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Development of the Theory-Based Exercise Education and Prescription Smartphone Application for Sedentary Individuals: A Randomized Controlled Trial

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Abstract

Introduction: This study aims to develop and test a Cognitive-Behavioral Theory (CBT) based mobile application in accordance with the evidence-based physical activity recommendations in order to improve the health-related physical fitness parameters of university students with inadequate levels of physical activity.

Methods: Participants were selected from students at … University, who did not meet the lowest level of physical activity recommended by the World Health Organization and the American College of Sport Medicine for healthy adults for the past 6 months. Experimental research design with randomized control group was used in the study. Participants were randomly distributed into the experimental (n=63) and control groups (n=62). Participants in the experimental group performed an average of 40 minutes of aerobic, strength and flexibility exercises 4 days a week for 8 weeks, using the Exercise Education and Prescription (ERVE) mobile application, developed within the scope of the research. They also received CBT-based exercise education through the ERVE application. Participants were evaluated for health-related physical fitness parameters before and after the study.

Results: As a result of the 8-week application through ERVE, the maximum oxygen consumption, maximum push-ups, maximum sit-ups, hand grip strength and body flexion values of the participants in the experimental group was found to statistically significantly differ than that of the control group ($p<0.05$).

Conclusions: As a result, the ERVE mobile application can help university students with insufficient levels of physical activity increase their physical activity levels and improve some of the health-related physical fitness parameters.

1. Introduction

Physical inactivity, one of the risk factors for non-communicable diseases, is recognized as a global public health problem [1]. Low level of physical activity is cited among the causes of chronic diseases such as cardiovascular disease [2], stroke [3], hypertension [4], certain types of cancer [5], obesity, and Type 2 diabetes [6]. However, according to data from the World Health Organization (WHO), 1 in every 4 adults and 3 in every 4 adolescents (11–17 age group) on a global scale have insufficient levels of physical activity [7].

In order to avoid the negative effects of physical inactivity, WHO and ACSM recommend that adults in the 18–64 group should perform moderate to severe aerobic exercise for at least 150 minutes per week or high intensity exercise for at least 75 minutes, or an equivalent combination of moderate and high intensity exercises [7]. An exercise needs to be individually prescribed to increase the level of physical activity, and to minimize the risks of exercise [9]. Exercise prescription consists of sub-components such as intensity, duration, frequency, scope, progress, and type [10]. However, characteristics such as age, gender, health history, fitness status, socio-economic and environmental factors are other issues that need to be taken into account when preparing the right exercise prescription [11].

Another important problem with exercise is that commitment to exercise is low for various reasons and people cannot maintain exercise behavior. Cognitive-Behavioral Theory (CBT) is one of the theories used in creating a behavioral change or sustaining a behavior [13]. This approach aims to create and maintain desired behavioral changes in people by interfering with emotional, behavioral and cognitive processes. Looking at the literature, it is seen that training programs prepared with behavioral theories in mind increase the adaptation and continuation rates of individuals [14, 15].

In addition to increasing compliance to exercise with a theory-based approach for a habit of regular exercise, the idea that the Internet can also be used as a supporting tool comes to the fore in line with technological developments in this regard. Internet-based applications have been shown to increase physical activity levels of individuals with various chronic diseases, and have a positive effect on their treatment [16, 17]. One of the most common uses of the technology-based approach today is smartphone applications. However, meta-analysis studies that investigate the nature of existing mobile exercise applications show that most applications in app stores are designed in a way that focuses on drawing attention, visuals, and marketing, far from scientific evidence-based information [18, 19]. As a result of our review of mobile applications, there was no mobile exercise application that have CBT-based training support and take into account the physical activity recommendations by WHO and ACSM.

The aim of this study is to develop a CBT-based mobile exercise application that complies with evidence-based physical activity recommendations, and to investigate the change in health-related physical fitness parameters university students with insufficient physical activity levels.

2. Methods

2.1. Study Design

This study was conducted using the randomized control trial (RCT) research design. The study adhered the SPIRIT 2013 declaration [21], and the intervention was reported according to the CONSORT-EHEALTH checklist [22].

