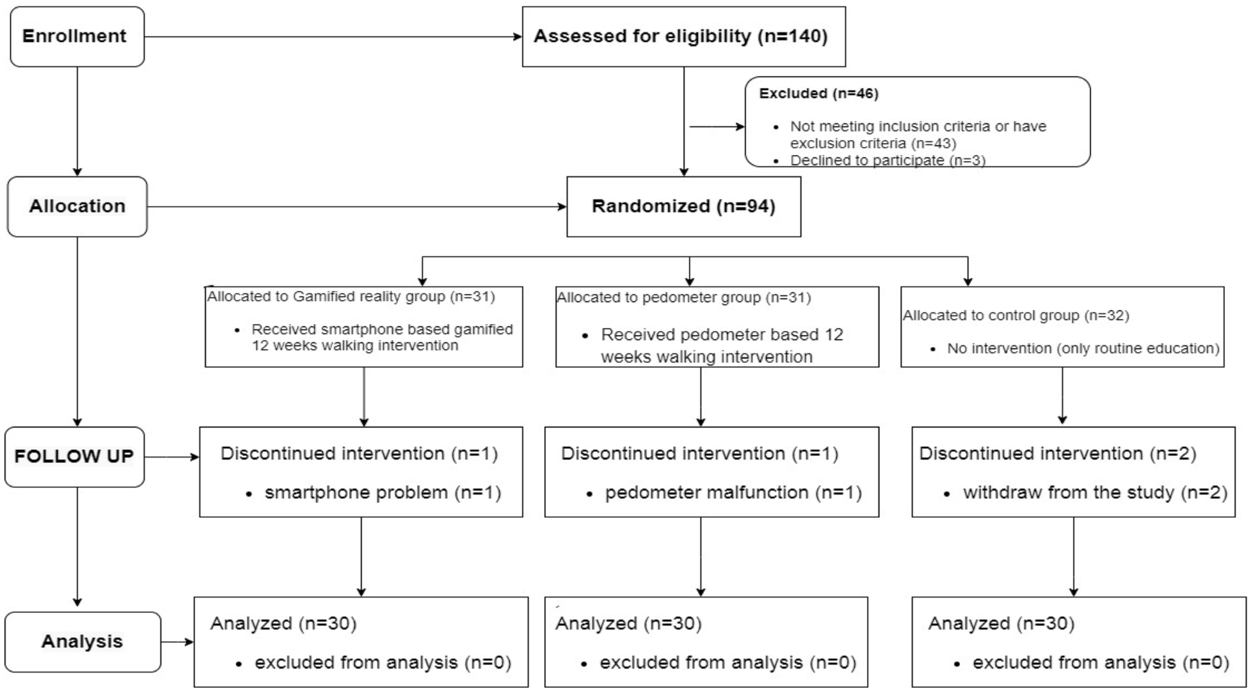

Fig. 1 Flow diagram of the study

and patient education. They hold PhDs in medical surgical nursing and have previous research with pedometer based walking interventions for cardiovascular patients and patients with knee osteoarthritis.

For group 1 (smartphone-based gamified walking intervention), the research personnel installed two free gamified step count applications (Fitbit and Sweat coin apps) on patients' smartphones after baseline assessment. These applications log steps walked each day.

The Fitbit app monitors step count, distance, calories burned, active minutes, and heart rate, providing users with detailed insights into their daily activity levels. It offers personalized fitness goals and progress tracking, helping users stay motivated to achieve their physical activity targets. Additionally, the app includes features like challenges and social sharing, allowing users to compete with friends or join community challenges. Users can earn badges for reaching step goals, completing challenges, or achieving personal bests, such as walking a certain number of steps daily, completing weekly activity goals, or walking consistently over a certain period. The badges are positive reinforcement and gamify the exercise experience, making it more engaging and rewarding. By unlocking various badges, users experience a sense of accomplishment, which can boost motivation and promote long-term adherence to physical activity routines (Fig. 2).

The *Sweatcoin* application is a smartphone-based platform that encourages physical activity by rewarding users for their steps. It uses the phone's built-in sensors to track steps and converts them into "Sweatcoins," a form of virtual currency (1 Sweatcoin per 1,000 steps). Users can earn Sweatcoins by walking, which can then be used to purchase various rewards, such as fitness-related products, gift cards, or discounts. There is also a feature to donate sweat coins to charity, allowing users to contribute their coins to causes they care about. The app also includes social features, allowing users to challenge friends, compare step counts on leaderboards, and participate in community-driven challenges, adding a gamified element to physical activity. The Sweatcoin app is widely used for walking and other forms of exercise, promoting increased physical activity through financial incentives and social engagement (Fig. 3).

