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Biofeedback system in remotely monitored exercise program in pregnant women with obesity: a pre-experimental research

Sistema de biofeedback en un programa de ejercicio monitorizado a distancia en mujeres embarazadas con obesidad: una investigación preexperimental

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Abstract. Objectives: E-health programs may be an excellent strategy to overcome some barriers related to the non-practice of exercise among pregnant women with obesity. This study aims to present a monitored exercise program for pregnant women with obesity using the Sword Phoenix® biofeedback system; and to evaluate pregnant women's perception of the biofeedback system and the exercise program protocol. Methods: A pre-experimental research was done through a One-shot case study design. Twelve pregnant women with Body Mass Index ≥ 30 kg/m^2, were invited to perform for two weeks a home-based structured exercise program protocol with a digital biofeedback system, during exercise the women used an accelerometer to measure the intensity of the exercises. At the end of the two-week exercise period, the pregnant women filled in a questionnaire to assess their perception of usability, satisfaction, safety and motivation regarding exercise program and biofeedback system. Results: The accelerometry results indicate that, during the exercise program protocol, the pregnant women spent 79.3% of the time in moderate activities. The adherence to the program had an average performance of 40%. The results of the questionnaire demonstrated that 100% (n=12) of the participants enjoyed the system and recognized it as a safe instrument with the potential to increase physical activity during pregnancy.

Discussion: The biofeedback system can be a useful tool for implementing an exercise program for pregnant women with obesity. The proposed exercise program complies with international recommendations for physical exercise during pregnancy, ensuring safety. Additionally, it reduces the team intervention, increases participant motivation, and has the potential to reduce sedentary behavior in pregnant women with obesity.

Keywords: remote; e-health; pregnancy; exercise, obesity; physical activity

Resumen. Objetivos: Los programas de e-salud pueden ser una excelente estrategia para superar algunas barreras relacionadas con la no práctica de ejercicio entre las mujeres embarazadas con obesidad. Este estudio pretende presentar un programa de ejercicio monitorizado para mujeres embarazadas con obesidad utilizando el sistema de biofeedback Sword Phoenix®; y evaluar la percepción de las mujeres embarazadas sobre el sistema de biofeedback y el programa protocolo de ejercicio. Métodos: Se realizó una investigación pre-experimental mediante el diseño de estudio de caso único. Doce mujeres embarazadas con Índice de Masa Corporal ≥ 30 kg/m2, fueron invitadas a realizar durante dos semanas un programa protocolo de ejercicio estructurado en casa con un sistema de biofeedback digital, durante el ejercicio las mujeres utilizaron un acelerómetro para medir la intensidad de los ejercicios. Al final de las dos semanas de ejercicio, las embarazadas rellenaron un cuestionario para evaluar su percepción sobre la usabilidad, satisfacción, seguridad y motivación del programa de ejercicios y del sistema de biofeedback. Resultados: Los resultados de la acelerometría indican que, durante el programa protocolo de ejercicio, las embarazadas dedicaron el 79,3% del tiempo a actividades moderadas. La adherencia al programa tuvo un rendimiento medio del 40%. Los resultados del cuestionario demostraron que el 100% (n=12) de las participantes disfrutaron del sistema y lo reconocieron como un instrumento seguro con potencial para aumentar la actividad física durante el embarazo. Discusión: El sistema de biofeedback puede ser una herramienta útil para la implementación de un programa de ejercicios para mujeres embarazadas con obesidad. El programa de ejercicio propuesto cumple con las recomendaciones internacionales para el ejercicio físico durante el embarazo, garantizando la seguridad. Además, reduce la intervención del equipo, aumenta la motivación de los participantes y tiene el potencial de reducir el comportamiento sedentario en mujeres embarazadas con obesidad.

Palabras clave: e-salud; embarazo; ejercicio, obesidad; actividad física

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Introduction

The Obesity in pregnant women is a major public health problem and has been rising is rising in last few recent years (Driscoll & Gregory, 2020).