2.2. Participants

Before starting the study, the sample size to be used in the research was calculated using the G-Power 3.1 power analysis program. In the power analysis, analysis of variance for mixed measurements was taken into account for 80% statistical power (1-β) at 0.05 (α) level of significance, and it was calculated that the sample size of 98 individuals would be sufficient. Considering the losses in number of subjects that may occur during the study, a sample group was formed with 125 participants who volunteered for the study and met the research inclusion criteria. The schematic structure of the research design is presented in Fig. 1. Flow diagram of the study

(Fig. 1 is here)

First, the research was announced to the students at ... University through posters, mails and social media. Since most of the volunteers to participate in the study were female (74%), the study group included only female participants. By contacting potential participants (n = 181), participants who did not meet the research inclusion criteria were identified (n = 37). Hundred-and-forty-four participants who met the inclusion criteria were invited to ... University Sports Performance Laboratory for the first measurements. Among those invited, 19 people refused to participate in the first measurements for various reasons. As a result, the first measurements were made with a group of 125 subjects.

The inclusion criteria for the study were as follows: a) Individuals who are 18 years or older; b) who did not meet the lowest level of physical activity recommended for healthy adults for the last 6 months (regular physical activity 3–5 days a week, 150 minutes of moderate intensity or 75 minutes of high intensity); c) who have an Apple or Android-based smartphone with a data plan; d) who did not have a health problem diagnosed by health care providers that hinders participating a moderate-severe regular physical activity.

The exclusion criteria of the study were as follows: a) Data from participants who did not complete at least 24 (75%) of the 32 training sessions in the ERVE exercise application were not used in Per-Protocol Analysis.

2.3. Randomization

After the first measurements, participants were randomly assigned to the experimental and control groups due to the design of the research, participants could not be blinded in terms of their assigned groups. At the evaluation stage of the results, however, the researcher performing the analysis was blinded to the groups.

3. Intervention

3.1. Control Panel of the ERVE Mobile Exercise Application

The ERVE application has a web-based control panel that can be accessed by the research team. Content for the mobile application can be managed through this control panel. In addition, users' behavior in the application can be monitored instantly via the control panel. For example, data such as the user's login, the time to start and end a training session, and the number training sessions completed can be accessed through the control panel.

3.2. Interface of the ERVE Mobile Exercise Application

When ERVE is downloaded for the first time via Android Play Store and Apple Store, the user is asked to sign up with his/her email address and password. Registered and logged in users are welcomed by 5 different buttons (see Fig. 2).

(Fig. 2 is here)

3.3. Development of the ERVE Mobile Application

The content and features of the ERVE applications were designed with an interdisciplinary approach by a team of experts in the field of exercise, health and software. The main aim of ERVE is help university students with insufficient physical activity levels via a mobile application to meet the lowest level of physical activity recommended by WHO and ACSM for healthy adults.

3.3.1. Exercise Prescription Component

The purpose of the exercise prescription component is to increase participants' physical activity levels in order to improve their health-related physical fitness parameters. The exercise prescription component offers an exercise program designed by taking into account the evidence-based information in the exercise prescription and tests guideline of ACSM [12] and the minimum level of physical activity recommended by WHO and ACSM.

A 32-session exercise program for the target group was created within the mobile application. Each session lasts 40–45 minutes. The sessions were divided into 3 main categories: aerobics, strength and flexibility. Sessions were prepared on the basis of general FITT-VP principle of exercise prescription (F:frequency, I:Intensity, T:Time, T:Type, V:Volume, P:Progression) by using 112 different exercise movements that can be performed at home without any equipment.

