Antenatal exercise using an innovative exergame program

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Doctor of Philosophy

under the supervision of
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Certificate of Original Authorship

I, Gemechu Kumera Wirtu declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the Faculty of Health, at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

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Preface

This thesis for the degree of Doctor of Philosophy is in the format of a thesis by compilation and abides by the 'Procedures for Presentation and Submission of Theses for Higher Degrees – University of Technology Sydney; Policies and Directions of the University'.

This thesis presents the feasibility, safety, acceptability and potential efficacy of antenatal exercise using an innovative exergame program. We have included three studies examining the safety, feasibility and acceptability of the home-based innovative exergame program for pregnant women. An introduction chapter provides descriptions of basic concepts mentioned in this thesis, including background information, significance of the research, aims, limitations and delimitations. A literature review chapter presents an overview of the health benefits of exergaming, levels of physical activity during pregnancy, and the effects of exercise interventions during pregnancy on pregnancy and birth outcomes. The three chapters, corresponding to Study 1, 2, and 3 are then organized following the progressive development of research concepts within this thesis. Findings and detailed descriptions of the methods used in the study are found in the respective chapters or studies. Each chapter or study follows a similar structure, encompassing an introduction, methods, results, discussion, and conclusion. The main findings from all studies are integrated into a discussion chapter, where the findings are interpreted and discussed in reference to relevant literature. The strength and limitations of the studies were also discussed. This thesis concludes with implications for practice, directions for future research and an overall summary.

Conference abstracts and Presentations

1. Kumera G, Garcia J, Duffield R, Salisbury J and Fox D: The suitability and safety of Nintendo switch exercise programs for pregnant women. Expert's Heuristic evaluation. ***The 6th Global Public Health Conference***: 23rd - 24th Feb, 2023| Colombo, Sri Lanka.

2. Kumera G, Garcia J, Duffield R, Salisbury J and Fox D: Heuristic evaluation of the suitability and safety of Nintendo switch exercise programs for pregnant women. ***HIPP EMR-C international Conference***: 18th Oct, 2022| Melbourne, Australia.

3. Kumera G, Garcia J, Duffield R, Salisbury J and Fox D: Heuristic evaluation of the suitability and safety of Nintendo switch exercise programs for pregnant women. "***Prenatal Society of Australia and New Zeeland Annual Congress:*** 5th-8th March, 2023| Melbourne, Australia.

4. Kumera G, Garcia J, Duffield R, Salisbury J and Fox D: Heuristic evaluation of the suitability and safety of Nintendo switch exercise programs for pregnant women. ***NSW Ministry of Health***: 11th August, 2022| St Leonards, Sydney.

5. Kumera G, Duffield R, Garcia J, Salisbury J and Fox D: Pregnant women's views and experiences of antenatal exercise using an innovative exergame program. ***Seminar organized by the collective for Midwifery, Child and Family Health, UTS on International day of the Midwife***: 5th May, 2023|Sydney.

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7. Kumera G, Garcia J, Duffield R, Salisbury J and Fox D: Heuristic evaluation of the suitability and safety of Nintendo switch exercise programs for pregnant women. ***UTS Annual Student Conference:*** 23rd - 24th Nov, 2022| Sydney, Australia.

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List of Abbreviations

BMI	Body Mass Index
CAG	Clinical Academic Group
GDM	Gestational Diabetes Mellitus
GH	Gestational Hypertension
GWG	Gestational weight gain
HE	Heuristic evaluation
HRECs	Human Research Ethics Committees
IOM	Institute of Medicine (National Academy of Medicine)
NSW	New South Wales
LTPA	Leisure-Time Physical Activity
PPAQ	Pregnancy Physical Activity Questionnaire
RANZCOG	Royal Australian and New Zealand College of Obstetricians and Gynaecologists
RCTs	Randomized Controlled Trials
SPHERE	The Sydney Partnership for Health, Education, Research and Enterprise
WHO	World Health Organization

Abstract

Regular physical activity during pregnancy is an important modifiable factor that can improve maternal physical and mental health and prevent adverse pregnancy and birth outcomes. Despite the significant health benefits of regular exercise, many pregnant women do not meet the current recommendations for physical activity, and others significantly decrease their physical activity participation during pregnancy. Perceived barriers to exercise for pregnant women have been identified, such as lack of motivation and enjoyment, physical discomfort, lack of time, unsuitable facilities, and uncertainty about how to exercise safely. Hence, to overcome many of these reported barriers, innovative approaches are required to engage pregnant women in regular physical activity and exercise. One such potential novel method involves exergames. An emerging technology that requires physical activity as part of gameplay, exergaming aims to promote physical activity through a medium that is engaging, fun and entertaining. However, the feasibility, safety and acceptability of using exergames have not been studied in pregnant women.

Hence, this thesis firstly aimed to evaluate the suitability and safety of exergame exercise programs (the Nintendo Switch) as a tool for pregnant women to exercise using expert's heuristic evaluation (Study 1). Following the implications for exercise prescription derived from the findings of Study 1, this thesis aimed to investigate the feasibility, safety and potential benefits of an exergaming programs tailored for pregnant women (Study 2). Lastly, this thesis aimed to explore pregnant women's views and experiences of the acceptability, benefits and potential barriers to using the home-based exergaming program (Study 3).

Study 1 involved the evaluation of the safety and suitability of Nintendo Switch exergame programs for pregnant women following the Heuristic Evaluation technique. The Heuristic Evaluation was undertaken by six experts with respective expertise in exercise physiology, midwifery, public health and exergame development. The major feasibility problems identified were inappropriate body position, intensity and mode of some exercises for pregnant women. Results suggested that rhythm games for legs and arms; minigames such as thigh rider, robo-wrecker, crate crasher, beginnia, and transient temple were appropriate to use during pregnancy. Further, structured exercises such as: front press, bow pull, squat, and thigh press could also be used by pregnant women.

Study 2 employed a single-arm pre-post testing design. Thirteen women participants were recruited via social media advertisements. The intervention consisted of prescribed exergaming sessions tailored for pregnancy using the Nintendo Switch console. Women participants were followed from trial entry (16 weeks of gestation) until 36 weeks of gestation/near birth. Results showed a significant increase in physical activity levels, from the trial entry to the mid-intervention ($p=0.01$). There was a significant positive correlation between physical activity levels (Mets) and adherence to the exergame exercise programs ($r=0.83$, $p=0.02$). There was no significant difference in systolic or diastolic blood pressure between trial entry and end of the intervention ($p>0.05$). However, none of the pregnant women were diagnosed with gestational hypertension or high blood pressure (>140/90). The mean gestational weight gain among women participants was 11.3 ± 4.4 kg and the mean birth weight was 3.55 ± 0.37 kg. No complications or adverse outcomes for both the mothers and babies were reported. The mean adherence to the exergaming program was 67.2±16.3%, and no injuries or contraindications associated with the exergaming program were reported.

Study 3 adopted a qualitative methodology to explore the experiences and views of pregnant women about the acceptability of the exergame programs. The study was conducted using semi-structured interviews. Twelve women participants were interviewed post-intervention (at 36 weeks of gestation/near birth). The women found that the exergaming programs are convenient, motivating and easy to use during pregnancy. The study findings suggest that exergames are a promising approach for encouraging regular exercise and addressing barriers to physical activity during pregnancy. The inclusion of user experience further confirms that tailored exercise programs are crucial, reaffirming the need for further customisation.

Overall, the exergaming program was found to be a safe, enjoyable and feasible approach for encouraging physical activity during pregnancy, given that exercise programs were designed by experts to be safe and appropriate for each trimester, and tailored according to individual pregnant women's needs and preferences. The study findings also demonstrated that the exergaming program has the potential to increase physical activity levels with acceptable adherence. These findings imply that exergames could provide a convenient and suitable option for pregnant women looking to incorporate exercise into their routine, particularly for those facing barriers to conventional physical activity, such as lack of motivation, limited access to outdoor activities or training facilities, limited time, or uncertainty how to exercise safely. The findings of this thesis have important implications for future game design to consider pregnant women's limitations and preferences. Further larger-scale randomized control trials are warranted to investigate the effects of exergaming during pregnancy.

Chapter One

Introduction

1.1. Background

1.1.1. Physical activity during pregnancy

Regular physical activity during pregnancy supports the health and well-being of both the mother and her unborn baby (1-4). For a normal and healthy pregnancy, the current physical activity guidelines encourage that pre-pregnancy physical activity be continued during pregnancy, whilst sedentary women commence exercising during pregnancy (2-4). Despite these recommendations, many pregnant women lead lifestyles that are sedentary, and for others there is a progressive decrease in physical activity across trimesters of pregnancy (4-6).

Current guidelines for physical activity during pregnancy recommend that all women without contraindications should perform an exercise program that leads to a goal of moderate-intensity physical activity for at least 30 minutes per day on most days of the week (2-4). However, only one-third (30%) of Australian pregnant women perform regular physical activity during pregnancy as per recommendations (1). The majority of pregnant women (70%) do not meet this recommendation, with just over half (54%) being insufficiently active and 16% inactive (1). Such lack of physical activity during pregnancy is a concern, as sedentary behaviour during pregnancy is strongly associated with substantial increase in short- and long-term adverse outcomes for both the mother and her baby during pregnancy, birth and the postnatal period (7-9).

Hence, providing individualised interventions to assist sedentary pregnant women to increase physical activity and reduce the risk of associated adverse maternal and neonatal outcomes is critical (10, 11). Sedentary behaviour is defined as any waking behaviour characterised by an energy expenditure of ≤ 1.5 METs (metabolic equivalents) while reclining, lying, or sitting (12).

A metabolic equivalent (MET) is a method used to measure the intensity of various physical activities (13). MET is defined as the amount of oxygen consumed at rest while sitting quietly in a chair, approximately 3.5 ml 0_2/kg/min. Concerns regarding sedentary/inactive lifestyles in pregnant women relate to the implications for the health of mothers and their babies, particularly related to associated adverse obstetric outcomes (7-9). For example, sedentary pregnant women have a higher risk of pregnancy complications, including hypertensive disorders, gestational diabetes mellitus, and are more likely to exceed healthy weight gain guidelines (8, 14-16). Pregnant women who are sedentary are also at a risk of complications and medical intervention during labour and birth, including instrumental birth and caesarean section (17-19). Furthermore, a sedentary lifestyle during pregnancy is also associated with adverse neonatal outcomes, such as macrosomia, preterm birth and a risk of future childhood obesity (9, 20, 21). Preventive strategies are needed to reduce the adverse pregnancy and birth outcomes associated with a sedentary lifestyle during pregnancy, with increasing regular physical activity being one of the most important approaches for its prevention.

The global prevalence of overweight and obesity has been significantly increasing over recent decades (22, 23), including among women of reproductive age (24). Although it is advisable that women achieve normal Body Mass Index (18.5 to 24.9 kg/m2) prior to pregnancy, an increasing number of women enter pregnancy at a BMI of >30 kg/m^2, raising significant implications for their perinatal health and for maternity care services (25-27). Obesity and overweight are commonly classified based on the body mass index (BMI) values. However, for pregnant women, a BMI of ≥ 30 kg/m^2 at the first antenatal visit is defined as obese, while increases in BMI are expected during pregnancy (27-29). In the Australian context, half (50.4%) the population of women of childbearing age are above a healthy weight, and one in four women have a BMI of ≥30kg/m^2 (30). The increasing rates of overweight and obesity during pregnancy are of concern, given the significant health consequences for both mothers and babies.

Regular physical activity and exercise during pregnancy have been identified as important modifiable factors to assist with weight management, reduce the risks of hypertensive disorders and gestational diabetes mellitus, and prevent complications during pregnancy (4, 10, 11, 31). International and national guidelines for physical activity during pregnancy recommend that all women without contraindications should perform an exercise program that leads to moderate-intensity physical activity for at least 30 minutes per day on most or all days of the week (2, 3, 32). In particular, the recent guidelines from the Royal Australian and New Zealand College of Obstetricians and Gynaecologists (RANZCOG) recommend that all healthy pregnant women should aim for 150 to 300 minutes of moderate intensity physical activity for at least 30 minutes per day on most, preferably all, days each week, in the absence of specific contraindications (2). However, these recommendations are based on limited evidence, given the lack of research regarding the safety or additional benefit of exercising at levels above these recommendations. Regardless, pregnant women should be encouraged to be physically active, and methods to encourage and engage pregnant women in regular physical activity are critical for healthy outcomes in mother and baby.

Initiating exercise during pregnancy may not be feasible for many women due to a number of perceived barriers to physical activity for the pregnant woman, such as lack of motivation and enjoyment, fatigue, physical discomfort, and concerns regarding fetal harm and pregnancy complications (33, 34). In addition, there are external factors that are perceived as barriers to exercise, such as lack of time, unsuitable facilities, lack of outdoor spaces to be active, uncertainty about how to exercise safely, and lack of childcare (33, 34). Therefore, novel exercise methods that overcome many of these barriers to exercise during pregnancy and promote physical activity are required.

1.1.2. Health benefits of exergaming

A novel method to promote exercise in otherwise sedentary populations may be via exergames (active video games). Recently, exergames have been found to encourage physical activity among sedentary and high-risk populations (35, 36) and have the potential to promote regular engagement in physical activity (37). Exergaming is an emerging technology that requires physical activity as part of gameplay, aiming to promote physical activity through a medium that is engaging, fun and entertaining (38-40). Exergaming requires the players to physically interact with the gaming console via a variety of body movements, such as walking, jogging and upper- and lower-body limb movements to control the characters or aspects of the game. They can be suitable for people of all fitness levels in various settings such as homes, antenatal clinics, community centres and fitness centres. Exergames can be played on a variety of devices such as consoles, computers and TV, and may be designed for solo play or multiplayer modes, allowing online interaction with others. One example of an extremely popular gaming console that is available worldwide is the Nintendo Switch and accompanying Ring Fit (Figure 1.1). Exergames are reported to be relatively safe, inexpensive and have already proven to be popular among sedentary and high-risk groups (35, 36, 41). As an example of the efficacy of exergaming, a number of studies rated playing exergames as light to moderate intensity physical activity that can contribute to daily minimal requirements of physical activity levels (42, 43). However, the optimal duration and intensity of the exergaming to provide maximal health benefits remains ambiguous, and it is also uncertain whether current exergames are feasible and acceptable to pregnant women.

Figure 1.1. Nintendo Switch Ring fit in action.