A 20-step test was used to calibrate the phone's sensitivity level for various users to guarantee that each participant's step count was accurately recorded [21]. The patients were told to carry the same smartphone for 12 weeks, from the time they get up until the end of the day, just before bedtime (except during showering). Moreover, they were shown how to use the application and knew their rewards (sweat coins, badges), other users' step count on the leaderboard, their rank, how to spend sweat coins or send prizes to others or donate

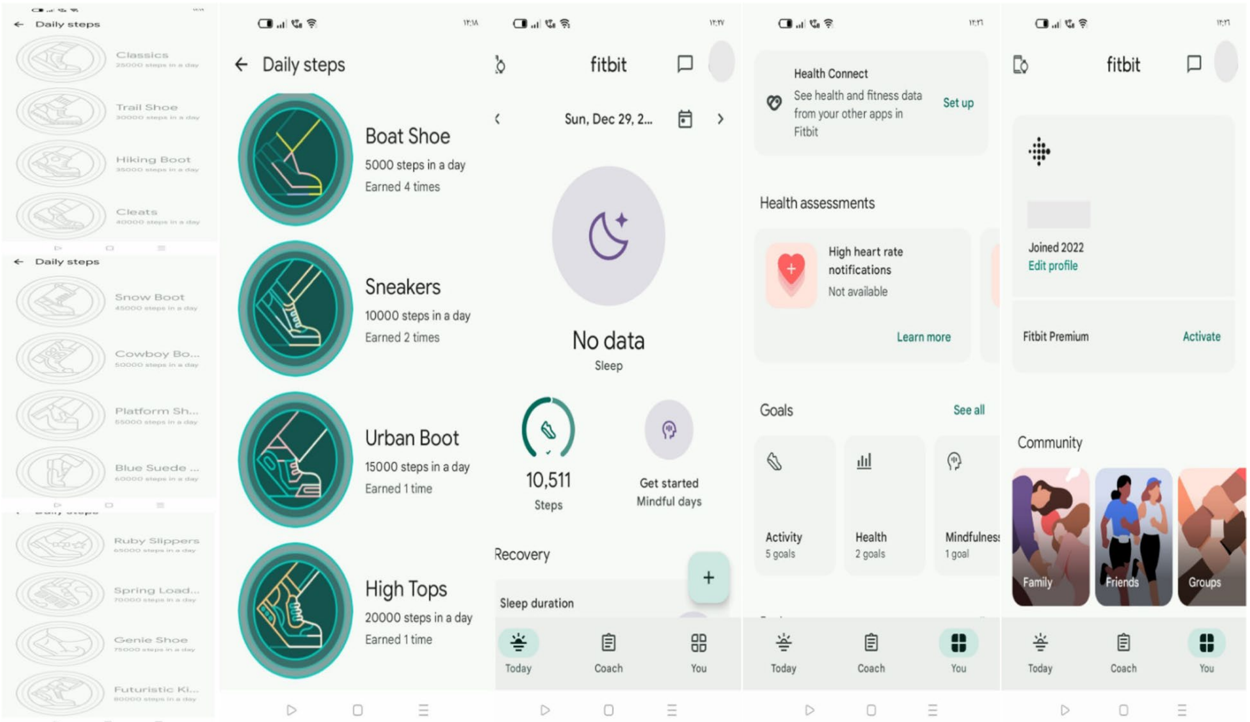

Fig. 2 screen shots from Fitbit app

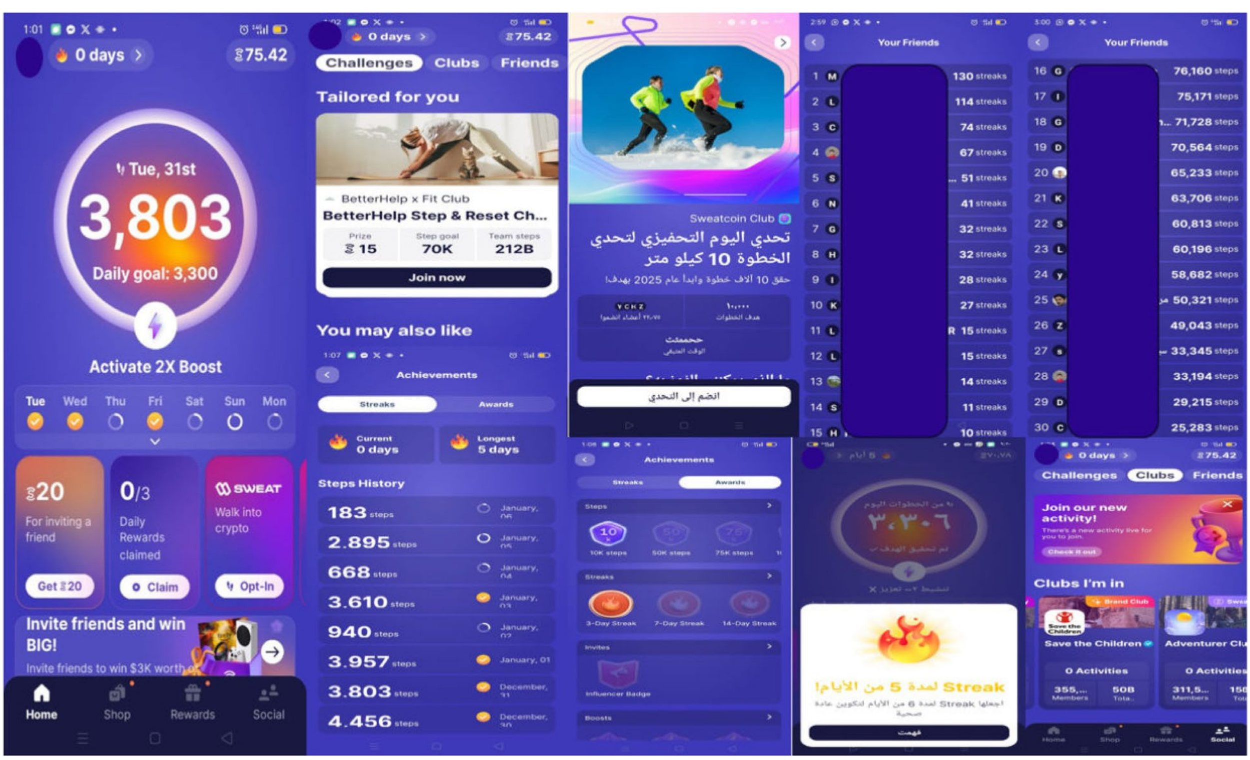

Fig. 3 screen shots from sweatcoin App

them to charity places, and how to challenge others or join challenges that the application announces each day. For relatedness, the research personnel assisted the participants in this group in inviting and adding each other and other friends and family members. During the weekly telephone semi-scripted counseling sessions, participants reported their step count log for the preceding week to the study researchers, who then set new targets for the next week and suggested new approaches by which participants could increase their daily walking. "Patients received individualized daily step count goals each week, with the target increasing by 10% of their baseline steps per day during weeks 2 to 12." Participants were motivated to walk at a comfortable pace. If participants did not achieve their weekly goal, they were not given a higher target for the next week. The first counseling session was held one week following the baseline assessment. In addition, they also received routine care.