Maternal obesity has been linked to a variety of adverse health outcomes for mothers and newborns, including gestational diabetes mellitus, hypertensive disorders, premature births, cesarean deliveries and postpartum hemorrhages (ACOG, 2015b; Bernardo, Carvalho, Ferreira, et al., 2023; Marchi et al., 2015). To prevent comorbidities, a healthy lifestyle, including dietary changes and physical activity, is recommended for all pregnant women, but especially for those who had overweight or obesity (Bogaerts et al., 2014). According to the American College of Gynecologists and Obstetrics and Royal Australian and New Zealand College of Obstetricians and Gynecologists, exercise, which is a subset of physical activity "is a safe practice indicated for improve health outcomes during pregnancy, as long as the intensity, duration and frequency of the exercise are tailored" (ACOG, 2020; Gallo-Galán et al., 2023; RANZCOG, 2020). The Home-based programs, applied delivered with the help of the internet, and defined as e-health (da Fonseca et al., 2021), are an excellent strategy to overcome some barriers related to the non-practice of exercise on a regular basis (Banbury et al., 2018), and have the potential to reach large numbers of people at a relatively low cost and provide 24-hour access to intervention materials, which appears to increase convenience and adherence to programs (Joseph et al., 2014; Matheve et al., 2017). With the COVID-19 pandemic, it became important to develop programs that maintain good health practices while protecting users.

The use of e-health with monitored home-based programs is an increasingly frequent common reality and is used applied in large number or pathologies, namely neurological, cardiac, musculoskeletal diseases and in pregnant women with obesity (Bernardo, Bobadilla-agouborde, et al., 2024; Block et al., 2016; Brouwers et al., 2020; Correia et al., 2018, 2019; Gandolfi et al., 2017; Matheve et al., 2017; Vieira et al., 2017). Furthermore, it has the advantage of maintaining the physical distance between professionals and patients, reducing travel/commuting time to the therapy centers, improving access to specialized services, providing educational benefits (Sarsak, 2020), increasing patient autonomy and minimizing the need for real-time human supervision (Correia et al., 2019). All of the above may be particularly useful for those who live in rural areas, have limited mobility, are socially isolated, or fear meeting new people (Banbury et al., 2018).

In recent years, studies have been conducted on the implementation of exercise programs for pregnant women with obesity (Garnæs et al., 2019; Seneviratne et al., 2016; Wang et al., 2017). However, all of these programs have been conducted under face-to-face clinical supervision, and there have been no studies that have allowed pregnant women to exercise at home under remote supervision using a e-Health systems. As women of reproductive age are particularly frequent users of the internet and smartphone applications, they seem to be the main candidates for e-Health care (Van Den Heuvel et al., 2018). With this in mind, it is important to create a home-based exercise program protocol specific for this population to improve maternal and neonatal outcomes and reduce sedentary behavior. It is also important to point note that pregnancy is a period when women are in regular contact with health professionals and can be easily motivated to change their behavior, so it constituting a unique and critical window in which health care interventions or recommendations are more likely to be adapted (Gascoigne et al., 2023).

The purpose of the current study was to present a remotely monitored exercise program for pregnant women with obesity using Sword Phoenix® biofeedback system; and to evaluate the participant´s pregnant women's perception of the biofeedback and the exercise program protocol.

Methods

Study design and participants

This study used a single case study design (a pre-experimental design) consisting of a treatment (exercise program) followed by an evaluation (system perception questionnaire). This research design was chosen to allow the researchers to analyze, adjust and evaluate the intensity of the proposed exercise program. The final evaluation simply asked participants about their perceptions of the exercise program, the biofeedback system and its potential to increase physical activity during pregnancy. Participants were recruited in specific care appointments for pregnant women with obesity at obstetric departments of University Hospital Center of São João (CHUSJ), Porto (Portugal).. Figure 1 shows the sample recruitment diagram.

Eligible women were: (i) pregnant women with obesity (BMI ≥ 30 kg/m^2); and (ii) aged 18 or older. Exclusion criteria included: (i) previous bariatric surgery; (ii) hemodynamically significant heart disease; (iii) restrictive lung disease; (iv) incompetent cervix or cerclage; (v) multiple gestation; (vi) persistent second- or third-trimester bleeding; (vii) placenta previa after 26 weeks of gestation; (viii) premature labor during the current pregnancy; (ix) ruptured membranes; (x) preeclampsia or pregnancy-induced hypertension; (xi) severe anemia (ACOG, 2015a); and (xii) inability to read and understand Portuguese.