3.3.2. Structure of the Exercise Program

Participants were provided 4 training sessions per week via the ERVE mobile application (frequency component). The main part of 2 weekly sessions is composed of cardio-based movements, and the main part of the other 2 sessions is composed of strength-based movements. The warm-up and cooling-down sections of each session are formed from movements based on flexibility. The Borg scale was used to determine the intensity of the exercises [23]. Prior to the application of the study, each participant was provided with the necessary information about the Borg scale and was expected to adjust the perceived difficulty level of the movements during the training sessions to 12 to 14 degrees of intensity (moderate intensity) (intensity component). The average duration of each exercise session is designed to be 40–45 minutes (duration component). Cardio exercises consisted of dynamic movements that can be performed in a home environment, which aims to raise pulse, strength exercises consisted of dynamic and static style movements to be performed without any equipment, but only the body weight, the preliminary flexibility exercises consisted of dynamic movements, and the final flexibility exercises consisted of static movements (type component). The scope of the exercise sessions was created by evaluating the duration, intensity and frequency components together, taking into account the fitness characteristics of individuals with insufficient physical activity levels (scope component). As the user moves between training sessions, the difficulty levels of the movements increase (progress component).

(Table 1 is here)

3.3.3. Exercise Education Component

A 7-part video training module was prepared in the exercise education component, accessible via the application. A training video was shared with users every week through the application. To allow the user to move to the next week's training video, the user must have watched the previous week's training video. This component of the mobile application is based on CBT principles, which include both behavioral and cognitive techniques to support change [13, 24]. Each training video focused on a specific topic planned to overcome the barriers to exercise and increase motivation and aimed to improve physical activity behavior. The focus of training is to eliminate negative thoughts about exercise and support exercise behavior.

Content of the Training Videos: 1) Benefits of exercise; 2) Setting goals; 3) Time management; 4) Exercise and coping with stress; 5) Exercise and coping with anger; 6) Setting and exceeding goals; 7) Exercise and coping with anxiety;

The physical activity behavior changes techniques used are as follows: providing information on the link between behavior and health link, informing about consequences, prompt barrier identification, providing instruction, providing a model or demonstrating the behavior, setting goals, motivational cuing, stress management, strategies for problem solving/coping, and time management [25].

3.4. Study Group

3.4.1. Control Group

Participants in the control group, however, were expected to maintain the level of physical activity they had. The pre- and post-test measurements of the participants in the control group were completed with an 8-week interval. At the end of the research, participants in the control group were given the opportunity to use ERVE according to their wishes.

3.4.2. Experimental Group

A document on how to use ERVE was provided to participants in the experimental group. Then, participants downloaded the ERVE application to their phones via Android and Apple stores. Participants in the experimental group were expected to regularly perform the ERVE exercise program for 8 weeks. On the other hand, participants were provided with expert support and CBT-based exercise education content through the application. After the first measurements, the final measurements were made in the participants in the experimental group after 8 weeks.

3.5. Measurements

Health-related physical fitness parameters of the participants were evaluated. For cardio-respiratory fitness, maximal oxygen consumption capacity (Max VO_2) was measured through the 20-meter shuttle run test. A hand dynamometer was used to evaluate the isometric strength. Maximum push-up and sit-up tests were used for determining the muscle endurance. For flexibility assessment, the flexibility at the hip joint, back, and hamstring muscles was evaluated by the trunk flexion test. For body composition evaluation, body mass index and body fat percentage were determined by the bio-electric impedance device.

3.6. Statistical Analyses

All the data were analyzed by SPSS (Statistical Package for Social Sciences), version 21 (SPSS Inc., Chicago, IL, USA). All participants in the experimental and control groups were included for intention-to-treat analyses. Baseline differences between the experimental group and the control group were evaluated using independent t-tests. Homogeneity of variance was investigated using the Levene test.

General Linear Model (GLM) repeated measures (RM) ANOVAs were used to determine the treatment effects of the ERVE app on body composition, muscular fitness, cardio-respiratory fitness, and flexibility in exercise. The GLM included time (pre- and post-test), condition (experimental group and control group) and time-by-condition as fixed effects and time as a repeated measure. Effect sizes were calculated with partial Eta squared (ηp^2) with small, medium and large effects defined as 0.01, 0.06 and 0.14, respectively. The level of significance was set at: $p < 0.05$.

3.7 Ethical Approval

Ethics approval numbered 60116787-020/4802 as obtained from the Ethics Committee of the Faculty of Medicine at ... University.

4. Results

At the beginning of the study, 125 participants were randomly assigned to the experimental (n=63) and control (n=62) groups. The average age of the participants was 21.51±1.50, and the minimum-maximum age range was 18-30. All participants were female. As a result of the first measurements, there was no difference between groups in terms of health-related physical fitness parameters (p>0.05).