For group 2 (traditional Pedometer), the intervention included giving pedometers (model KFJ-23 D) and weekly telephone semi-scripted counseling sessions provided by a study member at a predetermined time. KANGFU MEDICAL EQUIPMENT FACTORY manufactures the Pedometer and has the following characteristics (accuracy ± 5%, 3D, digital acceleration sensor, step range 0–99999, calorie range 0–9999.9 kcal, clamped on the waistband, 7 days memory and power saving mode). The Pedometer has been validated and demonstrated reliability in previous studies [22, 23]. After the baseline assessment, subjects were instructed to keep wearing the Pedometer and keep track of their daily steps for three months. They were asked to wear it from the time they woke up and to take it off at the end of the day, right before bedtime (except during showering), and they were shown how to attach it to a belt fixed around the left iliac crest level and monitor the number of steps accumulated each day. As a gamified group, weekly telephone semi-scripted counseling sessions provided goals for the upcoming week to increase their steps by 10% of their baseline steps per day during weeks 2 to 12.

Subjects in the control group (group 3) returned their pedometers following the initial week of baseline assessment, and they were not contacted throughout the intervention period; they received their routine weekly education only regarding walking 30 min per day by nursing staff and a brochure prepared by the HD unit regarding exercises for HD patients. Prospectively registered with ClinicalTrials.gov on 28/10/2022; registration number NCT05599646.