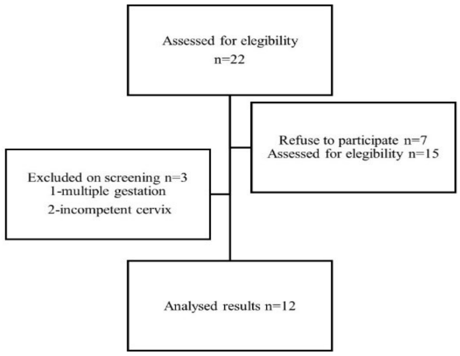

Figure 1. Flow diagram of patients through the study

Procedures

After recruitment, the women were invited to participate in a home-based exercise program with the biofeedback system (Phoenix ®). The physiotherapist in charge of the research instructed the pregnant women on the use of the biofeedback system and on the Borg scale to measure the perceived exercise intensity. The pregnant women were also asked to wear an accelerometer on the right anterior superior iliac crest during the home exercises in order to assess the intensity of the exercise. The daily data on the exercise execution (duration of exercises and frequency) were evaluated by the physiotherapist through the Sword Health platform. At the end of the 15 days of exercise, the biofeedback system and the accelerometer were collected, and the data were processed.

Biofeedback technical specifications

Sword Phoenix® (Figure 2) is a digital biofeedback feasible system for home-based physical rehabilitation developed by Sword Health Technologies, Inc. (Correia et al., 2021). For this particular study was adapted to prescribe

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exercise during pregnancy.

The system is composed by inertial motion trackers, placed on body segments that allow 3D movement quantification. For this study, the research team chose the Sword program "Active Living". This program uses five motion trackers: one on the right thigh, one on the left thigh, one on the right leg, one on the left leg and one tracker on the chest. The system digitizes pregnant women motion and communicates via Bluetooth with a tablet computer (Figure 3). The system provides a real-time audible biofeedback with a positioning correction message (e.g. "don't tilt your torso to the side", "lift your left knee") which indicate incorrect movements and allows participants to correct them in the following attempts, and a web-platform that allows the investigators to prescribe, monitor and adapt the exercise remotely (Correia et al., 2018, 2019). Upon the performance of a session, the results are uploaded to the platform and available for review. Based on this information, the clinical team can edit the session remotely and the pregnant woman can performed the exercise at home, without the need for constant supervision.

Exercise program protocol

The exercise program was individually tailored for pregnant women, by the physiotherapy team. We The research team developed the program for daily frequency, for 15 days and 30 minutes per session. The exercise list available, in the "Active Living" Sword Phoenix® system is described in Table 1, some exercises were adapted as the pregnancy progressed. Exercise intensity was set to ~60% of maximal capacity, corresponding to a 12-15 on the Borg scale (Borg, 1970). The research team tailored and adjusted the exercise program to for pregnant women individually. An example of an exercise prescription was is shown in Figure 3.

Figure 2. Sword Phoenix® Biofeedback System

Table 1.
Active living Sword Phoenix® System exercise list

Exercise Phase	Position	Exercise name	Description
Warm-up and Cold-down	Standing	March in the same spot	Hip flexion, below the waist level always in the same place.
		Knee flexion	Sitting on the chair, bend the knee, moving the foot backwards. One leg at a time.
		Hip abduction	Move the leg away from the midline of the body, bilaterally.
		Hip flexion with knee bend	Hip flexion with bended knee, until waist level.
		Hip Flexion with knee straight	Leg forward keeping the knee straight. One leg at a time.
		Hip Hyperextension	Leg backwards keeping the knee stretched throughout the movement. One leg at a time.
		Side Step	Step to the side. One leg at a time.
		Multidirectional steps	Hands-on waist and a step towards the requested direction.
		Square walking	Hands-on waist and take steps on different directions, drawing an imaginary square on the floor.
Conditioning	Standing	Climb a step	Lift the foot and put on the step, back to initial position. One leg at a time.
		Isometric forward lunge	Step forward and slightly bend the knees. Hold in that position. One leg at a time.
		Forward lunge	Step forward and bend the knee on that leg while taking the knee of the back leg to the ground. One leg at a time.
		Backward lunge	Step backwards and bend the knee towards the ground. One leg at a time.
		Side lunge	Open the leg to the side, keeping the foot pointing forward.
		Wall sit	Standing with back against the wall, bend the knees as if going to sit on a low chair.
		Squat	Bend the knees as if going to sit on a low chair.
		Isometric wall sit	Standing with the back against the wall, knees bended as if going to sit on a low chair. Hold in that position.
		Single leg squat	One knee bended as if going to sit on a low chair.
	Seated	Stand to sit	In front of a chair, lower the body down, sitting down on the chair.
	Lying	Hip flexion	Lie on back, lift the leg. One leg at a time.
		Hip flexion with knee bend	Lie on back, lift the leg while bending the knee. One leg at a time.
		Hip Abduction	Lie on back, open the leg to the side, keeping the foot pointing forward. one leg at a time.
		Straight leg raise	Lie on back, lift the leg, keeping the knee straight. One leg at a time.
		Clamshells	Lie on back, open the legs to the side without separating the feet.
		Bridge	Lie on back with knees bent. Raise the hips off the floor until hips are aligned with knees and shoulders.
		Unilateral bridge	Lie on back with knees bent. Raise the hips and one leg off the floor until hips are aligned with knees and shoulders. The knee oh raised leg is straight.
		Side lying hip abduction	Side lying on the floor move the leg away from the midline of the body.
		Side lying clamshells	Side lying on the floor, move the upper side, lying at the knee without separating the feet.
		Unilateral hamstring bridge	Lie on back, lift the hips from the bed using the one leg, always keeping the other leg raised.
Stretching	Standing	Hamstrings stretch	Place one foot in front of the other. Bend the body forward, keeping the front knee straight. Push the knee downwards with hands until the feel the back of thigh stretching. Hold this position. One side at a time.