4.1. Intent-to-Treat Analyses

Data from all participants (n=125) involved in the study were used in the Intent-to-Treat analysis. Regardless of the number of exercises for the experimental group, data from the entire study group were included in the analysis. In accordance with the Intent-to-Treat analysis, The first measurement results of the individuals who did not participate in the 2nd measurements were included in the analysis with the same values. For intention-to-treat analyses, two-way factorial repeated measures ANOVA was used to assess the main effects of condition and time, and the condition x time interaction (Table 2).

(Table 2 is here)

4.2. Per-Protocol Analyses

Per-Protocol analysis was used to see the change in health-related physical fitness parameters as a result of regular use of the ERVE mobile application. Only the results of participants who completed at least 24 or more of the 32 sessions within the ERVE mobile application were included in this analysis. In addition, data of individuals who did not participate in the second measurements were not included in the Per-Protocol analysis.

Twenty-five participants from the experimental group were not included in the Per-Protocol analyses since they performed less than 24 training sessions. Eleven people in the control group did not want to participate in the second measurements for various reasons. As a result, 38 people in the experimental group and 51 people in the control group were evaluated for analysis. Table 3 shows results of the per-protocol analyses outcomes.

(Table 3 is here)

5. Discussion

The aim of this study is to develop a CBT-based mobile exercise application that complies with evidence-based physical activity recommendations, and to investigate the change in health-related physical fitness parameters university students with insufficient physical activity levels. As a result of 8 weeks of use of the ERVE mobile application, the change in body weight, BMI, body fat ratio, max VO_2, hand grip strength, maximum push-ups, maximum sit-ups and body flexion values was investigated.

Looking at the change in the body composition of the participants, it can be stated that although there was a statistically significant difference ($p<0.05$) in the body weight and BMI values in favor of the experimental group as a result of the Intent-to-Treat analysis, there the change had no clinical significance. On the other hand, there was no statistically significant difference between the experimental and control groups in terms of body fat percentage ($p>0.05$). Participants received an average of 40 minutes aerobic exercises 2 days a week 2 days a week via the ERVE mobile application. These aerobic exercise sessions consist of dynamic movements based on time or repetition in order to increase the individual's pulse to a level above the resting pulse (for example, Jumping Jack, boxing, Burpee, etc.). Aerobic exercises may be the main reason for the statistically significant difference in body weight and BMI values between groups. This result is consistent with aerobic exercise studies in the literature [29]. On the other hand, poor clinical significance of this difference and no difference in body fat percentage may be due to short duration of the intervention and/or no intervention in the diet of the participants. It is observed in studies in the literature that changes in body fat ratio can be achieved over longer periods of time [30].

Considering the effectiveness of the application in terms of cardiorespiratory endurance characteristics, participants in the experimental group were found to statistically significantly differ compared to participants in the control group ($p<0.05$). However, the change in Max VO_2 has a moderate ($\eta p^2 = 0.09$) level impact according to the intent to treat analysis and a high level impact ($\eta p^2 = 0.21$) according to the per-protocol analysis. Looking at the max VO_2 values of the participants as a result of the first measurements in the study, their age group was found to be significantly lower than the average norm values [12]. This may be due to the insufficient physical activity levels of the participants. The ERVE mobile application aimed to keep participants in the experimental group physically active for an average of over 150 minutes per week (1 session is 40 minutes on the average; 4 sessions per week, 4 x 40 =160 min.). Therefore, the change seen in the max VO_2 values of the experimental group may be related to the increased physical activity level of the participants. The moderate level of impact according to the result of the Intent-to-Treat analysis, and the high level of impact according to the Per-Protocol analysis shows that the change observed in max VO_2 increases with the increase in the number of sessions performed. A positive relationship between high levels of physical activity and max VO_2 values of individuals has been shown in previous studies in the literature [31].