Measurements

The primary outcomes were increased patient PA (step count), reduced patient fatigue, and improved sleep quality; the secondary outcomes involved enhancement in patients' physical function and hemodynamics in the smartphone-based gamified group compared with the pedometer and control groups. Six tools were used in this study to evaluate outcomes, including:

Tool 1: Demographic and medical characteristics sheet

It was developed by the researcher and involved "sociodemographics" (age, gender, marital status, education, occupation, and residence) and "disease and treatment-related information (comorbidities, duration of dialysis, smoking status, BMI, hemoglobin level, and dialysis adequacy).

Tool II: Weekly Step Dairy:

The step count was evaluated using a pedometer. The mean weekly Step count was categorized into three levels: sedentary (< 5000 steps), low-active (5000–7499 steps), and active (≥ 7500 steps) [7].

Tool III: Short Physical Performance Battery (SPPB):

This tool aims to assess physical performance and functional status. It comprises three domains: walking speed, standing balance, and sit-to-stand performance. Every task receives a score out of four, then a total between 0 and 12 is obtained by adding the three domains' scores. The higher the score, the higher the physical function level [24].

Tool IV: Brief Fatigue Inventory (BFI)

The BFI consists of 10 questions. On a scale of 0 to 10, the questions evaluated the current, usual, and highest level of fatigue in the last 24 h and its impact on activities of daily living. A total fatigue score between 0 and 10 was calculated by adding the scores for questions 2–10 and dividing the total by nine. The higher the score, the higher the fatigue level [25]. This Arabic version has strong validity (Cronbach's alpha = 0.93) and high reliability (0.86).

Tool V: Pittsburgh Sleep Quality Index (PSQI):

Sleep disorders were assessed using the Arabic version of the PSQI [26]. It has acceptable validity (Cronbach's alpha = 0.65) and high reliability (0.82). Patients were classified as good or poor sleepers based on their responses to 19 self-reported questions that evaluated sleep quality, frequency, and severity of specific sleep-related troubles over the past month. The 19 items were grouped into seven components and scored from 0 to 3. The scores were summed to give a total PSQI score ranging from 0 to 21, and the higher the score, the poorer the sleep quality.

Tool VI: hemodynamics checklist

It was designed to assess heart rate (HR), systolic, diastolic blood pressure (BP), and respiratory rate at baseline and after intervention.

At the first interview, after obtaining informed written consent from the patient, demographic and disease-related characteristics were assessed using tool I, physical performance using tool III, fatigue using tool IV, sleep quality using tool V, and hemodynamic parameters using tool VI. Hemodynamic measurements were obtained pre-dialysis using the Biolight M69 monitor, with the patients lying down for 5 min before the measurement. Then, before using the Pedometer, each group underwent a 20-step test to ensure that the placement of the device at the waist provided accuracy within ± 2 of the actual steps.

After that, using Tool II, all groups completed a baseline week wearing a traditional pedometer (model KFJ-23 D), sealed with tape, for 7 days while awake (except during showering), with instructions not to alter their daily routine. The gamified and control groups wore only the traditional sealed Pedometer during baseline assessment and week 12.

After 12 weeks of intervention, physical performance was assessed using tool III, fatigue using tool IV, sleep quality using tool V, hemodynamic parameters using tool VI, and step count using tool II.

Ethical considerations

The study was approved by the Ethics Committee at the Faculty of Nursing, Mansoura University (P.0269), and was conducted in accordance with the Declaration of Helsinki. All patients provided informed written consent. Enrollment in the study was voluntary, and patients could withdraw without penalty. Assurances were given to maintain patient confidentiality and privacy, with data being kept private and encrypted.

Statistical analysis

The data were analyzed using the SPSS 27 program. The Shapiro-Wilke test was used to determine the normality of the data. Descriptive statistics were expressed through mean, standard deviation, median, interquartile range, frequency, and percentage, and inferential statistics included chi-square tests, Fisher's exact tests, paired t-tests, Mann–Whitney U tests, independent t-tests, Kruskal-Wallas tests, ANOVA tests, and Wilcoxon tests according to the normality of the distribution of data. The level of $p < 0.05$ was set as the statistical significance threshold.

Results

At baseline, no statistically significant differences were found between the three groups regarding age, gender, social status, education level, residence, dialysis adequacy, hemoglobin, BMI, HD duration, or comorbidities ($P > 0.05$) (Table 1).

A per-protocol analysis was conducted in this study, including only participants who completed the study according to the protocol. Those who dropped out or deviated from the assigned interventions were excluded from the final analysis.