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	Quadriceps stretch	Standing tall and holding onto a table or a rail, bend the knee backwards and hold the foot with hand, until feel the muscles stretching. Hold this position. One side at a time.
	Posterior leg stretch	Place the foot forward with knee slightly bent while keeping the other leg straight. Then, move the weight towards the front foot, until feel the backward leg stretching. Hold this position. One side at a time.
Lying	Posterior tight stretch	Lying on back, bring the knee towards the chest, with the help of hands, until feel the muscles stretching. Hold this position. One side at a time.
	Knee over to hand stretch	Lying on back with the legs straight, open the arms slightly. Bend the knee and move it to the ground, close to the opposite hand. Use it to keep the knee there. Hold this position and switch legs.

The "Active Living" program does not include sensors for assessing the upper limbs; however, patients are advised to keep their upper limb movements during the exercises

Figure 3. a) Motion trackers placed on body-segments. b) Pregnant women performing exercise in interaction with Sword Phoenix® system.

Accelerometer

To objectively assess the exercise intensity (Crouter et al., 2013), participants were asked to wear an accelerometer, with a belt attachment, on the right hip (Bernardo, Carvalho, Leirós-Rodríguez, et al., 2023; Harrison et al., 2011; Hayes et al., 2015; Kinnunen et al., 2011), while performing the exercise program protocol with Sword Phoenix® biofeedback. Accelerometers are portable devices that measure body segment accelerations and are considered the gold standard for assessing the intensity of physical activity, since they detect accelerations in three axes (i.e., vertical, medio-lateral and antero-posterior axes). The signal is usually filtered and pre-processed by the monitor to obtain activity counts (Migueles et al., 2017).

To collect the data, the research team used the Actigraph wGT3X-BT (Actigraph, Pensacola, Florida, USA) model. The accelerometers collected and analyzed movements in three different axes: vertical, anterior-posterior, and medio-lateral (ActiGraph Software Department, 2012). The Actigraph has been shown to be a good tool for predicting energy expenditure in young and adult populations (Santos-Lozano et al., 2013). It is also suitable for use during pregnancy (Conway et al., 2018) and has previously been used to assess physical activity in pregnant women with obesity (Hayes et al., 2015). The accelerometer output is digitized by a 12-bit analog-to-digital converter at a rate of 30 Hz. To obtain the Actigraph output in 'counts', each sample is summed over specific periods of time called 'epochs' which are defined as 5 seconds (ActiGraph Software Department, 2012). The counts obtained during a time period are linearly related to the subject's physical activity (PA) intensity during that period (Santos-Lozano et al., 2013).

The time spent by a pregnant woman at each activity level is expressed in minutes, and the intensity of activity during each recording period is expressed in counts (Santos-Lozano et al., 2013). Energy expenditure is expressed in counts.min-1 and is converted to metabolic equivalents (METs) in specific intensity levels: light (100-1952 counts.min-1), moderate (1953-5724 counts.min-1), and vigorous (> 5725 counts.min-1), according to the protocol adopted by Freedson et al. (1998) (Freedson et al., 1998; Harrison et al., 2011; Hayes et al., 2015; Kinnunen et al., 2011; Santos et al., 2016).