The use of an entertaining and interactive gaming (exergame) system for exercise has been shown to encourage inactive individuals to be more physically active (44). The engaging nature of these exergames may be due to the integration of physical activity with electronic games, to make exercise motivating and enjoyable (45). Enjoyment during exergaming is a primary reason why exergames may be a promising substitute to traditional physical activity and have the potential to promote long-term engagement in regular physical activity (37, 46-49). Research in non-pregnant populations has shown that playing exergames have a positive impact on physiological factors (for example, higher energy expenditure, maximum heart rate, and maximum oxygen uptake) (43, 50-52), psychological factors (for example, greater enjoyment and motivation, and improved mental health) (46-48, 53-58), and greater adherence to training (37, 49). Exergaming has also been shown to have a positive effect on physical fitness (59), attitudes towards participating in other forms of exercise (60), and weight management (61-67) in non-pregnant populations. However, it is unknown whether exergames can provide health benefits for pregnant women.

In summary, exergaming has been proposed as a method to encourage physical activity in sedentary and high-risk populations (35, 36, 61). Fittingly, exergames may be advantageous to aid motivation for exercise by connecting the fun of electronic games with physical activity in the home environment (44, 45). Home based exergaming provides a unique avenue for sedentary or inactive individuals to incorporate regular and intense physical activity into their daily activities (68, 69). This is particularly important for pregnant women with sedentary lifestyles because they are less likely to engage in regular physical activity (70) within public settings such as gyms or parks. Home based exergaming may be more desirable than exercising in groups, especially for women above a healthy weight who may have a poor body image (71-73). Moreover, in circumstances where access to training facilities is limited due to factors such as transport, climate or pandemic conditions, home-based exergaming options are preferable, palatable and enjoyable to ensure continued physical activity. However, the feasibility, safety and acceptability of using exergaming during pregnancy, as well as its potential impact on pregnancy and birth outcomes, have not been studied before. Thus, this thesis will investigate the feasibility, safety and acceptability of a home-based exergaming intervention during pregnancy and investigate its associations with improved health in pregnancy and birth outcomes.

1.2. Aims

Despite the significant health benefits of regular exercise during pregnancy, many pregnant women find it challenging to meet physical activity recommendations during pregnancy due to perceived barriers to physical activity. Hence, novel exercise methods to overcome these barriers and promote physical activity are required. One such potential innovative approach may be via exergames. In turn, this thesis aims to:

1. Evaluate the suitability and safety of a commercially available exergame (the Nintendo Switch) as a tool for pregnant women to exercise, using expert's heuristic evaluation (Study 1).
2. Investigate the feasibility, safety and potential benefits of a home-based exergaming intervention for pregnant women (Study 2).
3. Explore pregnant women's views and experiences of the home-based exergaming intervention (Study 3).

1.3. Significance of the research

Many pregnant women either do not meet recommendations for physical activity, or reduce their level of physical activity while pregnant (74, 75). Women who are sedentary/inactive during pregnancy are a crucial group to target for lifestyle interventions, given their higher risk for adverse pregnancy and birth outcomes (76-78). To mitigate these adverse pregnancy and birth outcomes, preventive strategies are required, with novel exercise methods to encourage regular physical activity being the most important approach. Given the perceived barriers to physical activity for pregnant women identified earlier, innovative approaches to engage pregnant women in regular and safe exercise in their own environments are critical. One such potential novel approach to promote regular exercise and overcome barriers to physical activity during pregnancy may be via exergames.

Home-based exergaming has the potential to overcome some of the perceived barriers to physical activity during pregnancy, as it provides an opportunity to undertake physical activity in the safety, convenience and privacy of their own home. This is particularly meaningful for women who have sedentary lifestyles and are above a healthy weight during pregnancy, who may be less likely to travel to engage in regular physical activity in traditional exercise settings (73, 79). Home-based exergaming may be more desirable than exercising in groups for women who prefer not to engage in exercise groups for personal or cultural reasons. Exergaming (Nintendo Switch) provides the player with training, support and instruction on how to exercise using the console, and enables online connection and social networking with other players.

This innovative study is the first project to evaluate a home-based exergaming intervention aiming to improve maternal and birth outcomes in pregnant women. It addresses a key indicator identified by the NSW Health (Australia) 'Get Healthy in Pregnancy' Program, that women require multimodal support to meet National guidelines for physical activity and exercise goals throughout pregnancy. Evidence garnered from the current study will provide evidence for the feasibility, safety, and acceptability for a future larger Randomised Control Trials (RCTs) in a clinical environment. The findings of this project may provide evidence for designing future health promotion policies and recommendations for improving the likelihood for women to reach the weekly physical activity guidelines during pregnancy.

1.4. Limitations

- A possible limitation of this study might be the small sample size, which could limit the generalisability of the findings to the wider pregnant women population.
- The recruitment of women participants via social media might introduce participation biases/self-selection bias.
- A feasibility study was required to demonstrate the safety of exergaming program for pregnant women before a NSW Health ethics committee would accept an application to run a clinical trial in a health service/clinical setting. As a result, we had to redesign the project from a RCT in a clinical setting to a feasibility study.
- As there are no prior studies on the use exergaming as tool to exercise during pregnancy, this made it difficult to compare study results.

1.5. Delimitations

- We recruited voluntary pregnant women who have no known contraindication to physical activity via social media advertisement. We used this approach as we were unable to obtain permission from the NSW Health HREC to conduct the study in one of their facilities without a prior feasibility study.
- There are many exergames/exercise games on the market currently, each offering different types of exercise and intensity levels. In the current study, we selected the Nintendo Switch console as it offers a full-body workout, including low-impact aerobic exercises, resistance/strength training exercise and yoga that can be tailored for pregnant women. Additionally, the Nintendo Switch provides exercise programs which are fun and engaging.

- We did not employ objective tools such as, heart rate monitors to measure the intensity of the exercise programs. However, the exergaming programs were tailored to accommodate the common limitations experienced by pregnant women and physiological changes that occur during pregnancy. The exercise program commenced with lower intensity and volume of exercise followed by a gradual increase, and then the volume and intensity of exergaming were progressively decreased again in late pregnancy.

- The restrictions and lockdowns caused by the COVID-19 pandemic posed delays in recruiting women participants. Additionally, the COVID-19 pandemic affected the willingness of pregnant women to attend UTS City Campus. Moreover, the pandemic made it difficult to conduct in-person familiarization and/or training sessions at the UTS City Campus due to the lockdowns. As a solution to this challenge, we have adopted an alternate method by conducting virtual sessions via Zoom. This approach broadened our reach to include women participants from other regions across Australia, including those in rural settings.

Chapter 2

Literature Review

2.1. Overview and approach to the literature review

This literature search strategy included a specific focus on literature exploring exergaming exercise programs in pregnancy. The literature search included electronic databases of Medline/PubMed, Embase, Scopus, Cochrane Library, CINAHL and SPORT Discus to source the literature. The keywords used as search terms to narrow the search were: physical activity* or exercise*, exergam* or video gam* or interactive gam* or active gam* or Nintendo* or computer gam* or serious gam*. Only papers published in the English language were considered in the search. Additional studies were identified by reviewing the references cited by each eligible study. However, no literature was identified that specifically addressed the topic of exergaming as tool for exercise in the context of pregnancy.

Due to the lack of literature about exergaming in pregnancy, any study that used exergaming as an intervention to enhance physical activity and improve health outcomes was deemed eligible for inclusion. The aim of this literature review was to establish the conceptual background for this thesis by providing an overview and summary of existing knowledge exploring the health benefits of exergaming in non-pregnant populations. The purpose was to inform the development of an exergaming program for pregnant women. The first part of this literature review explores the effects of physical activity interventions during pregnancy on outcomes such as gestational weight gain, gestational hypertension, mental health and birth outcomes. The search was made in MEDLINE/PubMed, with additional articles searched in Google Scholar.

2.2. Health benefits of exercise during pregnancy

Regular exercise is generally acknowledged as a way to remain healthy and to reduce complications during pregnancy (80). Several health benefits of physical activity during pregnancy have been documented in the literature, including reduced risk of hypertensive disorders and gestational diabetes, improved cardiovascular health, enhanced mental well-being, better weight management, faster postpartum recovery and positive neonatal outcomes (2, 4, 10, 11, 19, 31). According to the Canadian Guidelines for Physical Activity during Pregnancy (2019), regular exercise during pregnancy has been shown to have numerous positive effects for both mother and their babies. These benefits include reduced risk of excessive weight gain, improved cardiovascular fitness and reduced pregnancy complications. Overall, this review suggested that despite some concerns, the benefits of exercise during pregnancy outweigh any potential harms (3). Further, the guidelines suggest that incorporating exercise into a pregnant woman's routine is both safe and achievable.

A systematic review and meta-analysis that aimed to investigate the relationship between prenatal exercise, gestational weight gain, and postpartum weight retention, further supports the health benefits of exercise during pregnancy (10). The findings of this review demonstrated that exercise interventions during pregnancy have the potential to prevent excessive gestational weight gain and reduce postpartum weight retention; however, the quality of the evidence was low to moderate. Exercise only interventions decreased total gestational weight gain (n=5819; −0.9 kg, 95%CI −1.23 to –0.57 kg, I2 =52%) and reduced the odds of excessive gestational weight gain (n=3519; OR 0.68, 95%CI 0.57 to 0.80, I2 =12%) compared with no exercise. A dose–response relationship was found between prenatal exercise duration, frequency and volume and total gestational weight gain. Similarly, exercise only interventions decreased postpartum weight retention (n=420; −0.92 kg, 95%CI −1.84 to 0.00 kg, I2 =0%) compared with no exercise (10). Overall, almost all evidence from the literature demonstrates that engaging in regular physical activity during pregnancy is beneficial for both the mother and her baby.

2.2.1. Physical activity and gestational weight gain

Gestational weight gain is an important factor that needs significant research and practitioner attention, as excessive weight gain during pregnancy is associated with adverse pregnancy and birth outcomes (10). Evidence from the literature shows that exercise during pregnancy can potentially reduce excessive gestational weight gain. For example, a randomised controlled trial (RCT) involving 962 healthy pregnant women, randomly assigned to either an exercise intervention group or a standard care group, showed that exercise interventions reduced excessive gestational weight gain (EGWG) compared to the control (standard care) group (81). The exercise intervention involved supervised light- to moderate-intensity aerobic and resistance exercises performed three days a week (50-55 minutes per session). Women in the exercise intervention group gained less weight compared to those in the control group (mean difference, 1.039 kg; 95% CI, 0.534-1.545 kg; p<.001). They were also less likely to exceed weight gain beyond the IOM/National Academy of Medicine recommendations compared to those in the control group (odds ratio, 0.625; 95% CI, 0.461-0.847) (81).

Similarly, a randomised control trial involving 765 pregnant women (382 in the exercise group and 383 in the control group) demonstrated that supervised exercise interventions reduced the risk of excessive gestational weight gain (82). The exercise intervention involved aerobic exercise, muscular strength, and flexibility performed three days a week (50-55 min/session). The control group received standard care. Women in the exercise group gained less weight compared to those in the control group (12.1 ± 3.7 vs 12.9 ± 4.5 kg, p=0.01, respectively). Pregnant women who did not exercise were 1.5 times more likely gain excess weight (OR, 1.47; 95% CI, 1.06–2.03, p=0.02) (82).

Further, a recent meta-analysis of RCTs indicated that prenatal exercise interventions reduced the odds of EGWG by 32% compared to the control group (OR 0.68, 95% CI 0.59 - 0.78), while increasing the odds of adequate gestational weight gain (10). In line with this, a recent meta-analysis of randomised controlled trials involving 33 studies (9320 women) found that diet and physical activity-based interventions during pregnancy significantly lowered weight gain compared to the control group (83). Less weight gain occurred in the intervention group than in the control group (mean difference −0.70 kg, 95% confidence interval −0.92 to −0.48 kg) (83). This reduction in gestational weight gain holds statistical significance; however, its clinical significance might be limited, considering that 0.7 kg can be gained in a single day of heavy eating and hydration.

Furthermore, a meta-analysis involving RCTs and cohort studies indicated that physical activity during pregnancy was associated with lower weight gain during pregnancy (21). The meta-analysis of the RCT studies (1605 women in the control groups and 1598 in the exercise groups) showed that women in the exercise interventions group gained less weight during pregnancy than those not taking part in an exercise intervention (mean difference, -1.11 kg, difference in standard error -1.53; -0.69) (21). The decrease in weight gain has statistical significance; however, its clinical significance might be limited since an increase of 1.1 kg could still occur easily. Similarly, the meta-analysis of the cohort studies (9795 women) demonstrated that compared to inactive women, active women during pregnancy had an 18% lower risk of GWG exceeding the IOM recommendations (OR 0.82; 95 % CI 0.68–0.99) (21).

A systematic review of 24 randomised controlled trials (involving a total of 7096 women) showed that an exercise and dietary intervention during pregnancy reduced the risk of excessive gestational weight gain by 20% overall (average risk ratio 0.80, 95% CI 0.73 to 0.87) (16). In summary, there is strong evidence showing that engaging in exercise interventions during pregnancy reduces the risk of excessive weight gain while increasing the likelihood of achieving adequate weight gain.

A meta-analysis examining the impact of exercise interventions on gestational weight gain in pregnant women above a healthy weight showed that exercise interventions significantly reduced gestational weight gain (mean difference = −1.14 kg, 95% CI = [−1.67 to −0.62], $p< 0.0001$). In this meta-analysis thirteen studies involving 1439 pregnant women were included (84). Likewise, a randomised control trial conducted among 389 pregnant women with a BMI of ≥30kg/m^2 found that physical activity interventions reduced GWG compared with the control group (85). This study compared 3 groups: 1) physical activity intervention group (n =142); 2) physical activity and dietary intervention group (n = 142); and 3) control group receiving standard care (n=141). The physical activity intervention involved motivating pregnant women to enhance their physical activity levels, targeting a daily step count of 11,000. This progress was monitored by pedometer assessment on seven consecutive days every four weeks. The dietary intervention involved regular follow-up on a hypocaloric Mediterranean-style diet. A dietician provided instructions for participants every two weeks.

Gestational weight gain (median [ranges]) was lower in each of the intervention groups [physical activity: 9.4 kg (-3.4 to 28.2) kg; physical activity and dietary intervention: 8.6 kg (-9.6 to 34.1) kg)] compared with the control group: 10.9 kg (-4.4 to 28.7) kg (p=0.024). No significant difference was found between the two intervention groups. Physical activity intervention reduced GWG by a mean of 1.38 kg (p=0.04) compared with controls, in a multivariate analysis. The recommendations for gestational weight gain were more frequently followed in the intervention groups compared to the controls. In the exercise group, 49% achieved a maximal gestational weight gain of 9 kg, whilst this was achieved by only 37% of controls (p= 0.013) (85). These findings suggest that exercise interventions can effectively reduce gestational weight gain in pregnant women above a healthy weight compared to standard care, with a notable adherence to recommended weight gain limits among intervention groups. Overall, the findings from the literature suggest that regular exercise during pregnancy has the potential to reduce the risk of excessive weight gain during pregnancy and might be an important approach for weight management during pregnancy.