Following the intervention, the step count increased significantly more in the smartphone-based gamified group with financial incentives than in the pedometer and control groups ($p < 0.001$). Moreover, the fatigue level decreased significantly only in the smartphone-based gamified group, with significant differences from the Pedometer and the control groups ($p = < 0.001$). Sleep quality was improved considerably in the smartphone-based gamified group only, with substantial differences from the pedometer and control groups ($p = < 0.001$). Concerning physical performance, no statistically significant differences were found between groups after the intervention; However, the paired comparison revealed considerable differences in only the smartphone-based gamified group ($P = 0.03$) (Table 2).

Regarding hemodynamics, no significant differences were shown between groups in SBP, DBP, RR, or HR following the intervention (*p* = *0.659, 0.355, 0.474, and 0.796*, respectively) (Table 3).

Discussion

According to evidence, all HD patients must be motivated to raise their PA levels. The present study examined whether smartphone pedometers with gamified elements (badges, competition, social interaction, and financial incentives) would increase PA in HD patients and affect fatigue level, sleep quality, physical function, and hemodynamics.

Regarding activity level, both the gamified and Pedometer groups significantly increased step count after the intervention; however, the difference in increase was significant between the two groups. Therefore, the hypothesis of our study was confirmed: gamified interventions can increase HD patients' activity levels in the gamified group compared to both the pedometer and control groups. This agreed with a study carried out among coronary heart disease patients where Smartphone-based gamified intervention significantly raised PA among patients in individual groups over twelve weeks, and this increase was sustained during the follow-up period [27]. Also, Mazeas et al. (2022) [15] reported statistically

Table 1 Comparison of demographic, medical, and activity levels of HD patients at baseline ($N=90$)

Variables	Gamified group $N=30$	Pedometer group $N=30$	Control group $N=30$	Significance
Age years	48[40–54]	48[44–55]	49[47–55]	K = 1.313 $p=0.519$
Gender				
Male	19 (63%)	21 (70%)	17 (57%)	$x^2=1.148$ $p=0.563$
Female	11 (37%)	9 (30%)	13 (43%)	
Social status				
Single	10 (33%)	5 (17%)	8 (27%)	$x^2=2.219$ $p=0.330$
Married	20 (67%)	25 (83%)	22 (73%)	
Education level				
Read and write	4 (13%)	5 (17%)	7 (23%)	$x^2=4.116$ $p=0.391$
Moderate level	18 (60%)	22 (73%)	19 (63%)	
Higher level	8 (27%)	3 (10%)	4 (13%)	
Residence				
Rural	13 (43%)	18 (60%)	17 (57%)	$x^2=1.875$ $p=0.392$
Urban	17 (57%)	12 (40%)	13 (43%)	
Std Kt/V	1.44[1.14–1.54]	1.34 [1.14–1.57]	1.34[1.14–1.44]	K = 1.143 $p=0.565$
Hemoglobin	11[11-12]	12[11-12]	11[11-12]	K = 4.307 $p=0.116$
BMI	27.3 ± 3	27 ± 3.11	27.9 ± 2.9	F = 0.652 $p=0.524$
Dialysis duration months	36[14.8–84.5]	38[19.5–57]	34.5[24–61.3]	K = .167 $p=0.920$
Comorbidities				
HTN	25 (83%)	24 (80%)	21 (70%)	$x^2=1.671$ $p=0.434$
DM	9 (30%)	6 (20%)	7 (23%)	$x^2=0.842$ $p=0.656$
CAD	6 (20%)	7 (23%)	5 (17%)	$x^2=0.417$ $p=0.812$
arrhythmia	5 (17%)	5 (17%)	4 (13%)	FET = 0.255 $p=0.919$
Currently smoking	5 (17%)	7 (23%)	4 (13%)	$x^2=1.064$ $p=0.587$
Baseline Activity Level				
Sedentary	22 (73%)	23 (77%)	27 (90%)	$x^2=2.917$ $p=0.233$
Low active	8 (27%)	7 (23%)	3 (10%)	

NB: Data presented as percentage or median [interquartile range]

Abbreviations: *BMI* body mass index, *Std Kt/V* standardized measure of dialysis adequacy, *HTN* hypertension, *DM* diabetes mellitus, *CAD* coronary artery disease, *K* Kruskal Wallis test, *FET* Fisher exact test, x^2 Chisquare test

significant differences when comparing gamified interventions to inactive control or active control groups receiving a non-gamified PA intervention. In contrast, Edney et al. (2020) [28] reported a non-significant difference in the gamified group compared to the basic self-monitoring app and the control group. This may be because this study was based on active team intervention, not individual intervention, as in our research, and teamwork may not be suitable for all individuals. In our study, only Leaderboards were used for social comparison to provide a competitive environment between patients and not to achieve goals as a team. Using a leaderboard as a social comparison tool increased PA among gamified groups [29]. In addition, we used real financial incentives, which are more suitable for adults than teamwork. This agrees with Agarwal et al. (2021) [16], who reported a significant increase in PA among groups receiving gamified intervention with social support and financial incentives;