When we examined the changes in the muscular fitness parameter, a statistically significant difference was found in the values of right hand grip strength, maximum push-ups and maximum sit-ups in favor of the experimental group as a result of the Intent-to-Treat analysis ($p<0.05$). Moreover, the change in right hand grip strength had a moderate level of impact ($\eta p^2 = 0.09$), while the change in maximum push-ups ($\eta p^2 = 0.22$) and maximum sit-ups ($\eta p^2 = 0.28$) had a high level of impact. Participants were provided with approximately 40-minute strength exercises using their own body weight, without using an equipment, via the ERVE mobile application for 2 days a week (e.g., plank, sit-ups, push-ups, Russian twist, etc.) In addition, according to the progress principle of the exercise prescription, the difficulty level of the strength training movements was designed in an gradually-increasing manner. It has been shown in the literature that properly structured exercises can result in achieving significant changes in strength development [32,33].

When the body flexion values were examined to observe the change in flexibility characteristics, the experimental group was found to be statistically significantly different from the control group ($p<0.05$). According to the results of the Intent-to-Treat analysis, the change in the average values of the experimental group has a high level of impact ($\eta p^2=0.16$). In the ERVE application, the preliminary section of each exercise session contains dynamic warm-up flexibility exercises, and the final section contains static cooling flexibility exercises. Although the study group initially consisted of individuals with insufficient physical activity levels, no participant complained of an exercise-related injury or adverse condition at the end of the study. Studies in the literature show that low flexibility is positively associated with a high level of injury risk [34]. This may indicate that the flexibility training program in the ERVE mobile application allows the experimental group to appropriately improve their flexibility.

Along with all this information, recent research shows that mobile applications and the Internet-based approach are being used as an effective tool in the field of exercise and health. Researchers have tried to increase the level of physical activity or awareness in different groups, such as patients with cancer [41], children with heart disease [42], people with diabetes [43], the elderly [44] and office workers [45], through mobile applications. As a result of the literature review conducted in conjunction with these current approaches, there was no study of evidence-based physical activity recommendations with CBT-based training support. ERVE mobile exercise application can be stated to be the first study in the literature to have this approach.

Conclusion

As a result, the ERVE mobile application can help university students with low levels of physical activity increase their physical activity levels and improve their health-related physical fitness parameters, when used regularly.

Declarations

Author Contribution

…: Conceptualization, Data curation, Formal analysis, Methodology, Validation, Writing - review & editing. …: Data curation, Writing - review & editing, Supervision, Visualization.

Declaration of Competing Interests

The authors would like to declare that there is no issue related to conflict of interest for this study.

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Data Availability

Please contact the author for access to further information about the study.

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Tables

Table 1
Structure of the Exercise Program

Type	Duration	Intensity	Frequency	Volume
Flexibility Exercise	In the pre and post part of the exercise 10–15 Dk.	Borg scale (level 12–14)	4 day/week	Duration
Strength Exercise	In the main part of the exercise 30–40 dk.	Moderate level		x Intensity
Aerobic Exercise	In the main part of the exercise 40–45 dk.			x Frequency

***** An exercise session is designed solely as strength or cardio training. Flexibility exercises were performed in the pre and post parts of both training types.

Table 2
Intent-to-Treat analyses: Primary and secondary measure means, SDs, effect sizes, and F-values for condition, time, and condition × time interaction