2.2.2. Physical activity and hypertensive disorders of pregnancy

Physical activity during pregnancy has been shown to have a positive impact on reducing the risk of hypertensive disorders of pregnancy, including gestational hypertension and pre-eclampsia (86-88). A recent meta-analysis examining the effect of exercise interventions during pregnancy concluded that prenatal exercise interventions reduced the risks of developing gestational hypertension and pre-eclampsia, compared with a control group (11). The pooled estimate indicated that prenatal exercise interventions lower the odds of developing gestational hypertension by 39% (OR 0.61, 95% CI 0.43 - 0.85). Similarly, the odds of developing pre-eclampsia was reduced by 41 % (OR 0.59, 95% CI 0.37 - 0.9) in the intervention/exercise group (11).

Evidence further supports the above findings that prenatal exercise interventions were effective in reducing the risk of hypertensive disorders of pregnancy, such as gestational hypertension and pre-eclampsia. For example, a randomised control trial involving 765 pregnant women (382 in the exercise group and 383 in the control group), demonstrated the potential role of supervised exercise interventions as a preventive measure against pregnancy-induced hypertension (82). The exercise intervention involved aerobic exercise, muscular strength, and flexibility performed three days a week (50-55 min/session) from gestational weeks 9-11 until weeks 38-39. The control group received standard care. Pregnant women who did not exercise were three times more likely to develop hypertension (odds ratio, 2.96; 95% CI, 1.29–6.81, p= 0.01). The incidence of hypertension was higher in the control group compared to the exercise group (5.7% vs 2.1%, p= 0.009). Similarly, the incidence of pre-eclampsia was higher in the control group compared to the exercise group (2.3% vs 0.5% vs, p= 0.03) (82).

A population-based, case–control study involving pre-eclamptic (n=258), gestational hypertensive (n = 233), and normotensive (n = 182) women showed that leisure time physical activity (LTPA) and increasing the amount of time spent active each day were associated with a reduced risk of pre-eclampsia (89). In this study, physical activity exposures were self-reported. The study demonstrated that, after adjusting for pre-pregnancy BMI, higher levels of LTPA were associated with a reduced risk of preeclampsia (trend, p= 0.02). Moreover, increasing amount of time spent active each day was associated with decreasing risks for preeclampsia (adjusted, trend; p= 0.03). Conversely, an increased amount of time spent sitting per day was associated with an increasing risk of preeclampsia (adjusted, trend; p= 0.10). Nevertheless, most analyses examining the risk of gestational hypertension yielded inconclusive or null findings (89).

A recent meta-analysis (13 studies, 1439 women) that aimed to examine the effect of physical activity on maternal and infant outcomes in pregnant women above a healthy weight, found no significant difference in the incidence of gestational hypertension between the exercise group and the controls (standard antenatal care group) (RR = 0.63, 95% CI = [0.38-1.05], p= 0.08) (84). Likewise, there was no significant difference in risks of preeclampsia between the exercise group and controls (RR = 1.39, 95% CI = [0.66-2.93], p= 0.38) (84). Furthermore, a systematic review of randomised controlled trials found no significant effect of interventions involving diet and exercise during pregnancy on pre-eclampsia (RR 0.95, 95% CI 0.77 to 1.16) (16). However, gestational hypertension was reduced in the intervention group compared to the control group overall (average RR 0.70, 95% CI 0.51 to 0.96) (16).

Results from a recent meta-analysis of RCTs suggested that to achieve greater reduction in the odds of developing hypertensive disorders of pregnancy, pregnant women need to accumulate at least 600 MET-min/week of moderate-intensity exercise (e.g., brisk walking, stationary cycling, water aerobics or resistance training) (11). Accordingly, the findings of this meta-analysis recommended that pregnant women aim for exercise sessions of at least three days/week, with each session lasting at least 25 minutes, to increase physical health benefits (11). The findings of this study highlighted the significance of exercise intensity, duration and frequency to achieve meaningful health benefits for pregnant women. These recommendations should be considered in the development of future exercise prescription models. In summary, there is strong evidence from the literature that engaging in physical activity during pregnancy is beneficial for reducing the risk of developing hypertensive disorders of pregnancy. However, a few studies did not find a significant effect of exercise interventions on hypertensive disorders during pregnancy (84). Despite this, most of the literature supports the positive impact of physical activity.

2.2.3. Physical activity and birth outcomes

In recent years, exercise during pregnancy has been a topic of interest due to its effects on various birth outcomes. Several studies have investigated the relationship between prenatal exercise and various birth outcomes, such as the mode of birth, birth weight, and overall maternal and neonatal health. Recent meta-analysis findings showed that prenatal exercise interventions reduced the risk of instrumental birth by 24% (OR 0.76, 95% CI 0.63-0.92)(19) and reduced the odds of macrosomia by 39% (OR 0.61, 95% CI 0.41-0.92) compared with women who did not exercise, without affecting the odds of low birth weight (31). However, there was no relationship between prenatal exercise and preterm birth, gestational age at birth, induction of labour, length of labour, vaginal tears, or birth by caesarean section (31). A recent meta-analysis of RCTs and cohort studies also indicated that participation in LTPA was associated with lower likelihood of delivering a large-for-gestational-age infant and lower risk of preterm delivery (21). Another meta-analysis revealed that there was no clear difference between the intervention (exercise) and control groups with regard to birth by caesarean section, although the effect estimate suggested a small difference (5%) in favour of the interventions (16). Similarly, there were no significant difference between groups with regard to preterm birth, and in the risk of other neonatal outcomes (16). Overall, the literature suggests that physical activity during pregnancy can have beneficial effects on pregnancy and birth outcomes, though the extent and magnitude of these benefits remains to be better determined. Accordingly, more research is required to further understand the effects of exercise during pregnancy on pregnancy and birth outcomes.

For pregnant women who are above a healthy weight, a meta-analysis which focused on physical activity interventions found no significant effect of physical activity during pregnancy on birth by caesarean section (84). Similarly, this meta-analysis indicated that there were no significant differences in terms of preterm birth, small for gestational age, large for gestational age, macrosomia, and birthweight between the exercise group and controls (84). Possible reasons for this were suggested to be the small sample size in this meta-analysis. Another meta-analysis of RCTs revealed that pregnant women above a healthy weight who were randomised to exercise interventions had a lower rate of preterm birth compared with controls (86). The incidence of birth by caesarean section was similar in both exercise and control groups (86). In addition, no significant difference in stillbirth, birthweight, low birthweight, macrosomia, and gestational age at delivery between the exercise group and controls were found (86). However, exercise during pregnancy was not associated with adverse maternal outcomes or neonatal complications (19, 31). Moreover, results from a meta-analysis of RCTs showed that there is no evidence for a dose response relationship between intensity, frequency, duration or volume of exercise interventions and birth and labour outcomes (19, 31). More studies are needed, particularly focusing on specific populations such as pregnant women who are above a healthy weight, to examine the effects prenatal exercise on various outcomes.

2.2.4. Physical activity levels during pregnancy

Maintaining an appropriate level of physical activity during pregnancy has been shown to contribute to improved fitness, better weight management, and reduced risk of adverse pregnancy and birth outcomes (90). However, most pregnant women do not meet the current recommendations for physical activity, and others significantly decrease their physical activity participation during pregnancy (1, 91). Table 2.1 provides a summary of guidelines for physical activity recommendations during pregnancy that can be used by future studies to better refine the type, mode and intensity of exercise prescribed to pregnant women. The guidelines recommend 150-300 min/week of moderate intensity exercise, including aerobic activity, pelvic floor and muscle strengthening exercises. They also offer lists of warning signs to cease exercise and the types of exercise/activity which should be avoided. Such information is important for any new modes of exercise as these factors need to be considered and proposed, prior to any feasibility trials being undertaken. Moreover, a recent systematic review which examined the level of physical activity during pregnancy from different geographic regions has demonstrated that the level of physical activity during pregnancy is low compared to recommendations proposed by international physical activity guidelines (74). Further supporting these findings, studies conducted in different countries have reported low rates of physical activity during pregnancy (92-95). Some studies have reported higher physical activity levels at the second trimester than at the first or the third trimester (96, 97), whereas other studies have found a progressive decrease in physical activity across trimesters of gestation (94, 98).

A randomised controlled trial conducted among pregnant women with BMI ≥30kg/m^2 indicated that a 12-week supervised exercise intervention promotes an active lifestyle throughout pregnancy in pregnant women with obesity (99). The program involved supervised aerobic exercise (a stationary cycle ergometer and treadmill walking) performed three times per week. Pregnant women in the exercise group maintained or increased their physical activity levels, whereas physical activity decreased in the control group during the intervention period. This improvement was supported by a maintained cardiorespiratory fitness level (difference in fitness change = 8.1%) in the exercise group, compared to controls (99). Compared with controls, a supervised exercise intervention was effective in attenuating the decline in physical activity observed in late pregnancy (99). Similarly, another RCT study showed that compared with the control, pregnant women in the exercise group improved their aerobic fitness and muscular strength (100). At baseline, the aerobic fitness was virtually similar between groups. Following the intervention, the aerobic fitness improved steadily in the exercise group compared with the control, and became significantly higher at 30–32 weeks of gestation (100). Muscular strength improved significantly in the exercise group after 6 weeks and remained significantly higher through 6 weeks postpartum (100). In summary, the level of physical activity decreases during pregnancy, and most women do not reach the recommended level of physical activity during pregnancy. Hence, innovative methods to promote and engage pregnant women in regular physical activity are critical.

Table 2.1. Summary guidelines for physical activity recommendations during pregnancy

Guidelines	Safe exercise	Exercise to avoid	Absolute contraindications	Relative contraindications	Volume and intensity
Royal Australian and New Zealand College of Obstetricians and Gynaecologists (101)	▪ Walking ▪ Swimming ▪ Stationary-cycling	▪ Jumping or bouncing ▪ Walking lunges ▪ Horse-riding ▪ Learning to ski ▪ Team sport-games ▪ Excessive-stretching ▪ Exercises in a- supine position	▪ Persistent bleeding ▪ Placenta praevia ▪ Pre-eclampsia ▪ Pregnancy-induced Hypertension ▪ Multiple pregnancy ▪ Ruptured membranes Premature contractions ▪ Shortened cervical length)	▪ Foetal growth-restriction ▪ Poorly controlled thyroid disease ▪ Anaemia	▪ 150-300 minutes of MIPA each week. ▪ At least 30 minutes at a time on most, preferably all days. ▪ For inactive & OW or OB pregnant women 3-4 days on non-consecutive days ▪ 15-20 minutes at commencement

2019 Canadian guideline for physical activity (3)	▪ Brisk walking ▪ Stationary cycling ▪ Swimming	▪ Scuba-dive ▪ Non-stationary cycling ▪ Hot yoga ▪ Horseback riding ▪ Downhill skiing ▪ Ice hockey ▪ Gymnastics ▪ Olympic lifts	▪ Ruptured membranes ▪ Premature labour ▪ Unexplained persistent vaginal bleeding ▪ Placenta praevia after 28 weeks' gestation. ▪ Pre-eclampsia ▪ Incompetent cervix ▪ Intrauterine growth restriction ▪ High-order multiple pregnancy (eg, triplets)	▪ Recurrent pregnancy loss ▪ Gestational hypertension ▪ A history of spontaneous preterm birth ▪ Mild/moderate cardiovascular or respiratory disease ▪ Symptomatic anaemia ▪ Malnutrition ▪ Eating disorder ▪ Twin pregnancy after the 28th week	▪ A minimum of 3 days each week; however, being active every day is encouraged ▪ At least 150 minutes of moderate intensity physical activity each week. At least 30 minutes at a time

			▪ Uncontrolled type I diabetes ▪ Uncontrolled hypertension ▪ Uncontrolled thyroid disease	▪ Other significant medical conditions	
American College of Obstetricians and Gynaecologists (90)	▪ Walking ▪ Swimming ▪ Stationery cycling ▪ Low impact aerobics ▪ Yoga ▪ Pilates ▪ Running or jogging ▪ Racquet sports ▪ Strength training	▪ Ice hockey ▪ Boxing ▪ Soccer ▪ Basket ball ▪ Downhill snow skiing ▪ Water skiing ▪ Surfing ▪ Off-road cycling ▪ Gymnastics ▪ Horseback riding ▪ **S**cuba diving	▪ Hemodynamically significant heart disease ▪ Restrictive lung diseases ▪ Incompetent cervix ▪ Multiple gestation at risk of premature labour ▪ Persistent 2nd or 3rd trimester bleeding	▪ Anaemia ▪ maternal cardiac arrhythmia ▪ Chronic bronchitis ▪ Extreme morbid obesity ▪ Poorly controlled type 1 diabetes ▪ Extreme underweight ▪ History of extremely sedentary life style	▪ Moderate intensity exercise for at least 20-30 minutes per day on most or all days of the week.

		▪ **S**ky diving ▪ Hot yoga ▪ Hot Pilates	▪ Placenta Previa after 26 weeks of gestation ▪ Premature labour during the current pregnancy ▪ Ruptured membrane ▪ Pre-eclampsia or pregnancy induced hypertension ▪ Severe anaemia	▪ Intrauterine growth restriction in current pregnancy ▪ Poorly controlled hypertension ▪ Orthopaedic limitation ▪ Poorly controlled seizure disorder ▪ Poorly controlled hyperthyroidism ▪ Heavy smoker	
Get Healthy in Pregnancy (NSW Health)	▪ Walking ▪ Swimming	▪ Excessive stretching ▪ Jumping up and down ▪ Squash ▪ Skiing	-	-	▪ 30 minutes of moderate intensity exercise on most days

		▪ Horse riding ▪ Scuba diving ▪ mountain climbing			
Physical activity Australia National fitness registration	▪ Walking ▪ Jogging ▪ Swimming ▪ stationary cycling ▪ Low-impact aerobic exercise ▪ Aquarobics ▪ Yoga ▪ Pilates	▪ Trampolining ▪ Rollerblading ▪ Downhill skiing ▪ Horse riding ▪ Basketball ▪ Competition sports ▪ Exercises that involve lying on your back ▪ Jumping ▪ Frequent changes of direction	-	-	▪ 150 minutes of moderate intensity or 75 minutes of vigorous intensity exercise each week • Aerobic activity should be performed in bouts of at least 10 minutes duration.

		▪ Excessive stretching (such as gymnastics)			

MIPA: Moderate Intensity Physical Activity, O: obese, OW: Overweight

2.3. Pregnant women's experiences of physical activity during pregnancy

Exercise during pregnancy has been associated with numerous health benefits, such as reduced risk of gestational diabetes mellitus, excessive weight gain and hypertensive disorders of pregnancy (11, 19). However, there are various individual, interpersonal, and environmental factors that can influence a pregnant woman's ability to engage in regular physical activity. Hence, understanding the barriers and facilitators to physical activity during pregnancy is critical for promoting regular physical activity and developing effective interventions.