Table 2 Step count, fatigue, sleep, and physical performance measurements before and after intervention in the gamified, Pedometer, and control groups

Variables	Time	Median score and interquartile range			Overall comparison	Between-group comparisons		
		Gamified group *N* = 30	Pedometer group *N* = 30	Control group *N* = 30		Gamified VS pedometer	Gamified VS control	Pedometer VS control
Step count	Before intervention	2928[1938–5054]	3885[2457–4995]	2701[2054–4020]	K = 1.994 $p = 0.369$			
	After intervention	6440[5025–8269]	5076[3537–6602]	2842[2053–3993]	K = 32.952 $p < 0.001$	$P = 0.04$*	$p < 0.001$ **	$P = 0.003$**
Sig		Z = —4.782 $p < 0.001$	Z = —4.001 $p < 0.001$	Z = —0.648 $p = 0.517$				
BFI	Before intervention	6.4[5.4–7.4]	6.3[5.2–7.2]	7[6–8]	K = 2.966 $p = 0.227$			
	After intervention	3.1[3-4]	5.2[4.2–7]	6.8[5.2–8]	K = 53.58 $p < 0.001$	$p < 0.001$ **	$p < 0.001$ **	$p = 0.089$
Sig		Z = —4.784 $p < 0.001$	Z = —3.895 $p < 0.001$	Z = —1.433 $p = 0.152$				
PSQI	Before intervention	9[8-10]	9[7–9.3]	9[8–9.3]	K = 1.833 $p = 0.400$			
	After intervention	4[4-6]	7[4-9]	8[7-10]	K = 34.796 $p < 0.001$	$P = 0.001$ **	$p < 0.001$ **	0.07
Sig		Z = —4.570 $p < 0.001$	Z = —2.933 $p = 0.003$	Z = —1.201 $p = 0.230$				
SPPB	Before intervention	9.5[8-11]	9.5[8–10.3]	9[8-10]	K = 0.862 $p = 0.650$			
	After intervention	10[9-11]	10[8-11]	9[8-10]	K = 4.387 $p = 0.112$			
Sig		Z = —2.132 $P = 0.03$	Z = —1.155 $P = 0.248$	Z = —0.905 $P = 0.366$				

Data presented as median [interquartile range]

Abbreviations: *BFI* Brief Fatigue Inventory, *PSQI* Pittsburgh Sleep Quality Index, *SPPB* Short physical performance battery

K: Kruskal Wallis test, Z: Wilcoxon test

[a] Adjustment for multiple comparisons: Bonferroni

[*] Significant at $P < .05$, **Highly significant at $P < .01$

however, the increase was not sustained during follow-up, which may be because the financial incentives in this study were virtual while in our study, they were real. However, other studies need to confirm whether gamified interventions with real financial incentives will lead to the maintenance of PA over the follow-up period in HD patients.

Concerning fatigue, only the gamified group significantly decreased fatigue levels after the intervention compared to both the pedometer and control groups. Therefore, the second hypothesis of our study was confirmed. This agrees with a multidimensional nurse-led study where walking, motivational interviewing, and nursing health education were provided over 6 months and significantly reduced fatigue among HD patients [30]. In contrast, Sheshadri et al. (2020) [8] reported a non-significant decrease in fatigue among HD patients who received a pedometer-based walking intervention with weekly step count goals over 3 months. This may be since in this study, the pedometer group achieved only a 2256 step difference from baseline after 3 months, while in our study, the gamified group achieved a mean difference of 3022 steps from baseline compared to the pedometer group, which achieved an increase of only 1340 steps. This proves that the higher the step count, the lower the fatigue level; Sheshadri et al. (2019) [5] reported that every 1000 steps per day lowers fatigue severity by 0.2 points among HD patients.