Body Composition	Measure	Group	Pre-test	Post-test	Condition			Time			ConditionxTime		
			M (SD)	M (SD)	ηp^2	p	F	ηp^2	p	F	ηp^2	p	F
	Body Weight (kg)	Experimental	60.37 (9.55)	60.09 (9.17)	.01	.14	2.11	.00	.78	.07	.05	.01*	6.76
		Control	57.71 (9.09)	57.93 (9.28)									
	Body Mass Index (kg/m^2)	Experimental	23.10 (3.42)	22.99 (3.26)	.00	.77	.08	.00	.83	.04	.05	.01*	6.72
		Control	22.81 (3.96)	22.90 (4.04)									
	Body Fat Ratio (%)	Experimental	25.54 (7.19)	25.41 (7.24)	.00	.35	.85	.00	.33	.92	.01	.16	1.92
		Control	23.90 (7.59)	24.65 (7.75)									
Muscular Fitness	Right Hand Grip (kg)	Experimental	26.43 (3.76)	27.67 (3.97)	.07	.00*	9.64	.13	.00*	18.58	.09	.00*	12.25
		Control	24.88 (3.86)	25.01 (3.93)									
	Left Hand Grip (kg)	Experimental	24.98 (4.63)	25.64 (4.22)	.05	.01*	6.89	.05	.00*	7.00	.02	.09	2.79
		Control	23.51 (2.98)	23.66 (2.92)									
	Maximum Push-Ups (number)	Experimental	3.68 (3.85)	6.87 (5.33)	.06	.00*	8.30	.25	.00*	41.41	.22	.00*	35.22
		Control	3.30 (3.35)	3.43 (2.87)									
	Maximum Sit-Up (number)	Experimental	19.50 (10.35)	24.66 (10.50)	.07	.00*	9.98	.20	.00*	31.71	.28	.00*	48.60
		Control	16.72 (10.21)	16,17 (9,81)									
Cardio-Respiratory Fitness	Max VO_2 (ml/kg/dk)	Experimental	24.29 (2.57)	25.42 (2.99)	.01	.14	2.15	.22	.00*	35.86	.09	.00*	12.76
		Control	24.08 (2.19)	24.36 (2.19)									
Flexibility	Trunk Flexion (cm)	Experimental	6.04 (8.43)	8.90 (8.06)	.01	.17	1.88	.18	.00*	27.92	.16	.00*	24.73
		Control	5.29 (9.41)	5.38 (9.38)									

Experimental group: (n = 63), control group: (n = 62), M: Mean, SD: standard deviation, np^2: effect sizes, F: Test value, *$p < 0.05$

Table 3
Per-protocol analyses: Primary and secondary measure means, SDs, effect sizes, and F-values for condition, time, and condition × time interaction

Body Composition	Measure	Group	Pre-test	Post-test	Condition			Time			ConditionxTime		
			M (SD)	M (SD)	ηp^2	p	F	ηp^2	p	F	ηp^2	p	F
	Body Weight (kg)	Experimental	59.51 (8.88)	59.21 (8.53)	.00	.54	.36	.00	.90	.01	.06	.01*	6.29
		Control	58.04 (9.28)	58.32 (9.50)									
	Body Mass Index (kg/m^2)	Experimental	23.05 (3.43)	22.93 (3.23)	.00	.95	.00	.00	.89	.01	.06	.01*	6.26
		Control	22.88 (4.11)	22.99 (4.20)									
	Body Fat Ratio (%)	Experimental	25.31 (7.03)	25.04 (7.15)	.00	.72	.12	.00	.47	.51	.01	.19	1.71
		Control	24.17 (7.91)	25.08 (8.06)									
Muscular Fitness	Right Hand Grip (kg)	Experimental	26.30 (3.69)	28.20 (4.04)	.08	.00*	7.93	.26	.00*	31.04	.20	.00*	22.30
		Control	24.77 (4.18)	24.92 (4.25)									
	Left Hand Grip (kg)	Experimental	24.87 (5.06)	25.97 (3.04)	.05	.03*	4.75	.11	.00*	11.12	.06	.01*	5.72
		Control	23.55 (3.10)	23.73 (3.04)									
	Maximum Push-Ups (number)	Experimental	3.57 (3.53)	9.02 (5.06)	.14	.00*	14.96	.58	.00*	119.92	.55	.00*	106.87
		Control	3.27 (3.49)	3.43 (2.93)									
	Maximum Sit-Up (number)	Experimental	20.13 (10.48)	26.78 (9.84)	.13	.00*	13.20	.28	.00*	34.83	.37	.00*	52.07
		Control	16.09 (10.41)	15.43 (9.88)									
Cardio-Respiratory Fitness	Max VO_2 (ml/kg/dk)	Experimental	24.28 (2.49)	25.92 (3.11)	.02	.14	2.12	.38	.00*	55.06	.21	.00*	23.42
		Control	24.15 (2.32)	24.50 (2.31)									
Flexibility	Trunk Flexion (cm)	Experimental	6.92 (7.71)	10.73 (6.19)	.04	.05	3.78	.29	.00*	36.94	.27	.00*	33.05
		Control	5.29 (9.44)	5.40 (9.41)									