A recent qualitative systematic review aimed to determine pregnant women's perceptions of barriers to physical activity demonstrated that pregnancy symptoms, lack of knowledge of what constitutes safe activity, and the opinions of women's social circles were common barriers to physical activity during pregnancy (102). In line with this, a qualitative study which explored experiences of pregnant women on physical activity during pregnancy showed that the growing body, discomfort associated with pregnancy, and a sense of insecurity with physical activity were barriers to maintaining a pre-pregnancy levels of physical activity (103). Similarly, a qualitative study conducted among pregnant women who were above a healthy weight attending a public antenatal clinic in a maternity hospital, highlighted several barriers to physical activity for pregnant women. These barriers include lack of knowledge on safe activities during pregnancy, working, a lack of time, and having other children (104). Furthermore, a qualitative study aimed to explore pregnant women's experiences with physical activity throughout the course of pregnancy revealed that participants felt the need to reduce their physical activity levels due to physical changes brought on by pregnancy such as nausea and/or vomiting, fatigue and risk of injury (105). Another study highlighted the perceived barriers to active behaviours during pregnancy, such as lack of information and the absence of a supportive exercise partner (such as a pregnant buddy) during pregnancy. Interestingly, this study suggested the potential of using technology to support and enhance physical activity during pregnancy (106).

In addition to these qualitative studies, a quantitative study conducted among large number of pregnant women (n=1083), using a structured self-administered questionnaire on perceived barriers to physical activity participation during pregnancy, demonstrated the major barriers to physical activity during pregnancy (107). These include tiredness, lack of time, discomfort work commitments, non-accessibility to physical activity and safety concerns for the mother and the baby. These are important concepts to understand as new exercise modes and altered prescription models need to careful consider the experiences and perceptions of pregnant women.

A recent systematic review focusing on pregnant women's views of physical activity during pregnancy have shown common enablers of physical activity during pregnancy. These include social support and the experienced benefits such as physiological, psychological, and social benefits (102). Similarly, another study identified having the social opportunity to engage in physical activity as an enabler to physical activity during pregnancy (104). The women participants in this study also mentioned that being active was easier when supported by their partners. Further, another study showed that being informed by a gynaecologist about the benefits of physical activity during pregnancy helped pregnant women to stay active during pregnancy (77). Overall, multiple barriers to physical activity for pregnant women identified in the literature highlight the need for innovative exercise interventions to overcome these barriers. In future, better prescription of exercise for populations such as pregnant women can be informed by research evidence about their experiences and preferences.

2.4. Exergames

Although the health benefits of physical activity are widely known; many people do not meet the recommendations of physical activity to obtain those benefits (108). Consequently, individuals may need strategies to encourage them in regular physical activity, and this is particularly the case for pregnant women (90). Many attempts have been made to promote physical activity, and one entertaining method to encourage individuals to be more physically active may be via exergames.

Exergames, also known as active video games, are emerging technologies that require physical activity or exercise as part of gameplay (109, 110). They are designed with the aim to encourage physical activity in an engaging, enjoyable, and entertaining manner (109). Exergaming requires the players to physically interact with the gaming console via a variety of body movements, such as walking, jogging and upper- and lower-body limb movements, to control various aspects within the game. Exergames are compatible with a range of devices, including consoles, computers, and TVs. It may be designed for both individual gameplay and online multiplayer modes, enabling players to engage and interact with others. They can be suitable for individuals of different fitness levels and can be used in various settings such as homes, antenatal clinics, community centres and fitness facilities.

The perceived enjoyment during exergaming is suggested as the key factor why exergames may be a promising alternative to traditional physical activity, by creating the potential for greater engagement in exercise (36, 111, 112). The exergame features offer players not only a fun and enjoyable way to exercise, but also incorporate training, and instructions on how to exercise with the game console. Exergames are reported to be relatively safe, inexpensive and have already been proven to be popular among sedentary and high-risk groups (35, 36, 41). However, the cost of exergames varies based on the technology used and gaming platform. Furthermore, the accessibility of exergaming may be influenced by socioeconomic factors, as not all individuals may have equal access to the necessary technology or facilities.

Exergaming has gained popularity as a means to promote physical activity and improve health outcomes, particularly among children, adolescents, and older adults (113-116). The appeal of exergaming lies in its ability to make exercise enjoyable and engaging by integrating it with interactive gameplay (46, 48), contributing to its rising popularity. A popular exergame widely accessible worldwide is the Nintendo Switch, complemented by its accompanying fitness accessory known as the Ring Fit. The Nintendo Switch combines interactive gaming with physical activity, allowing users to engage in various exercises and challenges using the Nintendo Switch console and the Ring Fit controller (Figure 1.1). The popularity of Exergames, coupled with ongoing technological advancements, underscores the potential of exergaming to impact public health and wellness. Studies have shown that that regular engagement in exergaming can contribute to improved cardiovascular health, increased physical activity levels, weight management, and psychosocial wellbeing (36, 43, 46).

2.4.1. Exergaming and physical activity

Exergaming, active video games that require physical activity, has gained attention as a potential tool for promoting physical activity and improving health outcomes. A recent three-arm randomised controlled trial conducted in USA among sedentary adults reported that following a 12-week program of exercise videogames (exergames), participants in the exercise video game group engaged in significantly more moderate to vigorous physical activity than standard (treadmill) group, and controls (43). Those in the exercise video game arm engaged in 30 minutes/week more moderate to vigorous physical activity compared with standard exercise (treadmill) and 85 minutes/week more moderate to vigorous physical activity than the control group (43). A similar result was reported by studies (50, 117) among young adults. Overall, the collection of these studies suggests that exergames elicited moderate to vigorous levels of exercise intensity, in line with the current recommendations for physical activity. Hence, they may be a useful model for pregnant populations, though requiring initial exploratory evidence that is currently lacking.

Earlier studies have shown the effects of exergaming on energy expenditure and exercise intensity. Studies conducted among sedentary adults revealed that exercise intensity (heart rate, oxygen uptake, and rate of perceived exertion) and energy expenditure were significantly higher during active video gaming compared with sedentary video game play (51, 118-120). Similarly, the maximum heart rate, oxygen uptake, and energy expenditure achieved when exercising with exergame was significantly greater compared with traditional stationary cycling and brisk walking on the treadmill (52, 121). Energy expenditure during the exergames was greater in overweight participants compared with healthy weight participants (51). Studies conducted among overweight and obese populations also reported similar results. The energy expenditure, heart rate, oxygen uptake, and rating of perceived exertion were significantly higher during exergames than during sedentary video games and treadmill walking (122-129). In summary, literature collectively shows that exergaming can have positive effects on physical activity levels, promoting light to moderate-intensity physical activity; in turn, such outcomes may be appropriate for pregnant populations. However, the effectiveness of exergaming may vary depending on the type of game and the player (for example, age). Further research is needed to examine the effects of exergaming and its potential as a tool for promoting physical activity, and particularly in pregnant populations where no current evidence exists to guide usage.

2.4.2. Exergaming and weight management

Emerging research is exploring the effects of exergaming on body weight and body mass index (BMI), and its utility in weight management in children, adolescents and adults. A randomised controlled trial among postpartum women showed that there was a significant change in body weight and BMI, with a more marked decrease in the exergame group over the forty day period of exergaming (36). A similar result was observed among postpartum women (61) , as following a 12 week exergaming intervention, body weight and BMI was significantly lower than baseline (61). Study among healthy adults showed that interactive video dance game sessions performed for 6-weeks significantly reduce BMI (from 26.96 kg/m2 to 26.21 kg/m2; 2.87%) (122). Further supporting this, other studies among adult populations showed a significant change in body weight and BMI between pre and post-tests following exergame interventions (62, 63, 130). In studies that assessed the effectiveness of exergames in weight management for overweight and obese children and adolescents, participants in the intervention (exergames) group exhibited significant reductions in weight and/or body mass index compared to controls (35, 64-67, 131, 132).

On the contrary, studies among adults have shown that there were no significant differences in weight and BMI between the intervention (exergame) and control groups during pre- and post-tests (49, 53, 133-136). Similarly, studies conducted in children and adolescents have shown no significant differences in weight and BMI between exercise groups and controls (137-139). Variability in the results might be due to differences in the exercise dose components (that is, duration, frequency, and intensity of exergaming), adherence to the intervention and participant variables. Hence, these findings suggest initial exploratory evidence is required in specific populations, such as pregnant women, to determine the appropriateness and feasibility of this exercise mode.

2.4.3. Exergaming and psychosocial wellbeing

Exergaming has been found to have potential benefits for psychosocial wellbeing, including increased motivation, promote continued play, and enhanced self-efficacy. Previous studies have shown that enjoyment when exercising with exergames was significantly greater compared with exercising during sedentary video games and/or traditional exercises such as treadmill walking and stationary bike (47, 48, 127, 129, 140). Similarly, motivation for exercise for participants in the intervention group (exergaming) was significantly increased compared to the control group (sedentary video game and traditional exercise) (53, 63). Females had significantly greater enjoyment than males while playing exergames (48). In addition, experienced players exhibited significantly higher levels of enjoyment than inexperienced players while playing exergames (141). For the subsample of women with obesity in particular, enjoyment was significantly higher during exergaming than during generic physical activity (142). Research has also shown that playing exergames maintains happiness levels, while the happiness levels of those in the control group decreased (143). The maintained happiness levels were particularly more prominent among participants who were attempting to control their weight (143).

Enjoyment is important because studies have shown significant correlations between enjoyment and energy expenditure (124, 125). The studies showed that enjoyment can significantly predict energy expenditure during play of an exergame (124, 125). Aerobic games produced greater energy expenditure than balance games, and game-like aerobic games are more enjoyable than fitness-themed aerobic games (124). A study by Lyons et al. from 2012 has shown that enjoyment differs across various types of video games. For example, Wii Fit and dance simulation were not found to be as enjoyable as band simulation games, even though all exergames were rated by participants as enjoyable (123). Participants with above healthy weight found exergames more enjoyable than non-overweight participants (123). A study conducted in United Kingdom also revealed that energy expenditure was a significant predictor of interest and enjoyment during exergaming. As energy expenditure increased, so did interest and enjoyment (46). These findings may be of importance when considering the type and mode of exergaming for pregnant women, as specific and nuanced engagement with exergaming may affect the adherence and future health outcomes.

A randomised controlled trial in Canada revealed that there was a significant difference in the exercise adherence between exergames (Game bike) and traditional stationary bike groups (49). Participants in the exergame group attended more frequently than participants in the traditional stationary bike groups (78 ± 18%) vs (48 ± 29%), respectively. There was 30% more attendance in the exergame (Game bike) group. In comparison, there was a progressive decline in attendance rates in the traditional stationary bike group over time (49). Similarly, another Canadian study reported that exercise video gaming (Game bike) produced significant higher attendance than the control bike condition. Participants in the video gaming condition attended an average of 71% of sessions compared to 42% of sessions attended by the control group (37).

A pilot study involving 16 pregnant women randomly assigned to either motion-based games (n=8) or control (n=8) found that motion-based exercise programs decreased anxiety and depression among pregnant women. The exercise program comprised breathing exercises, breaks, and exposure to three Xbox Kinect games that lasted for one hour. A significant decrease in mean anxiety 48.50 to 42.88 (p=0.029) and depression 11.50 to 7.63 (p=0.022) scores were found in the exercise group, while no changes were noted in the control group (144). A randomised controlled trial consisting of 32 women in their third trimester, 15 pregnant women in the experimental group and 17 pregnant women in the control group, showed that there were no significant statistical differences in quality of life (p= 0.13) between the intervention and control groups (145). The intervention consisted of the Nintendo Wii Fit Plus® balance exercises performed in 12 sessions of 30 minutes each, three times a week for a period of four weeks.

2.5. Summary

There is a substantial body of literature showing that physical activity performed during pregnancy is associated with reduced risk of hypertensive disorders, excessive gestational weight gain, birth complications, as well as fewer neonatal complications, although the evidence is not conclusive. Regular exercise during pregnancy has also been related to physical benefits for maternal fitness, improved cardiovascular health, and enhanced mental well-being. Importantly, there is no evidence to suggest that regular physical activity during an uncomplicated pregnancy is detrimental to the mother or her fetus. However, there is limited evidence regarding the type, frequency, duration and intensity of exercise appropriate during pregnancy. Despite beneficial effects of regular exercise during pregnancy, most pregnant women remain inactive, or significantly reduce their exercise participation during pregnancy. The literature demonstrated various barriers to physical activity for pregnant women, highlighting the need for addressing these barriers to promote physical activity during pregnancy.

The literature demonstrates that exergames (active video games) are emerging as an enjoyable activity that may encourage physical activity. Exergaming can elicit light to moderate levels of exercise intensity and may contribute to the recommendations for physical activity. There is also strong evidence supporting the use of exergaming in non-pregnant populations to reduce body weight and BMI, increase physical activity levels, increase enjoyment and motivation, and improve exercise adherence. However, the optimal frequency, duration and intensity of the exergaming to provide maximal health benefits remains unclear, and it is also questionable whether current active video games/exergames are able to offer exercise programs that are suitable for pregnant women. Several studies have been conducted on exergaming recently. However, current exergaming research primarily focuses on children, adolescents and older people. No studies have yet assessed the potential of exergaming as tool for exercise for pregnant women, indicating a literature gap this study aims to address.

Chapter 3

Study 1

Heuristic evaluation of the suitability and safety of Nintendo switch exercise programs for pregnant women.

Abstract

Aim: This study investigates the potential suitability and safety of the Nintendo Ring Fit game as a tool for pregnant women to exercise.

Methods: The evaluation of the suitability and safety of the Nintendo Ring Fit exercise programs was completed following the Heuristic Evaluation technique. The evaluation focused on: ensuring safety, identifying potential barriers and usability issues. The Heuristic Evaluation was undertaken by six experts with respective expertise in exercise physiology, midwifery, public health, and exergame development.

Results: The major feasibility problems identified were inappropriate intensity and mode of some exercises for pregnant women. Results suggest that rhythm games for legs and arms; minigames such as thigh rider, robo-wrecker, crate crasher, beginnia, and transient temple were appropriate. Further, structured exercises such as: front press, bow pull, squat, and thigh press could also be used by pregnant women.

Conclusion: This study suggested that Nintendo Ring Fit could be used for pregnant women, provided that specific exercises are used that are safe for each trimester and tailored to the individual. These findings have significant implications for using exergames as a promising alternate way to encourage and engage pregnant women in regular exercise.