The PA perceived exertion was measured by the Borg Scale. After performing the exercise, pregnant women rated the effort in a scale of 6 "no exertion at all" to 20 "maximal exertion", if the perceived exertion ratings weren't between 12 to 15 on the Borg Scale, the women would send an SMS to the research team to adjust the exercise program by reducing the number of repetitions and replacing the exercises that presented greater difficulties with lighter intensity alternatives.

Pregnant women perception with biofeedback and exercise program

After the end of the protocol exercise program, the women filled out a questionnaire developed by the research team (appendix 1). This instrument was based on one applied in a study on home-based exercises using virtual reality for cardiac rehabilitation (Vieira et al., 2017). The aim of the questionnaire was to collect information in four different domains, biofeedback system usability; satisfaction; safety; and motivation to continue the exercise during pregnancy. They were asked if they had enjoyed the Sword Phoenix® presentation, if they considered the protocol exercise program to be adjusted to pregnancy, if they were motivated to continue performing the exercise program until the end of the pregnancy, and if they thought that Sword Phoenix® was an instrument with the potential to improve physical activity during pregnancy. They were also requested to refer, whenever appropriate, their main criticisms regarding to the biofeedback system.

Data Analysis

The data from the remote exercise sessions (number of sessions, execution time, exercise errors) was were taken from the Sword Health platform. The accelerometry data was were extracted using the Actigraph software and the pregnant women's perception questionnaire was collected at the end of the program and the data were exported to the database.

Statistics

Statistical analyses were performed using SPSS for Windows, Version 18 (IBM, Armonk, NY). Descriptive analysis was performed using absolute frequency, relative frequency, and measures of central tendency (mean) and dispersion (standard deviation) and percentages.

Results

Social-demographic and obstetric characteristics

Among 12 participants, 4 (33%) were in second gestational trimester, and 8 (66%) in third trimester. The mean of women's age was 29.7 ± 4.1 years old, and the mean of Body Mass Index were 34.0± 2.8 kg/m^2. Fifty-eight-point three percent (n=7) of women had a high education level and 91.7% (n=11) were employed. The sociodemographic and obstetric characteristics are shown in Table 2.

Table 2.
Socio-demographic and obstetric characteristics of sample at baseline (n=12)

Age (years), Mean (±SD)	29.7 (± 4.1)
18-29 years, n (%)	7 (58.3)
30-39 years, n (%)	5 (41.7)
Education Level	
Secondary, n (%)	5 (41.6)
College/University, n (%)	7 (58.3)
Professional Status	
Employed /Student, n (%)	11 (91.7)
Unemployed, n (%)	1 (8.3)
Gestational Trimester (weeks), Mean (±SD)	27.3 (±5.5)
2nd trimester, n (%)	4 (33)
3rd trimester, n (%)	8 (66)
Pre-gestational Body Mass Index (kg/m^2), Mean (±SD)	34.0 (± 2.8)
Obesity grade 1, n (%)	10 (83.3)
Obesity grade 2, n (%)	2 (16.7)
Baseline Body Mass Index (kg/m^2), Mean (±SD)	34.6 (±4.4)

Intensity exercise

The accelerometry results indicate that during the exercise program protocol the pregnant women spent 79.3% (mean of 23.8 ± 2.4 minutes/session) of the time in moderate activities (between 3.1 and 6 METs), and 20.7% (mean of 6.2 ± 2.4 minutes/session) in light activities, that corresponded to stretching exercises. The program was individually readjusted in a single case (one pregnant woman in the second day of the program) because the woman reported that the perceived exertion of effort was above 15 on the Borg scale. In parallel, the program was individually readjusted in three different pregnant women (on the 5th, 8th, and 12th days of the exercise program, respectively) because they reported exertion of effort below behind 12.

Adherence to the program

During the program duration, the adherence was a mean of 6.0±2.0 days (40% adherence rate). The pregnant women in the second gestational trimester had a mean of 5.0±2.4 days of exercise accomplished; and the pregnant women in the third gestational trimester had a mean 6.5±1.8 days. The data on Table 3 show the adherence rate was higher (44.0%) in women aged between 30-39 years old.