Concerning sleep, only the gamified group significantly showed improvement in sleep quality after the intervention compared to both the pedometer and control groups. Therefore, the third hypothesis of our study was confirmed. This agrees with Sheshadri et al. (2019) [5], where every 1000 steps daily lowers insomnia scores by 0.1 points among HD patients. Another study reported significantly improved sleep quality in the home-based

Table 3 Hemodynamic measurements before and after intervention in gamified, pedometer, and control groups

Variables	Time	Mean (SD)			Overall comparison
		Gamified group	Pedometer group	Control group	
SBP	Before intervention	142.9(20.7)	141.6(18.4)	142.4(19.3)	F = .063 p = 0.939
	After intervention	140.8(16.6)	140.2(17.7)	142.8(16.7)	F = 0.419 p = 0.659
Sig		t = 1.719 p = 0.096	t = 1.628 p = 0.114	t = —0.558 p = 0.581	
DBP	Before intervention	87.4(10.4)	84.6(13.1)	86.3(10)	K = 0.387 p = 0.824
	After intervention	86.4(7.9)	83.9(11.5)	87(9.2)	F = 1.049 p = 0.355
Sig		t = 0.855 p = 0.400	Z = —0.616 p = 0.538	t = −0.269 p = 0.790	
HR	Before intervention	80.9(10.1)	78.7(11)	79.4(11.9)	K = 0.895 p = 0.639
	After intervention	79.7(9.4)	77.2(10.9)	80(12.5)	F = 0.752 p = 0.474
Sig		Z = —1.594 p = 0.111	t = 0.982 p = 0.334	t = −0.849 p = 0.403	
RR	Before intervention	17.5(1.8)	17.7(1.7)	17.6(1.7)	K = 0.520 p = 0.771
	After intervention	17.2(1.3)	17.5(1.5)	17.4(1.9)	F = 0.228 p = 0.796
Sig		t = 1.511 p = 0.142	Z = —1.134 p = 0.257	t = −0.660 p = 0.514	

Data are presented as mean (SD)

Abbreviations: *SBP* Systolic Blood Pressure, *DBP* Diastolic Blood Pressure, *HR* Heart Rate, *RR* respiratory rate

F, one-way ANOVA; t, paired t-test; K, Kruskal Wallis test; Z: Wilcoxon test

walking exercises group [31]. In contrast, another study showed a non-statistically significant effect of intradialytic cycling on sleep quality among HD patients [32]. However, this study included only patients with restless leg syndrome, which is highly associated with insomnia [8]. In addition, a systemic review reported that moderate PA is more effective in enhancing sleep quality than vigorous activity [33].

In our study, despite improvements in step count, fatigue level, and sleep quality in the gamified group, no statistically significant difference was found between the groups regarding their physical function after the intervention. This is in accordance with Sheshadri et al. (2020) [8], who reported a non-statistically significant difference in physical performance after pedometer-based walking interventions. Another meta-analysis study reported that intradialytic exercises didn't result in substantial differences between groups in functional capacity [34]. In contrast, two studies reported that low-intensity walking interventions improved physical performance in HD patients [3, 35]. This may be due to the short intervention period (3 months) in our study and Sheshadri et al., 2020 [8], while the other two studies lasted 6 months. However, improving physical performance in HD patients is still a concern that needs further investigation to identify the intensity, type, time, and duration of the exercises required to increase HD patients' physical function.

Regarding hemodynamics, no statistically significant differences were found between groups after intervention. This agrees with Manfredini et al. (2017) [3], who reported non-significant changes in BP and HR after walking intervention. Also, a meta-analysis study reported a non-significant effect of exercises on either systolic or diastolic blood pressure at rest [36]. Another systematic review reported inconclusive data concerning exercise's effects on blood pressure [37]. In contrast, another study reported a significant impact of exercises on systolic and diastolic blood pressure among HD patients [38]. However, the training program in this study was conducted for four months and included resistance, cycling, and treadmill walking exercises, which have higher intensities than walking alone.

Limitations

However, our study has some limitations. First, no comparable studies have used gamified-based walking interventions in HD patients; few have used them in patients with chronic diseases, and most studies used gamification in healthy adults. Second, owing to limited resources, randomization was done by the scheduled time of dialysis rather than at the individual level; however, all groups were comparable at baseline. Third, all the study's subjects were adults and carried out in a single HD department. As a result, these findings can't be generalized to older people or other contexts. Finally, our intervention continued only for twelve weeks; thus, we could not evaluate the patients' long-term adherence to the exercise intervention and its effect on outcomes.