3.1. Introduction

Regular exercise during pregnancy has many health benefits for both mother and baby; including fitness, weight management, and psychological wellbeing (10, 16, 100). It is also associated with decreased risks of adverse pregnancy and birth outcomes (11, 19, 31). Guidelines for physical activity during pregnancy recommend that women aim for moderate-intensity physical activity for 30 minutes per day (3, 101, 146). However, exercise during pregnancy should always be undertaken with precautions, regardless of pregnant women's health status and fitness level, due to exercise contraindications and physiological adaptations during pregnancy (3, 32, 90, 101, 146). These physiological adaptations have implications for safety, intensity and mode of exercises to be used for pregnant women (3, 101).

Despite the significant health benefits of regular exercise, most pregnant women do not meet the current recommendations for physical activity (147, 148). Perceived barriers to exercise for pregnant women have been identified, such as lack of motivation and enjoyment, lack of time, unsuitable facilities, and uncertainty about how to exercise safely (71, 97, 149). Hence, innovative approaches to overcome these barriers are critical, such as engaging exercise modes that can be performed safely at home with minimised risk. One such potential method involves exergames, which are an emerging technology that uses interactive games to increase physical activity (38, 150). Exergames require the players to interact physically via a variety of body movements as part of the computer-generated gameplay, thereby increasing players' level of physical activity (150). Fittingly, exergames may aid motivation for exercise by connecting the fun of electronic games with physical activity (49). Hence, commercially available exergames, such as Nintendo Switch Ring Fit, may have the potential to encourage pregnant women in regular exercise in the privacy of their own homes. The Nintendo Switch and accompanying Ring Fit is a popular gaming console for exercise available worldwide (Figure 1.1). It can be suitable for individuals of different fitness levels and compatible with a range of devices, including consoles, computers, and TVs. It incorporates training, and instructions on how to exercise with the game console and the Ring Fit. The Nintendo Switch offers a full-body workout, including low-impact aerobic exercises, resistance/strength training exercise and yoga that could be tailored for pregnant women.

Recently, exergaming has been proposed as a method to encourage physical activity in sedentary and high-risk populations (35-37, 42, 48). However, whether commercially available exergames are able to offer exercise programs that are safe and suitable for pregnant women has not been previously studied. Hence, it is imperative to evaluate the safety and suitability of the Nintendo Switch Ring Fit exercises for pregnant women in order to achieve expected benefits, increase compliance with exercise programs and ensure the safety of pregnant women. This study is the first study to evaluate the suitability and safety of Nintendo Switch Ring Fit exercise programs for pregnant women. The findings will guide future implementation research and may provide evidence for recommendations on physical activity during pregnancy.

3.2. Methods

3.3.1. Heuristic Evaluation

Heuristic Evaluation (HE) is one of the most common methods to assess the usability of interactive systems (151-156). Experts evaluate the interface design to predict and identify usability problems that may occur when end users interact with the technology. Experts, assign usability problems to a specific category of heuristic and rate the severity of usability problems (152, 155, 157). In studies involving HE, three to five single-domain expert evaluators are considered acceptable (158, 159) to identify 74-87% of usability problems (159). Dual-domain experts can even find up to 90% of usability problems (159-161). The HE method was used in this study due to its capacity to identify usability and safety issues that pregnant women may encounter in real-world situations. Prior to implementing exergaming exercise programs, it was deemed important for a team of experts to evaluate their safety and appropriateness.

3.3.2. Expert evaluators

In this study, the HE was undertaken by six members of the research team who possess expertise in exercise physiology, midwifery, public health, and game development. Amongst the expert evaluators, there was a significant experience with exercise during pregnancy, the physiological adaptations of pregnancy, maternity care during the antenatal period, heuristic principles and undertaking usability evaluations. Details of experts who participated in the heuristic evaluation appear in Table 3.1. All participants involved in the Heuristic Evaluation of the Nintendo Switch exercise programs were expert members of the research team. Hence, ethical approval was not sought for this phase of the study.

Table 3.1: Details of experts who participated in the Heuristic Evaluation.

Experts	Role	Institution
Expert 1	Professor in Exercise Physiology: Extensive experience in designing and conducting clinical trials in the field of sport science and exercise. Significant experience in designing and implementing exercise programs aimed at improving health of high-risk and sedentary populations.	University of Technology Sydney (UTS)
Expert 2	Associate Professor in Exercise Physiology: extensive experience in exercise during pregnancy and the physiological adaptations that occur during this period.	University of Western Australia
Expert 3	Senior Lecturer in Games Development: Extensive experience in designing, developing and maintaining video games. Extensive experience in heuristic principles and undertaking usability evaluations.	UTS
Expert 4	Registered Midwife and A/Professor in Midwifery: extensive experience in designing and leading qualitative studies and clinical feasibility trials in the field of maternity care.	UTS

Expert 5	Registered Midwife and Senior Project Officer: extensive experience in maternity care during the antenatal period.	Clinical Policy and Engagement, NSW Ministry of Health
Expert 6	PhD Candidate in Public Health	UTS

3.3.3. Heuristics development

The approach for defining a set of heuristics was based on Nielsen's and Pinelle's concepts for Heuristic Evaluation (155, 157). While we adapted some of the heuristics from their concepts, we also incorporated additional considerations, such as intensity and mode of exercise and its safety for pregnant women, in line with physical activity guidelines during pregnancy (3, 101) (Appendix 1). Consequently, a list of ten heuristics was developed to evaluate the safety and suitability of the Nintendo Switch Ring Fit for pregnant women (Table 3.2). The concepts of these heuristics covered necessary aspects of user interaction with the game, and the intensity and mode of the exercise programs for pregnant women.

Table 3.2: The list of heuristics and its description

No	Heuristics	Descriptions
1	Intensity of exercise	Exercise programmes should be low impact exercises with intensity recommended for pregnant women in line with physical activity guidelines during pregnancy (3, 32, 90, 101).
2	Mode of exercise	Mode of exercise should be in line with recommendations for physical activity during pregnancy (3, 32, 90, 101).
3	Customisability	User should able to modify the game settings according to their individual needs (155, 157).
4	Skip non-playable content	User should be able skip introductory videos, and parts of the game which are repetitive and don't fit their needs (155, 157).
5	Visibility of system status	User should be consistently informed about key game elements and progress, using clear and timely feedback. The icons, avatars, and maps should be easily understandable and highly visible (155, 157).
6	The match between the system and real world	The game display on screen should respond according to the user movements, following real world conventions (155, 157).

7	User control freedom	Controllers should be easy to use, consistent and follow standard conventions (ease of navigation). The game should offer the user with option for undo and redo of previous actions (155, 157).
8	Provision of training, information and instructions	Users should be provided with training session before playing the real game, and enough instruction and information about game (155, 157).
9	Clear and feasible goal	The goal of the game should be clear and it should not be extremely difficult to achieve it (155, 157).
10	Engagement	Exercise programs should promote adherence, and provide fun and motivation to encourage ongoing participation (90).

3.3.4. Heuristic evaluation procedures

Based on physical activity guidelines during pregnancy (3, 90, 101, 146) and Nielsen's and Pinelle's concepts of Heuristic Evaluation (155, 157), a list of ten heuristics was developed to evaluate the safety and suitability of the Nintendo Switch Ring Fit for pregnant women (Table 3.2). The HE was conducted at the UTS Game Studio Research Lab (Appendix 1). The Nintendo Switch Ring Fit has five play modes with different exercise options including: Adventure, Quick Play, Multitask Mode, Rhythm Games and Custom mode. The Nintendo Switch games evaluated were Minigames, Rhythm games and Fit skills/structured exercises, based on an initial overall evaluation of all the options provided through this system. A demonstration of each Nintendo Switch Ring Fit exercise program was performed by the PhD candidate. Each expert then critically evaluated the suitability and safety of the Nintendo Switch Ring Fit exercise programs for pregnant women. Safety, intensity, and technical difficulties of each exercise program were evaluated in the context of use by pregnant women. During all the demonstrations, the experts provided feedback by remarking on the pros and cons of each exercise program for pregnant women, based on available evidence and clinical experience. The demonstrations and the experts' feedback during each evaluation session were video recorded using a digital recorder. At the end of the evaluation sessions, the PhD Candidate categorised comments or usability problems identified by each expert based on the heuristics outlined in Table 3.2. After the evaluation sessions, the problems/heuristic violations identified by each expert were merged and collected in a unique list. After removing duplication, the severity of each heuristic violation/usability problem was rated using the severity rating scale suggested by Nielsen and Molich (151, 162).

3.3.5. Severity rating and Scale

The severities of usability problems were rated based on three criteria: the frequency with which the problem occurs, the impact of the problem on the users when it occurs and its persistence (151, 157). Accordingly, each usability problem/heuristic violation was assigned a severity rating from 0 to 4: 0- not a usability problem at all, 1- cosmetic usability problem only, 2- minor usability problem, 3- major usability problem and 4- catastrophic usability problem.

3.3. Results

3.3.1. Heuristic violations/usability problems

The major usability problems/heuristic violations identified were inappropriate intensity [heuristic 1] and mode [heuristic 2] of some exercises for pregnant women. The problems were ranked as major. Heuristics 1 and 2 are particularly compelling as they mainly refer to specific limitations of pregnant women. The study findings also found difficulty using Joy-con control buttons [heuristic 7] to navigate easily through the game for first-time users. These heuristic violations are presented below.

3.3.2. Intensity and mode of exercises

3.3.2.1. Minigames

This study suggested that minigames such as: Beginnia, Transient temple, and Starting Block Bridge are appropriate for more progressive exercises for pregnant women, providing aerobic capacity and lower body exercises alongside interesting gameplay engagement (Figure 3.1). However, the unsupervised nature of exergaming always risks potential overexertion if not performed in a slow and controlled manner, and are factored into the heuristic evaluation of both exercise and gameplay demands.

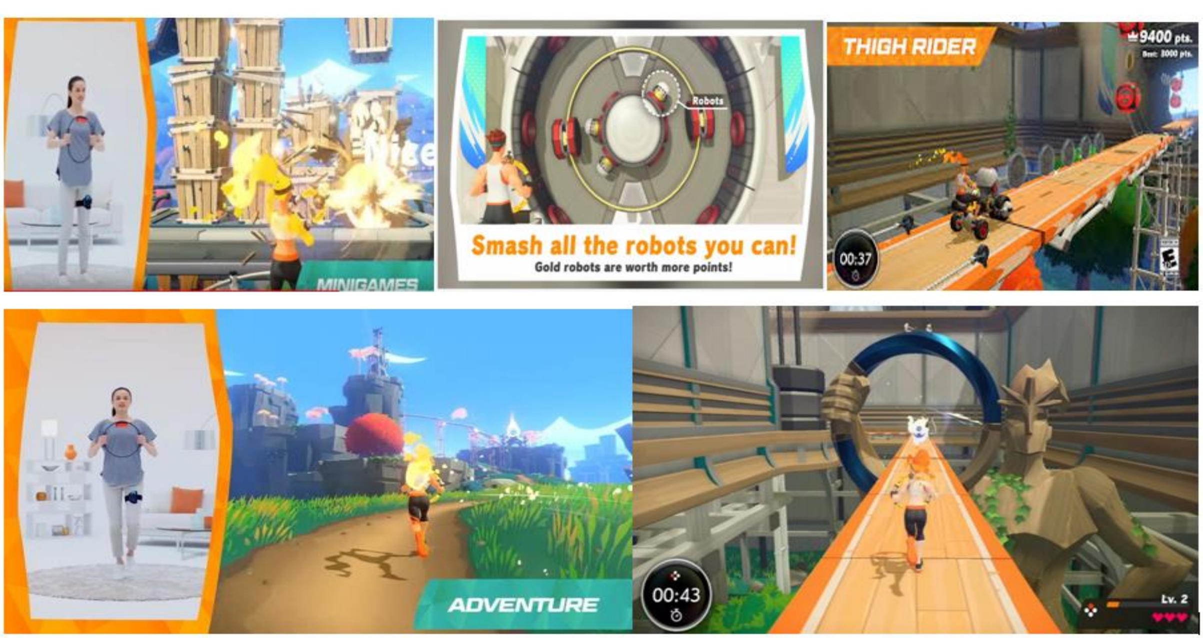

Figure 3.1: Screen shots of Nintendo Switch Minigames

Other Minigames such as: Aerochute, Dreadmill, Sportan highway, Monster den, Dragaux stadium seem unsuitable for pregnant women, as they include high intensity exercises which have a potential for overexertion, inappropriate positioning, pressure against the abdomen, excessive flexion and rotation, lower back stress and uncontrolled time pressure (3). Minigames that target abdomen/core such as: Bank Balance, Core crushing, Gluting gallery and Smack back are also probably inappropriate for this population, as they include excessive lateral flexion and rotation, fast movement and pressure against the abdomen (101). Hence, gaming techniques that may be advanced for a new user, increase lower back stress or create uncontrolled time pressure to complete the game were deemed inappropriate for pregnant women.

3.3.2.2. Rhythm Games

The experts suggested that Rhythm Games for core and legs were deemed unsuitable for this population, as they include pressure against the abdomen, inappropriate positioning (supine), twisting and torsion of spine, and uncontrolled time pressure (longer duration of contraction) (90).

3.3.2.3. Fit skills/structured exercises

The fit skills include structured exercises for upper body (arms), lower body (legs), abdomen/core, yoga, and warm up and cool down exercises.

a) Arms

The evaluation also showed that exercises such as: Overhead Arm Twist, Overhead Arm Spin, Back Press, Shoulder Press, and Overhead Press did not seem suitable for pregnant women, even though they provide good upper body strength exercises. These exercises were not deemed appropriate for this population due to inappropriate spinal position, overhead lifting, isometric contraction above the head, and torsion on the spine.