Experimental group: (n = 38), control group: (n = 51), M: Mean, SD: standard deviation, np^2: effect sizes, F: Test value, *$p < 0.05$

Figures

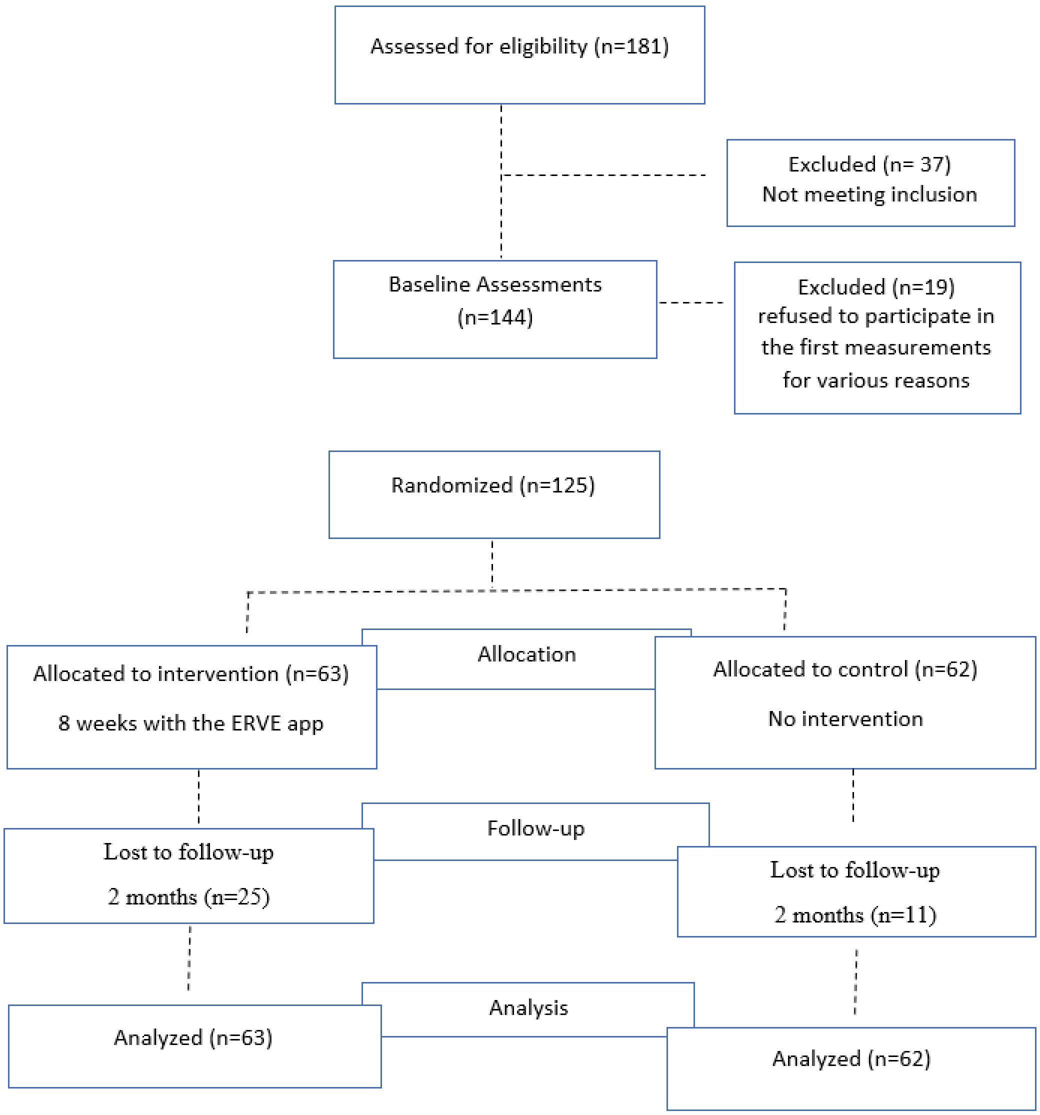

Figure 1

Flow diagram of the study

Figure 2

Screenshot ERVE app home page

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