Conclusion and recommendations

Our study shows that a three-month smartphone-based gamified walking intervention increased HD patients' step counts, reduced their fatigue, and improved their sleep quality. The elements of gamification in our study (i.e., badges, goals, leaderboards, ranks, challenges, sweat coins, financial incentives, and social relations) created a positive competitive environment and fostered the patient's motivation to walk. A smartphone-based gamified walking program is accessible for HD patients and can be considered an effective motivational method to increase their activity level, foster their adherence, lower their fatigue, and improve sleep quality. We recommend that nurses use smartphone-gamified PA applications as a feasible, safe, and inexpensive nonpharmacological therapy for HD patients to monitor and increase their activity level and manage their fatigue and insomnia.

However, Future studies must evaluate whether gamified walking interventions would give the same results among elderly patients. Further research is required to assess if a more prolonged gamified walking program could enhance physical function or alleviate distressing symptoms among HD patients. Also, comparing gamified walking interventions to intradialytic exercises or a combination of both in terms of fatigue, insomnia, and physical function. Moreover, the long-term sustainability of this smartphone-gamified home-based walking program needs to be evaluated. In addition, objective measures of sleep quality, such as a sleep lab or accelerometer, should be employed to enhance the reliability of gamified walking intervention. Future studies should also explore user satisfaction and any challenges patients and healthcare providers face in detail. This would help to refine further and improve the app for broader use.

Nursing implications

Fatigue, trouble falling asleep, and poor physical function are the most common symptoms experienced by HD patients and affect their quality of life. More sedentary patients experience worsening of those symptoms, and despite this, the PA levels of HD Patients are very low. As a result, such patients should get regular PA training programs as part of their nursing care. Smartphone activity tracker applications are feasible for all patients. It incorporates many gamified elements and offers financial incentives that promote patient self-management engagement, the establishment of regular walking programs, and lifestyle adjustments. Nurses should monitor the activity level of patients and use gamification and financial incentives as behavior-change strategies for HD patients. Our finding supports the implementation of smartphone-gamified walking interventions to increase patients' step counts, reduce their fatigue, and enhance their sleep quality.

Reproductivity and repeatability

To ensure the reproducibility and repeatability of this study, standardized methodologies, and clear protocols were employed. The intervention, either a smartphone-based gamified or traditional pedometer walking program, was implemented consistently across participants using the same devices (3D Pedometer and smartphone applications) to track activity and outcomes. Moreover, the same traditional Pedometer was used to measure step count across three groups at baseline and after 12 weeks. Randomization was done by dialysis scheduled times, ensuring comparable baseline characteristics across groups. Blinded researchers collected data to minimize bias; outcome measures such as step counts, fatigue, and sleep quality were assessed using validated tools. The detailed description of the methods, including the randomization process, intervention structure, and data analysis, allows for the replication of the study. However, limitations such as the small sample size and single-site setting may impact the generalizability and long-term reproducibility of the results, suggesting the need for multi-site studies with larger sample sizes and more extended follow-up periods in future research.

Abbreviations

HD	Hemodialysis
ESRD	End-Stage Renal Disease
PSQI	Pittsburgh Sleep Quality Index
BFI	Brief Fatigue Inventory

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Authors' contributions

M. E.H. E contributed to conceptualization, methodology, analysis, writing, editing, and reviewing. R. Hcontributed to analysis, writing, editing, and reviewing. B.S contributed to writing, editing, and reviewing. E. S contributed to analysis, writing, editing, and reviewing. N.F.M.S contributed to methodology, analysis, writing, editing, and reviewing. A.A contributed to the methodology, analysis, writing, editing, and reviewing.

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Data availability

The data utilized to support the results of the research are accessible to the corresponding author upon request.

Declarations

Ethics approval and consent to participate

The study was approved by the Ethics Committee at the Faculty of Nursing, Mansoura University (P.0269) and was conducted in accordance with the Declaration of Helsinki. All patients provided informed written consent. Enrollment is the study was entirely voluntary, and patients could withdraw at any time without penalty. Assurances were given to maintain patient confidentiality and privacy, with data being kept private and encrypted.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

[1]Medical-Surgical Nursing Department, College of Nursing, Jouf University, Sakaka, Saudi Arabia. [2]Medical-Surgical Nursing Department, Faculty of Nursing, Mansoura University, Mansoura, Egypt. [3]Faculty of Nursing, Arab American University, 13 Zababdeh, P.O Box 240, Jenin, Palestine. [4]Mansoura Nephrology and Dialysis Unit, Internal Medicine Department, Faculty of Medicine, Mansoura University, Mansoura, Egypt. [5]Gerontological Nursing Department, Faculty of Nursing, Mansoura University, Mansoura, Egypt.

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