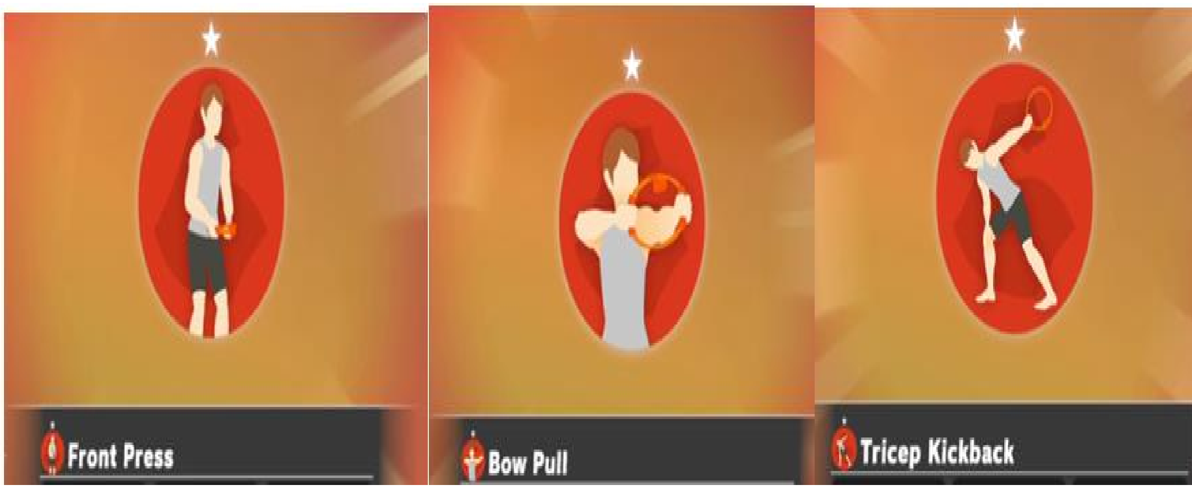

Figure 3.2: Screen shots of Nintendo Switch arm exercises.

b) Legs

Lower body exercises such as: Wide squat, Overhead Squat, Knee lift, Ring Raise Combo, Knee Lift Combo, Mountain Climber were not deemed suitable for a pregnant population. As explanation, they include inappropriate positioning and posture, fast pattern and speed of movement, overhead isometric hold, holding deep asymmetric squats, single leg requiring balance and have a potential for over exertion. The Hip lift is also not an appropriate exercise in late pregnancy as the weight of enlarged uterus may occlude venous blood return during supine position (101, 146).

Figure 3.3: Screen shots of Nintendo Switch leg exercises.

c) Abdomen/Core

Exercises targeting the abdomen/core were considered to be unsuitable during pregnancy as they include inappropriate body position, unstable and fast movements, inappropriate load through low spine (lumbar), twisting and flexion of spine, overhead movement, uncontrolled time pressure, increased risk of losing balance and limited range of motion in later stages (3, 101).

Figure 3.4: Screen shots of Nintendo Switch core exercise - Seated forward press

d) Yoga

The yoga exercises included in the Nintendo were not deemed suitable during pregnancy as they include inappropriate positioning, overhead movement, single leg balance and possibility of losing balance, lateral flexion, uncontrolled time pressure, inappropriate load on lumbar spine, and technical exercises requiring extensive flexibility (90, 101). Revolved Crescent Lunge pose may be safe when performed in a slow and controlled manner but may cause twisting of the spine.

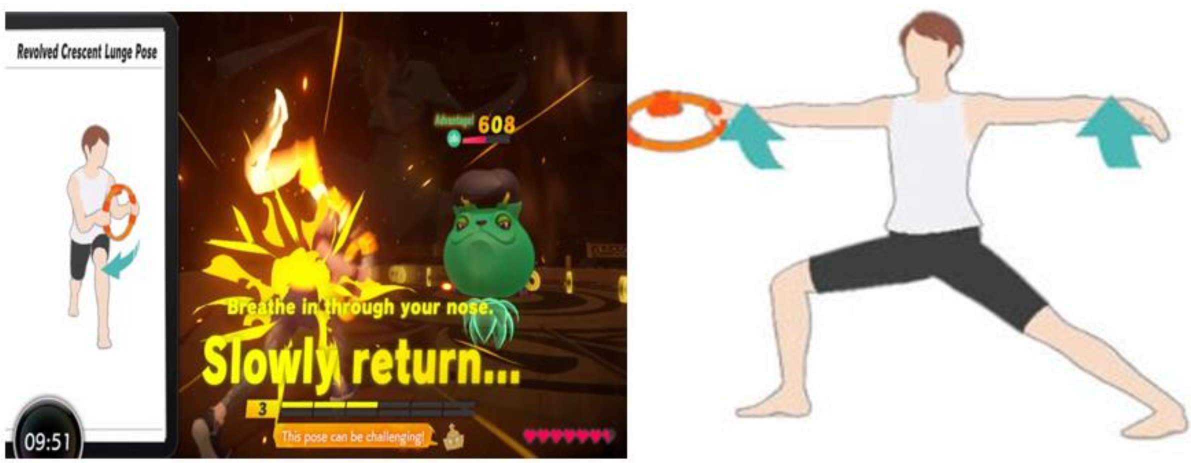

Figure 3.5: Screen shots of Yoga - warrior II pose and revolved crescent lunge pose

e) Warm up and cool down exercises

The provided warm up and cool down sessions were considered inappropriate as they have exercise programs which involve a potential risk of losing balance, pressure on the lumbar spine, and excessive flexion. Therefore, the provided warm up and cool down exercises may be best avoided. Instead, alternative options may be provided by users and practitioners.

3.3.3. User interface design

The expert evaluators suggested that the Nintendo Switch could be used for pregnant women as the user/player can customize the game settings according to their individual needs. The user can able skip non-playable content, including introductory videos, and parts of the game which are repetitive and don't fit their needs. Moreover, the game consistently informs the user about key aspects of the game and their interactions within it. This includes clear and timely feedback on their actions, progress, and changes within the game. As a result, players can make informed decisions and engage with the game experience. The goal of the game is clear and achievable while providing the exercise programs that are enjoyable, fun and engaging.

Minor technical issues on how to use Joy-con control buttons were identified for first time users [heuristic 7]. The variety of available control button options on Joy-con (X, Y, A, B, and +) might be confusing to new users. The function of these control buttons is not consistent, which may confuse the first-time user which button to press to start the game, navigate through the introduction to the game, select the game, play the game, and return to the main menu. To familiarise first-time users, a brief tutorial could be introduced at the start on the functions of each Joy-Con control button. This could help familiarize the user with the function of each button and may reduce confusion in navigation and gameplay.

Table 3.3: Lists of appropriate Nintendo switch exercises for pregnant women.

Training category	Activity	Exercise Target	Best time to use during pregnancy
Minigames	Legs		
	Squattery Wheel	Legs, Glutes, Quadriceps and chest	Throughout pregnancy
	Thigh Rider	Legs, Quadriceps	Throughout pregnancy
	Squat goals	Legs, Glutes and Quadriceps	Throughout pregnancy
	Arms		
	Robo-Wrecker	Core, Chest and Trapezius	Throughout pregnancy
	Crate Crasher	Upper arms, and Chest	Throughout pregnancy
	Bootstrap Tower	Upper arms, Chest and Trapezius	Throughout pregnancy
	Jogging		
	Beginnia	Arms, legs and aerobic	Early to mid-pregnancy
	Transient Temple	Arms, legs and aerobic	Early to mid-pregnancy
	Starting Block Bridge	Arms, legs and aerobic	Early to mid-pregnancy
Rhythm games	Rhythm games for arms and legs	Upper arm, chest and Legs	Throughout pregnancy
Exercises and Fit skills	Arms		

	Front Press	Arms and Chest	Throughout pregnancy
	Triceps Kickback	Upper arms, Triceps	Throughout pregnancy
	Bow Pull	Upper arms, Trapezius and	Throughout pregnancy
	Abdomen		
	Seated Forward Press	Upper arms, Abdomen and flexibility	Early stage of pregnancy
	Legs		
	Hip lift	Legs, Glutes	Early stage of pregnancy
	Thigh Press	Legs, glutes and Quadriceps	Throughout pregnancy
	Side Step	Upper arms, glutes and aerobic	Early to mid-pregnancy
	Squat	Legs, Glutes and aerobic	Throughout pregnancy
Yoga	Warrior II Pose	Upper arms, chest and shoulders	Throughout pregnancy
	Revolved Crescent Lunge Pose	Waist, lower body and core	Throughout pregnancy

3.4. Discussion

The current study shows that the Nintendo Switch offers a range of exercise options that target different body parts, including aerobic, resistance training and yoga exercises that can be prescribed for pregnant women. It also has interesting game mechanics, and exercise programs that are seemingly enjoyable and fun to play. However, as this game is not designed particularly for pregnant women and due to exercise contraindications during pregnancy, not all available gameplay or movements are appropriate. Hence, the expert panel identified a list of appropriate Nintendo Switch exercises to be considered for exercise prescription for pregnant women and subsequently developed an exercise program for this audience (Table 3.3).

The findings of this study revealed that some Nintendo Ring Fit exercises have the potential for excessive intensity or volume, which may be a risk for adverse events for pregnant women. This is a critical issue for pregnant women, given the high resting heart rates, and require lower workloads to reach the target heart rates (3, 32, 90, 101). Hence, exercises with potential for excessive intensity may be best avoided or undertaken with cautious monitoring of exercise intensity. A critical aspect of specific exergames, particularly for populations such as pregnant women, involves regulating the intensity and difficulty of exercise programs. These programs should be customised according to the capabilities and limitation of the user (3, 101). If the intensity and difficulty of the exercise programs are too high, it may pose safety risk and frustration for the user, resulting in adverse events or reduction in adherence to the activity.

The current study indicated that Nintendo Ring Fit has some exercises that involve inappropriate mode and positioning for pregnant women, which may result in adverse events.

Hence, exercises that involve excessive flexion, jumping, inherent risk of falling, rapid changes in posture, pressure against the abdomen, and unstable and fast movements may be best avoided, or at least undertaken with serious consideration of the potential risks (3, 101), especially if being undertaken at home without supervision. Pregnant women might be unable to perform all exercises as the game requires, due to the physiological adaptations to pregnancy. These physiological changes have implications for game designers, who may need to account for these limitations while designing exercise programs.

Change in centre of gravity due to the change in weight distribution in later stages of pregnancy may impact balance (3, 32, 90, 101). For this reason, modifications to exercise programs in later stages of pregnancy need to be considered. Exercises that require rapid changes in direction or a high degree of balance are probably best avoided or accomplished with consideration of the potential risks. An increase in body weight as pregnancy advances may also increase load at the joints. Hence, weight-supported exercises may be preferable and more enjoyable in the later stages of pregnancy (3, 32, 90, 101). Moreover, an increase in ligament laxity due to increasing hormone levels (relaxin) during pregnancy may have impact on the range of movement (3, 163). This has implications for the potential risk of injury. For this reason, exercises that require frequent changes in direction and jumping are best avoided or at least performed with serious consideration of the potential risks (3, 101).

In the later stage of pregnancy, the weight of the enlarged uterus may also occlude venous blood return (3). Hence, exercises that are accomplished in a supine position should be avoided during the second and third trimester of pregnancy (3, 101). Instead, exercises may be adjusted to be performed in a standing or sitting position. Furthermore, warm-up and cool-down exercises that can be performed in a slow and controlled manner, according to individual pregnant women's limitations, should be incorporated into the game.

This study suggested that minigames such as Crate crasher, Robo-wrecker, Thigh Rider, Bootstrap tower, Squattery wheel and Squat goals are suitable for pregnant women as they offer interesting gameplay, whilst also providing appropriate upper and lower body exercises, stable lower body position, and limited overhead movement. These minigames also offer exercises that minimise the potential for over-exertion, excess flexion or compression on the abdomen – especially given the unsupervised nature of the gameplay. The experts also considered rhythm games for legs and arms are appropriate for pregnant women, as they offer good upper body exercises, a stable base, and have minimised likelihood of overexertion due to the more controlled gameplay style (90). Further, yoga such as Warrior II pose and Revolved crescent lunge pose are also appropriate for pregnant women as they provide a stable position, isometric contraction of large muscle groups, and well-controlled speed (101).

Structured lower body exercises such as: Squat, Thigh Press, Side Step and Hip lift were evaluated as exercises that are appropriate during pregnancy. The Squat is a fundamental lower body exercise undertaken in a controlled intensity and stable lower body position. The Thigh Press and Hip lift incorporate muscles of the pelvic region and groin and offer a controlled posture, stable positioning, controlled intensity and number of repetitions. Side step also provides upper and lower body exercises with controlled intensity and number of repetitions. However, this exercise should be performed with limited overhead lifting and slower movement. Further, upper body exercises such as: Front Press, Triceps Kickback, and Bow Pull can be used safely during pregnancy as they are a good upper body exercise, with controlled intensity and number of repetitions, whilst offering a stable postural positioning and less likelihood of over-exertion (48). A summary of appropriate Nintendo Switch exercises to be considered for exercise prescription for pregnant women is provided in Table 3.3.

The major strength of this study was that a multi-disciplinary team of experts conducted the HE. This study is the first usability evaluation of Nintendo Switch for pregnant women and the results presented here will provide key information for game designers and developers who may adapt future versions of the game for the needs of pregnant women. The study shares the inherent limitation of heuristic evaluation methods of its reliance on the expertise of the evaluators (164). This study provided insights into the suitability and safety of Nintendo Ring Fit exercise programs for pregnant women that informed the design of the intervention in Study 2 and may give direction to future game designers and developers.

3.5. Conclusion

In conclusion, the study findings suggested that the Nintendo Ring Fit exercise program can be used for pregnant women, given that the specific exercises chosen for the program are safe for each trimester and tailored according to individual pregnant women's needs. These findings have significant implications for using exergames as a promising alternative way to encourage and engage pregnant women in regular exercise. The study findings also demonstrated usability concerns related to the intensity and mode of some Nintendo Switch exercises that may inhibit pregnant women's use of the game efficiently. These usability issues require the attention of game designers and developers to tailor the game according to pregnant women's needs and physiological adaptions to pregnancy. Based on implications derived from the findings of this study, in the next phase of this study, we investigate the feasibility, acceptability and potential benefits of the home-based exergaming program that was tailored for pregnancy based on the findings of this Heuristic Evaluation.

Chapter 4

Study 2

The feasibility and potential efficacy of antenatal exercise using an innovative exergame program during pregnancy.

Abstract

Aim: The study aimed to evaluate the feasibility and potential efficacy of an exergaming intervention (Nintendo Switch) for pregnant women to increase physical activity and improve pregnancy outcomes.

Methods: A single-arm pre-post testing design was employed. Thirteen women participants were recruited via social media advertisements. The intervention consisted of prescribed exergaming sessions tailored for pregnancy using the Nintendo Switch console. Women participants were followed from trial entry until 36 weeks of gestation/near birth. Pregnancy and birth outcomes were recorded as part of standard care and retrieved from each woman's pregnancy record. Physical activity levels were measured using the Pregnancy Physical Activity Questionnaire. Adherence to the exergaming program was estimated using self-reported exercise diaries and a record from the Nintendo Switch.

Results: There was a significant increase in physical activity levels, measured in metabolic equivalents (Mets), from the trial entry to the mid-intervention ($p=0.01$). There was a significant positive correlation between physical activity levels (Mets) and adherence to the exergame exercise programs ($r=0.83$, $p=0.02$). The mean adherence to the exercise program was $67.2 \pm 16.3\%$. No injuries or contraindications associated with exergaming program were reported.