Table 3.
Adherence to the exercice program (n=12)

Days performing the exercise program	Mean (±SD)	Adherence rate (%)
All pregnant women	6.0 ± 2.0	40
By Gestational Trimester		
2nd trimester	5.0 ± 2.4	33.3
3rd trimester	6.5 ± 1.8	43.3
By Body Mass Index		
Obesity grade 1	5.0 ± 2.2	33.3
Obesity grade 2	6.5 ± 1.8	43.3
By Age		
18-29 years	5.6 ± 2.1	37.3
30-39 years	6.6 ± 1.9	44.0

Pregnant women perception with biofeedback and exercise program

According to the questionnaire, in terms of usability 100% of the participants (n=12) enjoyed the biofeedback system presentation and 33.3% (n=4) reported that were easy to use and 66.7% (n=8) reported that it was very easy (Figure 4). Regarding to satisfaction and safety domains, all pregnant women considered the biofeedback system and protocol exercise program to be adjusted and safe to perform during pregnancy, however, 2 (16.7%) pregnant women considered the time of exercise too long. Concerning the motivation domain, 83.3% (n=10) mentioned that without the biofeedback system do not had performed exercise during pregnancy and the pregnant women were unanimous in recognizing that biofeedback system as an instrument with potential to improve physical exercise during pregnancy. No criticism was pointed to out regarding the biofeedback system. Table 4 presents the overall results for each participant. Notably, the pregnant woman with the highest pregestational BMI perceived the duration of the exercise program as excessively long. She requested modifications to the exercise program due to a perceived exertion level above 15, demonstrated approximately 50% adherence to the program, and stated that without the exercise system, she would not have engaged in physical activity during her pregnancy.

Table 4.
Global results per participant

Participant Number	BMI (kg/m^2)	Gestational trimester	Adherence to exercise program (days)	Time in moderate intensity during the exercise (minutes)	Readjustment of the exercise intensity (Borg scale)	Perception of exercise time	Motivation to exercise without the use of the Sword system
1	39,76	Third	6	25	Borg > 15	Too Long	No
2	38,67	Third	9	22	Borg 12-15	Adequate	Yes
3	34,89	Third	7	26	Borg 12-15	Adequate	No
4	34,42	Third	3	18	Borg 12-15	Adequate	No
5	33,80	Third	8	23	Borg 12-15	Too Long	No
6	33,56	Second	2	25	Borg 12-15	Adequate	No
7	33,20	Second	4	26	Borg 12-15	Adequate	Yes
8	33,12	Second	7	24	Borg < 12	Adequate	No
9	33,09	Third	6	27	Borg <12	Adequate	No
10	32,46	Third	7	23	Adequate	Adequate	No
11	30,85	Second	7	22	Adequate	Adequate	No
12	30,46	Third	6	25	Borg < 12	Adequate	No