Conclusions: Exergame exercise programs could be a feasible and safe exercise option for pregnant women, potentially increasing their physical activity levels and adherence to

exercise. However, consultation with healthcare providers, adherence to physical activity guidelines, and training on the use of exergame equipment are crucial to ensure safety.

4.1. Introduction

Pregnancy is a unique phase of a woman's life that entails numerous physiological changes, necessitating a tailored approach to physical activity (3, 90, 101, 165) . During this period, women often experience changes in balance, hormonal fluctuations, increased body weight and cardiovascular and respiratory function (3, 90, 101). Consequently, adapting exercise programs to these changes is crucial, ensuring their ongoing effectiveness, safety, and comfort for pregnant women (90, 91, 101). The benefits of exercise during pregnancy for maternal and fetal health is well established (11, 19, 31, 166), yet many pregnant women find it challenging to adhere to the recommended guidelines for physical activity (74, 147). Hence, exploring alternative approaches, such as exergames, appear to be a promising and potentially effective way to promote physical activity during pregnancy.

Guidelines for physical activity during pregnancy recommend moderate-intensity physical activity for at least 30 minutes per day, in the absence of specific contraindications (3, 90, 101, 146). However, most pregnant women do not meet the current recommendations for physical activity, and others significantly decrease their physical activity participation during pregnancy (74, 167). For instance, only 3 in 10 pregnant women in Australia meet the current guidelines for physical activity during pregnancy (147). Reasons for this low adherence to physical activity during pregnancy include safety concerns, lack of motivation and enjoyment, time limitations and limited access to training facilities (102, 168-170). Hence, innovative approaches to overcome these constraints are critical. In particular, attention should be paid to exercises that can be performed safely at home and are easily adhered to by pregnant women. One such potential novel approach to promote regular exercise in pregnant women may be via exergames.

A number of studies have classified playing exergames as light to moderate intensity physical activity that can contribute to daily minimal requirements of physical activity levels (42, 43, 171). Exergaming has been shown to have numerous health advantages, including increased enjoyment, motivation to engage in physical activities, and a higher level of adherence (46-48, 172-174). Moreover, exergaming has demonstrated positive effects on physical fitness and weight control, in non-pregnant populations (175-178). However, the potential health benefits of exergames for pregnant women remain an area yet to be explored.

Home-based exergaming has the potential to address some constraints of physical activity during pregnancy, as it allows undertaking physical activity in privacy at home, at a time when it is convenient. This is especially meaningful for pregnant women who have a sedentary lifestyle and are above a healthy weight, as they may have less motivation to participate in regular exercise within public settings such as gyms or parks (70, 79, 104). Additionally, home-based exergaming may be a favourable option for those women who prefer not to join group exercise due to cultural reasons or poor body image. Moreover, in circumstances where access to training facilities is limited due to travel, weather conditions or during pandemic, home-based exergaming options are preferable and convenient means to ensure continued physical activity.

As exergames have the potential to encourage regular exercise while meeting pregnant women's physiological needs, it is imperative to evaluate the feasibility and safety of exergame exercise programs during pregnancy to identify its potential benefits and challenges and ensure pregnant women's safety. However, the feasibility and benefits of exergaming during pregnancy have not been studied before. Thus, this study aims to address this gap by investigating the feasibility and safety of exergaming and its potential benefits during pregnancy. This innovative study is the first to evaluate the feasibility, safety and potential benefits of a home-based exergaming intervention during pregnancy. The findings from this study will provide valuable insights for the development of future trials and may provide evidence for designing health policy and recommendations on physical activity during pregnancy. Furthermore, the study findings may give directions to game designers to develop more effective exergame exercise programs specifically designed for this group in the future.

4.2. Methods

4.2.1. Study Design

A single arm pre-post testing design was conducted among pregnant women in Australia, to evaluate the use of Nintendo Switch exercise programs for exercise during pregnancy. Participants were recruited via social media. In this design, each pregnant woman was used as their own control. Each woman undertook two assessments; at trial entry (pre-test at ≈16 weeks) and then the same measurements were repeated at the end of the intervention (post-test at ≈36 weeks). Feasibility studies often adopt this approach to evaluate the potential of intervention implementation. The findings from this design provide insights into potential benefits, safety and other trends associated with using exergaming, and may inform the design of a future randomised controlled trial.

The feasibility of the exergaming program was defined as the extent of the potential success of the exergaming program tailored specifically for pregnant women to increase physical activity in pregnant women. Feasibility was assessed in terms of 1) the safety and suitability of exercise programs, 2) adherence to the exergaming program, and 3) pregnant women's views and experience of exergaming during pregnancy. The effectiveness of exergaming programs to increase physical activity in pregnant women has not been studied before, which indicates the need for future randomised controlled trials. Feasibility studies are recommended to inform the design of such trials to address the key question, 'Can it work? (179, 180). Hence, the aim of this study was to assess the feasibility of exergaming programs for pregnant women. In this study, we used the definition of feasibility studies proposed by Bowen et al. (2009) (181). The public health approach to defining feasibility studies of Bowen et al. (2009) identifies eight appropriate areas of focus. This study addresses six of these. They are: acceptability, implementation, practicality, adaptation, integration and expansion.

4.2.2. Participants

Pregnant women who self-identified as sedentary and not engaging in regular and structured exercises were eligible for inclusion in the study. Additionally, pregnant women between 18 and 40 years of age with a singleton pregnancy were eligible for inclusion. Pregnant women were deemed ineligible for the study if they had any of the following characteristics: under 18 or over 40 years of age, multiple pregnancy, ongoing smoking during the current pregnancy, and unable to understand the implications of participation. The women were ineligible if they were smokers as smoking can reduce lung function and cardiovascular health, leading to decreased oxygen supply during exercise and potentially affecting endurance (182, 183).

Pregnant women were also ineligible if they had medical or obstetric conditions that meant they were recommended not to engage in physical activity during pregnancy (101).

4.2.3. Recruitment

Women participants were recruited via social media using advertisements containing a description of the purpose of the study and conditions for eligibility. Participants were recruited from four Australian states (New South Wales, Victoria, Australian Capital Territory, and Queensland). The study was advertised on different social media platforms between January and December 2022, including a large Facebook group dedicated to mothers and pregnant women. The advertisement included a link to a web-based survey (Google Forms) where interested pregnant women were asked several eligibility screening questions. Eligible participants were then asked to provide their contact details. Responding women were then provided with detailed study information including the study's purpose, potential risks and benefits, informed consent requirements, confidentiality measures, and other relevant information needed for the women to make an informed decision about their participation. The women were then invited to provide consent to participate in an eligibility screening. The absence of contraindication for physical activity was verified using a screening tool for exercise during pregnancy (184) and by requesting the women to provide clearance from their midwife or medical practitioner for them to engage in physical activity (Appendix 2). Women who met the eligibility criteria were then invited to either come to the university campus in person, or were given the option for virtual communication via Zoom, with the PhD researcher and a midwife.

4.2.4. Intervention: Development of exergame exercise programs tailored for pregnancy

The exercise intervention used a home-based Nintendo Switch console and games (Nintendo Co Ltd, Kyoto, Japan), tailored for pregnant women by our research team. Each pregnant woman was followed from trial entry to 36 weeks of gestation or near birth. The exergame has five play modes with different exercise options including: Adventure, Quick Play, Multitask Mode, Rhythm Games and Custom mode. The 'custom mode' has an option where the players can tailor exercise programs according to their individual needs.

As described in Study 1, Chapter 3, our multidisciplinary research team evaluated the suitability and safety of Nintendo Switch exercise programs for use by pregnant women using an expert's heuristic evaluation. Based on this initial exploratory work, we developed Nintendo Switch exercise programs tailored specifically for pregnant women using a variety of exercises available on the Nintendo Switch (Appendix 3). This exercise programs were tailored to accommodate the common limitations experienced by pregnant women and their physiological changes during pregnancy. For example, this intervention includes a combination of low impact aerobic exercises, strength training exercises, and yoga. Examples of these exercises are given, and a detailed list can be found in Table 3.3.

During the intervention period, women participants were provided a Nintendo Switch console and all necessary accessories to keep at their homes. Before starting the intervention, participants were thoroughly familiarised with all equipment, exercises and training programs in person at the university campus or virtually via Zoom. This familiarisation involved how to connect the console to their home TV system (Appendix 4), exergaming prescriptions with weekly exercise targets (duration, frequency and intensity) and safety precautions/considerations during exergaming (Appendix 5). The women were also advised on physical warning signs to be aware of, and when to discontinue exergaming and contact the research team and their health care provider. Subsequently, the women participated in the exercise program with support from the research team either in person or via Zoom once a fortnight during the intervention period.

The intervention (exercise program) started with prescribed sessions on two days per week (20 min/session) in week 1, building to three days per week (25 min/session) by week 3 (Table 4.1). The duration and frequency of prescribed exergaming varied over the intervention period. Exergaming duration and frequency were progressively increased throughout the intervention period, with the aim of achieving three to four days per week (30-40 min/session), accomplished at moderate intensity. The duration and intensity of exergaming were progressively decreased again during late pregnancy. The exercise program was individualised for each women considering her trimester of pregnancy, previous exercise experience, level of fitness, and exercise preferences and comfort. Each exergaming session began with a 5-minute warm-up period, and conclude with a 5-minute cool down period, with static stretching of major muscle groups. The details of each exergaming session are provided in Appendix 3. Women were encouraged to maintain their prescribed exergaming (exercise) sessions until at least 36 weeks of gestation. Each pregnant woman was provided with an exercise diary to document the details of each exercise session, including the frequency and duration of each exergaming session.

Regular contact was maintained with all participants during the entire intervention period to assess their progress, motivate and encourage them and to check whether they had any challenges with equipment, exercises and training programs. Throughout the intervention period, women were encouraged to continue their usual activities of daily living and physical activity routines. They also received standard antenatal care as per hospital protocol for the duration of their pregnancy.

Table 4.1: An example of 2 weeks of the Exergaming sessions for pregnant women.

Week 1			
Exercises	**Repetition (Reps)**	**Session 1 (20 min)**	**Session 2 (20 min)**
		Time/duration	**Time/duration**
Warm up	1	5 min	5 min
Crate crasher Thigh Rider Crate crasher Transient Temple	1	10 min	10 min
Cool down	1	5 min	5 min
Week 2			
Exercises	**Repetition (Reps)**	**Session 1 (25 min)**	**Session 2 (25 min)**
		Time/duration	**Time/duration**
Warm up	1	5 min	5 min
Robo-Wrecker Thigh Rider Beginnia Robo-Wrecker Squattery Wheel Beginnia	1	15 min	15 min
Cool down	1	5 min	5 min

4.2.5. Measurements and outcomes

Physical activity levels

The primary outcome of this study was an increase in physical activity. Physical activity levels were measured using the Pregnancy Physical Activity Questionnaire (PPAQ) (185). Each woman was requested to complete the PPAQ at trial entry, and mid-intervention (24-28 weeks), at a time when exergaming prescription is maximal. The PPAQ is a widely used tool for the assessment of physical activity during pregnancy. It provides a quantitative measure of the intensity, duration, frequency and types of physical activity, including sedentariness (185). The PPAQ has been shown to be a valid and reliable tool for measurement of the physical activity level during pregnancy (186-188). The questionnaire records self-reported time spent participating in activities, including household/caregiving, occupational, sports/exercise, transportation, and inactivity (sedentary activities). The PPAQ appears in Appendix 7. At the end of the lists of activities in the ''Sports and Exercises'' section of the PPAQ, an open-ended section (questions #30 and 31) allows the women to report any unlisted activities. For each activity, women are asked to select the category that best estimates the amount of time spent on an activity during the current trimester of their pregnancy. Number of hours spent in each activity was multiplied by the activity intensity to calculate average daily energy expenditure (measured in MET-hours per day) attributable to each activity (13, 189, 190). A metabolic equivalent (MET) is a method used to measure the intensity of various physical activities (13). MET is defined as the amount of oxygen consumed at rest while sitting quietly in chair, approximately 3.5 ml 0_2/kg/min. For instance, an activity with a MET value of 2 would require two times more energy than resting (13).

Gestational weight gain

Women's weight and height measurements were recorded as part of standard care by their medical practitioner or midwife and were retrieved from each woman's handheld pregnancy record. Weight in early pregnancy and at the end of intervention (36 weeks of gestation or nearest to birth) were recorded. Subsequently, maternal BMI was determined by dividing the weight in kilograms by the square of the height in meters (kg/m^2). Gestational weight gain (GWG) was determined in accordance with the recommendations from the Institute of Medicine (IOM) (191). The IOM considers a range of gestational weight gains for each BMI category (Appendix 6). For example, excessive gestational weight gain is defined as a weight gain of >9 kg for obese, >11.5 kg for overweight, >16kg for normal weight, and >18kg for underweight pregnant women.

Blood pressure

Blood pressure measurements were recorded as part of standard care and retrieved from each woman's handheld pregnancy record. Blood pressure measurements were recorded as systolic and diastolic pressure at trial entry and at the end of intervention (36 weeks of gestation or near birth). The diagnosis of gestational hypertension (GH) was defined according to the criteria of the International Society for the Study of Hypertension in Pregnancy (192). GH was defined as systolic blood pressure at ≥140 mmHg and/or the diastolic blood pressure ≥90 mmHg) (192).

Birth Outcomes

Data on birth outcomes such as mode of birth, birth weight, gestational age at delivery, perineal tears and length of hospital stay were recorded as part of standard care by medical practitioner or midwife and were retrieved from discharge reports provided by the participating women after they gave birth.

Adherence and adverse events

Adherence to the exergaming program was estimated using self-reported exercise diaries (Appendix 8). The Nintendo Switch console records the duration of each exergaming session, the types of exercises performed within each session, and the number of times each exercise is repeated. The recorded data is stored automatically in the games system. To retrieve this data, users can navigate through the games menus which provide summaries of their exercise history, including exercise types, durations and estimated calories burned. Adherence was reported as the percentage of prescribed exergaming sessions accomplished during the intervention period of each participant. Additionally, each study participant was monitored for any adverse events or injury. Women were advised to stop the intervention (exergaming) and notify their health care provider and research team immediately in the event that they felt unwell (for example, chest pain, persistent excessive shortness of breath, severe headache, persistent dizziness/feeling faint, regular painful uterine contractions, vaginal bleeding, and persistent loss of fluid from the vagina), or if they experienced any other problems with their pregnancy (Appendix 5).