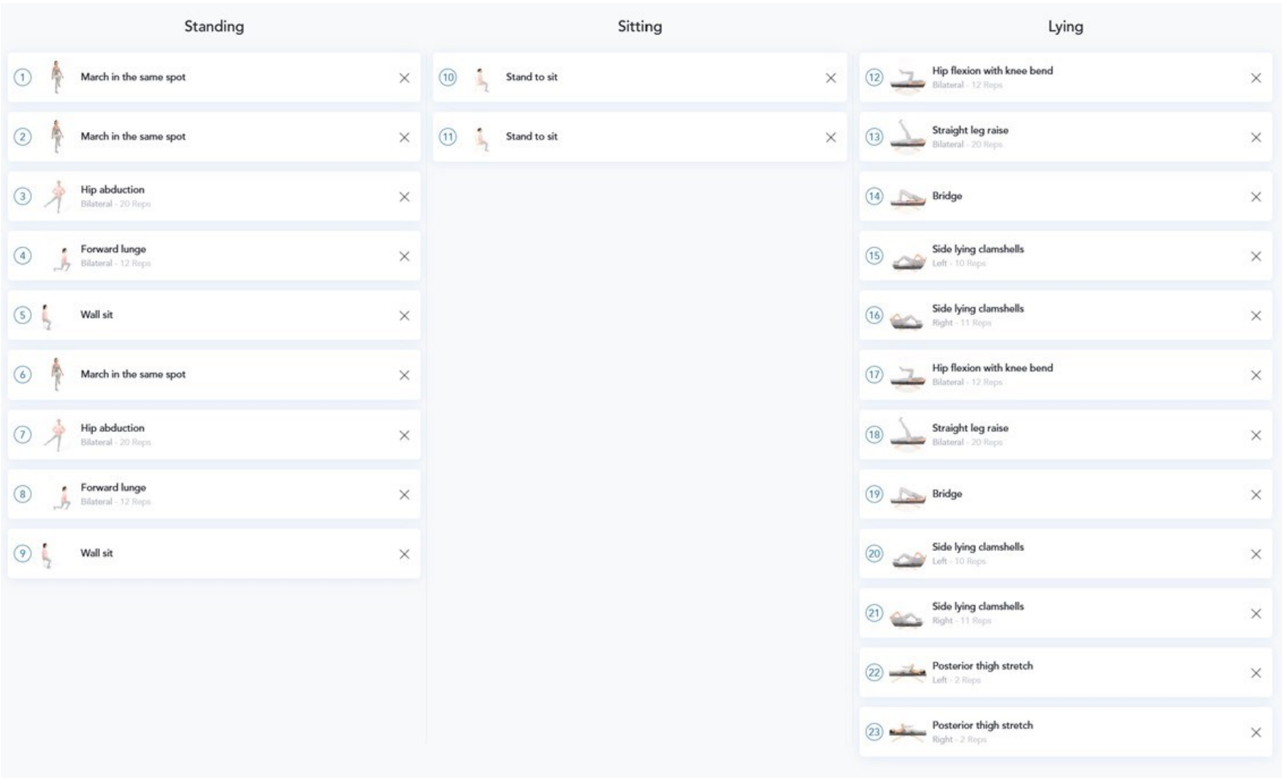

Figure 4. Exercise program example retrieved from the SWORD Health platform

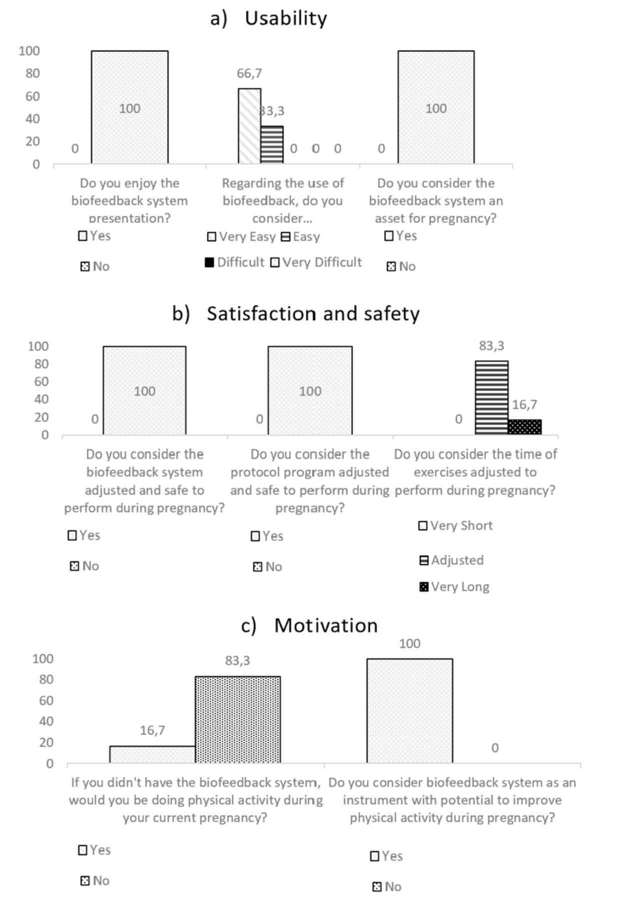

Figure 5. Pregnant women perception with biofeedback and exercise program. (a) Usability domain; (b) Satisfaction and safety domain; (c) Motivation domain.

Discussion

The data from this study show that the proposed remote monitored exercise protocol program, meets the recommendations of the American College of Obstetricians and Gynecologists (ACOG, 2020) and involved light-to-moderate intensity aerobic, resistance, and flexibility exercises. The main challenge faced by many of the home-based programs is how accurately and adequately do the patients follow the orders and perform prescribed exercises at home in the absence of a therapist (Hosseiniravandi et al., 2020). In the present study this issue was ensured due to the fact that we used a biofeedback with inertial sensors, which indicate the incorrect movement and record the sessions carried out, as well as the time of each session and the difficulty of performing the exercise (Correia et al., 2018).

Studies that aim to evaluate the effects of exercise programs on pregnant women with obesity are commonly analyzed (Bernardo, Carvalho, Conde, et al., 2023; Bisson et al., 2015; Garnæs et al., 2016; Seneviratne et al., 2016), however, to date this is the first study to analyze the potential of a remote exercise system on pregnant women with obesity. The remote program presented had similar results to supervised exercise programs (Bisson et al., 2015; Garnæs et al., 2016; Seneviratne et al., 2016) and has proven to be safe and adapted to prescribe exercise in pregnant women with obesity**.** The biofeedback functionalities combined with the fact that the exercise program was individualized and that pregnant women were always in touch with the research team allowed for adjusting the exercise program protocol and establishing the biofeedback acceptability. All participants rated the biofeedback system positively in satisfaction and safety and reporting that it helps hers them improve physical activity levels during pregnancy. This finding is consistent with what was identified in a previous systematic review, where the authors identified that the combination of increased patient empowerment and home pregnancy care could lead to more satisfaction and efficiency in perinatal care (Van Den Heuvel et al., 2018). Also the Additionally, the study carried out by Correia et al., 2018 (Correia et al., 2018) found that 90% of patients gave it the maximum recommendation of the Phoenix® system, proving the user satisfaction.

Although technology-supported lifestyle interventions in pregnancy hold potential as a safe and sustainable adjunct to traditional health-care models, performing exercise in a home context can present some limitations, especially in what concerns regard to exercise adherence (Fuchs et al., 2018). This study shows a low exercise program adherence, consistent results were also found in other studies among pregnant women with obesity (Bisson et al., 2015; Garnæs et al., 2016; Seneviratne et al., 2016), the pregnant women were low motivation to perform exercise (Hayes et al., 2015), and showed resistance to interventions and behavioral changes (Hui et al., 2014; Polley et al., 2002). Qualitative studies that have assessed barriers to physical activity during pregnancy state that environmental factors such as access to exercise opportunities educational factors (Morales-Suárez-Varela et al., 2023), including misconceptions about the safety of physical activity, sociocultural, socioeconomic, and individual factors, including physical and emotional barriers, are the main barriers to participation in physical activity during pregnancy (Kianfard et al., 2022). Some authors considered that e-health interventions motivate to engage in exercise programs (Ainscough et al., 2020; Gonzalez-Plaza et al., 2022) and the use of computer-tailoring in PA interventions among pregnant women seems to increase participant acceptability and efficacy (Banbury et al., 2018).

Some limitations of the current research should be considered. The small number of participants does not allow to for extrapolate the results, nonetheless, it was considered appropriate in for feasibility studies (Billingham et al., 2013), strategies to increase motivation and improve understanding of the benefits physical activity benefits literacy are necessary to improve adherence to therapeutic programs (Vieira et al., 2017). Another significant limitation was that the exercise program was conducted for only two weeks, a duration too short to draw conclusions about long-term adherence. To address this, it is essential to implement longer interventions. Such extended programs would enable participants to observe meaningful improvements in their physical capacity, mental health (Santos et al., 2024) and quality of life (Bernardo, Sousa, et al., 2024), which would likely enhance their motivation and, consequently, their adherence to the exercise regimen

This study shows that the Phoenix® biofeedback system can be a useful tool in the implementation of an exercise program among pregnant women with obesity, considering the positive feedback from by the participants which reduces staff intervention and enhances the participants' motivation to reduce sedentarism sedentary behavior.

Given the positive results of this study in terms of usability, safety, and motivation, it would be important to develop large-scale randomized trials to verify the clinical effects of the remote biofeedback exercise program on maternal outcomes (gestational weight gain, gestational diabetes, and cardiorespiratory fitness) and fetal outcomes (birth weight, Apgar scores).

Conclusion

This study shows that the Phoenix® biofeedback system can be a useful tool in the implementation of an exercise program among pregnant women with obesity, considering the positive feedback from by the participants, it reduces staff intervention and enhances the participants' motivation to reduce sedentarism sedentary behavior.

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Ethical considerations

The study was approved by the Ethics Committee of CHUSJ (N/REF.ª 35/22 (14/10/22) and it was conducted in accordance with the Declaration of Helsinki. All women gave their informed, written consent to participate, and the confidentiality of the data provided was assured.

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