4.2.6. Statistical Analysis

Analyses were performed using SPSS Software, version 28 (IBM Corporation, Armonk, NY). Descriptive analysis was done using mean and standard deviation for continuous variables, and frequency and percentage for categorical variables. Normality distribution was checked using the Shapiro-Wilk and normal Q-Q pilot. Pearson's correlation was used to estimate the association between physical activity (Mets) and adherence to the exergame program. Mean systolic and diastolic blood pressure between trial entry and end of the intervention was compared using a paired-sample t-test. Mean physical activity levels (Mets) between trial entry and mid-intervention were compared using a paired-sample t-test. Statistical tests was two-tailed, and significance was set at $p<0.05$. Confidence was set at the 95% interval.

4.2.7. Ethical considerations

Ethical approval was granted by the Human Research Ethics Committee of the University of Technology Sydney (ETH20-5283). All participants were provided with detailed written and verbal information about the study (Appendix 9), were given sufficient time to consider and understand the information, and the freedom to decide whether or not they wished to participate. Participants were informed that their participation was voluntary, and they were free to withdraw from the study at any time, without giving reasons. They were also assured that they were not obliged to answer questions they didn't want to answer. Written informed consent was obtained from each study participant after the full nature of the study was explained to them (Appendix 10). To maintain confidentiality, all data were stored securely in a locked office and in secure cloud storage software on a password-protected computer.

4.3. Results

4.3.1. Recruitment

Following social media advertisements, we received contact from 30 pregnant women expressing their interest in participating in the study through a web-based survey (Google Forms) accessed via a provided link. Out of 30 potential pregnant women, 18 women provided consent to participate in the study and underwent an eligibility assessment. Five pregnant women were excluded at screening due to ineligibility and 13 pregnant women were recruited for the study. Recruiting an adequate number of pregnant women within the planned timeframe through social media advertisements posed significant challenges. These challenges may have arisen due to restrictions associated with COVID-19 and/or due to the concerns pregnant women may have had about the study or the safety and the validity of exergaming exercises during pregnancy. However, women who consented to participate became interested in exergame exercise programs upon discovering the Nintendo Switch, its diverse exercise programs, and innovative training techniques. The flow of women participants through the study is shown in in Figure 4.1.

4.3.2. Retention

Out of the 13 women initially recruited for the study, eight women attended the exergame exercise program until its conclusion. Apart from one pregnant woman who dropped the study for personal reasons, the other four pregnant women were excluded from the study (Figure 4.1) due to the development of medical conditions, gestational diabetes (n=2) and pelvic pain (n=2). One pregnant woman participated in the program for a duration of 4 weeks, while the other three pregnant women attended for a period ranging from 7 to 14 weeks. Despite their willingness to continue being part of the study, these women were excluded as they required close monitoring from their healthcare provider. These pregnant women received the appropriate treatment in accordance with the protocols followed by their hospital. All pregnant women who attended the minimal amount of required exergaming sessions, at least four weeks, were included in the analysis.

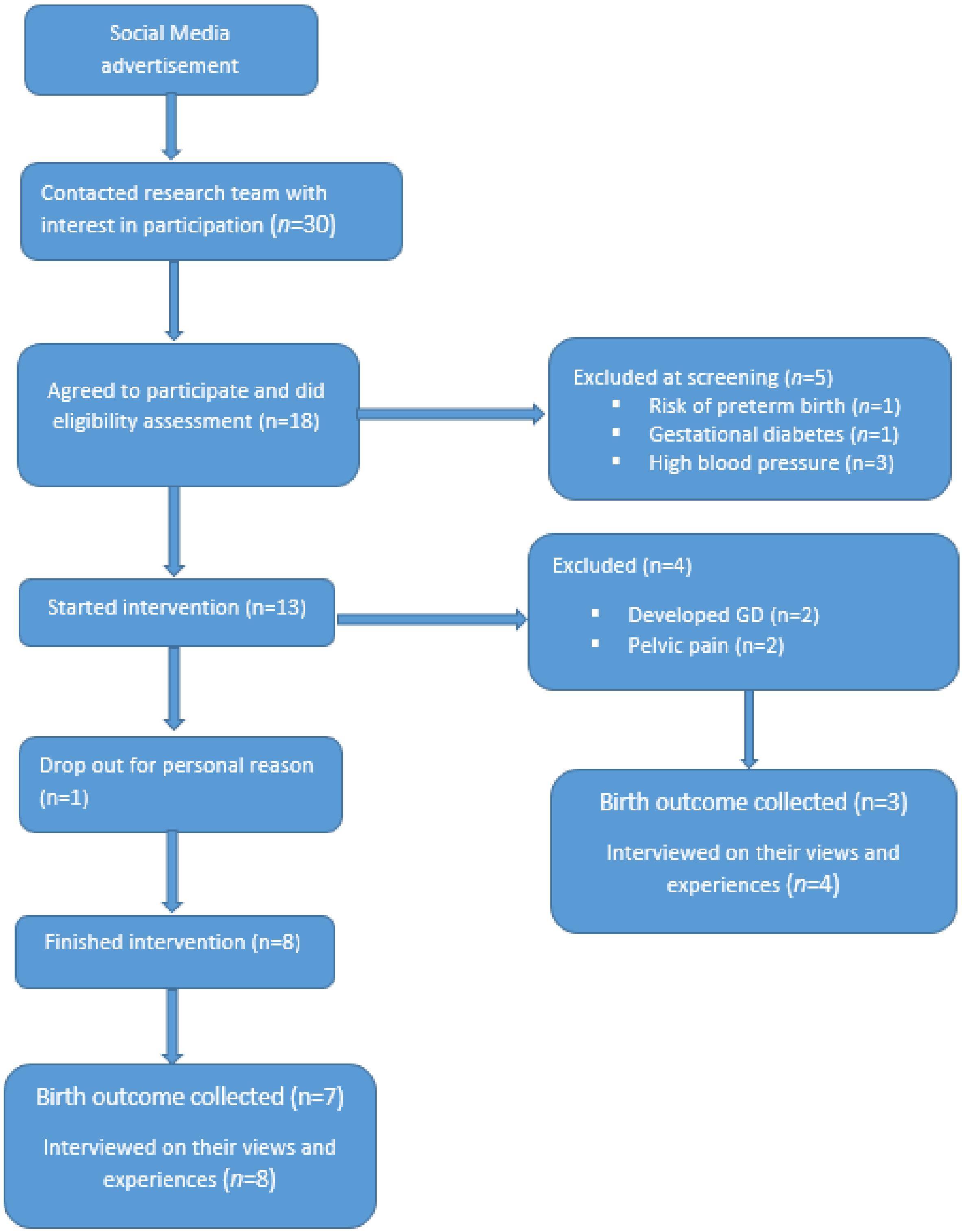

Figure 4.1: Flow chart of study participant recruitment and engagement in the study.

4.3.3. Baseline characteristics

Table 4.2 presents the baseline characteristics of women participants. The mean age of the pregnant women at trial entry was 32.5 ± 2.7 years. The majority of the women participants (8 out of 12) started the intervention at 16 weeks of gestation. One pregnant woman commenced intervention at the beginning of her third trimester (28 weeks of gestation). More than half of the woman participants (7 out of 12) had a normal weight (BMI between 21.3 and 24.5 kg/m^2) at trial entry. However, two women had a high BMI at trial entry, with BMI values of 37.7 kg/m^2 and 39.5 kg/m^2.

Table 4.2: Baseline characteristics of women participants (n=12)

Characteristics	Mean ± SD	Min	Max
Age (years)	32.5 ± 2.7	29	38
Pre-pregnancy weight (kg)	72.3 ± 18.6	50	109
Height (m)	1.64 ± 0.09	1.44	1.78
Pre-pregnancy BMI (kg/m^2)	26.7 ± 6.0	21.3	39.5
Gestational age at trail entry (weeks)	18 ± 4	16	28
		Number	**Percentage (%)**
Pre-pregnancy BMI (kg/m^2)	Normal weight (18.5–24.9)	7	58.3
	Overweight (25.0–29.9)	3	25
	Obese (≥ 30)	2	16.7
Parity	0	4	33.3
	1	4	33.3
	2	4	33.3
State/region	NSW	8	66.7
	VIC	2	16.7
	QLD	1	8.3
	ACT	1	8.3

Values are expressed in mean ± SD or number and percentage of the group.

4.3.4. Pregnancy outcomes

Table 4.3 provides details on the pregnancy outcomes of the participating women. None of the pregnant women were diagnosed with gestational hypertension or high blood pressure (>140/90). There was no significant difference in systolic or diastolic blood pressure between trial entry and end of the intervention ($p>0.05$). The mean gestational weight gain among women participants was 11.3 ± 4.4 kg. Two women participants developed gestational diabetes mellitus during the study. Subsequently, these women were provided with standard treatment according to the hospital protocol for managing gestational diabetes mellitus.

Table 4.3: The pregnancy outcomes of women participants (n=11)

Pregnancy outcomes	Mean ± SD	Min	Max	P-value
Weight (kg)				
Pre	73.2 ± 19.2	50	109	
Post	84.9 ± 17.4*	63	120	<0.001
Systolic blood pressure (mm Hg)				
Pre	111 ± 17	90	140	
Post	110 ± 11	95	128	0.8
Diastolic blood pressure (mm Hg)				
Pre	72 ± 12	60	90	
Post	70 ± 7	58	80	0.30

* represents significantly different to Pre-intervention (p<0.05)

4.3.5. Birth outcomes

Table 4.4 provides a summary of the data pertaining to birth outcomes. The results indicate that the women participants experienced favourable birth outcomes, with no reports of severe complications or negative outcomes for mothers or babies. Only one of the pregnant women who completed the intervention did not provide data on her birth outcomes. The majority (70%) of women participants gave birth vaginally. This is a promising figure that warrants further research in an adequate sample size, given that the national rate of vaginal births is 62% (193). For those who had a normal vaginal birth, the mean length of hospital stay was (1.41 ±1.27) days. Only 26.7% of the Australian birthing population in 2021 stayed in hospital less than 2-3 days, hence this is another outcome that may warrant further investigation in a larger cohort. All women in the study gave birth at term, after completing a gestation period of more than 37 weeks. Moreover, all the babies were born within the normal birth weight range, with a mean birth weight of (3.55 ± 0.37 kg).

Table 4.4: The birth outcomes of women participants (n=10)

Birth and newborn outcomes	Mean ± SD	Min	Max
Gestational age at birth (days)	276.4 ± 7.7	261 (37+2 wks)	287 (41 wks)
Baby birth weight (kg)	3.55 ± 0.37	2.8	4
Length of Hospital stay (days) (n=6)	1.41 ± 1.27	0.25	3
		Number	**Percentage (%)**
Mode of birth	Vaginal (normal)	6	60
	Vaginal (instrumental)	1	10
	C/S	3	30
Perineal tears	Yes	2	20
	No	8	80

Values are expressed in mean ± SD or number and percentage of the group.

4.3.6. Physical activity levels

The study found that there was a significant increase in the mean physical activity level (Mets), as measured by the Pregnancy Physical Activity Questionnaire (PPAQ), from the trial entry to the mid-intervention period between 24-28 weeks of gestation (p=0.01) (Table 4.5). Ten participants completed the PPAQ at baseline and at 24-28 weeks of gestation following enrolment. The other participants completed the questionnaire at baseline only. The results of the PPAQ showed that the pregnant women in this study had a higher energy expenditure in household/caregiving and occupational activities. Slow walking is the most frequently reported activity. There was a significant positive correlation between physical activity levels (Mets) and adherence to the exergame exercise programs (r=0.83, p=0.02).

Table 4.5: Physical activity levels at baseline and mid intervention (n=10).

Activity	Met-hr/day (Mean ± SD)	Min	Max	P-value
Baseline/Pre	48.9 ± 12.5	32.2	71.4	
Mid intervention	55.7 ± 17.4*	36.5	86.0	0.019*

*represents significantly different to baseline/Pre (p<0.05), Met- Metabolic equivalent, SD- Standard deviation

4.3.7. Adherence to the exercise programs

The mean adherence to the exercise program was 67.2 ± 16.3%, with a range of 41.2 % - 92.1 %. Apart from one pregnant woman, all participants attended more than 50% of prescribed exercise sessions. Notably, half of the women participants were able to attend more than 70% of the prescribed exergaming sessions, with adherence rate ranging from 71.4% to 92.1%. However, the mean exercise adherence rate dropped to 20.0 ± 21.4 % after 35 weeks of gestation. The women mentioned common pregnancy-related issues such as increasing pelvic pressure, lower back pain, and tiredness as the main reasons for not attending all exercise sessions. The analysis of adherence for two pregnant women was not possible because the women either did not complete the exercise diary or failed to return the Nintendo Switch device.

4.3.8. Safety

No injuries (such as falls, strains, sprains, joint injuries, or other musculoskeletal problems) related to the exergame exercise programs provided by the research team were experienced by the participants. None of the women participants developed concerning symptoms (such as chest pain, shortness of breath, severe headache, persistent dizziness/feeling faint, regular painful uterine contractions, vaginal bleeding, or persistent loss of fluid from the vagina) requiring termination of the exergaming program.

4.4. Discussion

In this study, we presented a novel approach aimed at encouraging regular exercise in pregnant women. To the best of our knowledge, this is the first study to evaluate the feasibility, safety and potential benefits of a home-based exergame intervention during pregnancy. The study findings show that the Nintendo Switch exercise programs are a feasible and safe form of exercise to use during pregnancy if tailored specifically for pregnancy. The results of this study demonstrated that exergame programs can increase physical activity during pregnancy and showed acceptable rates of adherence. Furthermore, exergame programs resulted in no injury or contraindications requiring termination of the exergaming program. Hence, exergames could be used to promote regular exercise during pregnancy. However, larger RCTs of exergame programs are required to validate the safety and potential benefits of this type of exercise as an option for pregnant women.

The study found that the levels of physical activity were significantly increased from baseline to mid-intervention in the pregnant women using the exergame. Additionally, a positive correlation was found between physical activity levels (Mets) and adherence to the exergame programs. The study findings are consistent with previous studies conducted in sedentary and high-risk populations, which also indicated that exergaming has a positive effect on physical activity levels (172, 174, 177, 194), fitness (175, 195), and attitudes towards doing other forms of exercise (60, 196). The study findings also align with a previous RCT study that implemented an individualized exercise program twice per week during pregnancy, which consisted of aerobic exercises on a treadmill and resistance exercises, leading to a higher level of physical activity (197). A recent systematic review of effectiveness of physical activity interventions also demonstrated that physical activity interventions increase physical activity levels of pregnant women (198). The findings of this study suggest that exergames could be a viable exercise option to encourage an active and healthy lifestyle during pregnancy. However, further large-scale randomised controlled trials are required to fully validate the effects of exergaming on physical activity levels during pregnancy.

The study showed high rates of retention and acceptable rates of adherence to the exergame program. This could be attributed to the convenience offered by the exergame program, enabling pregnant women to exercise at their preferred time, thereby eliminating some barriers to physical activity during pregnancy. Additionally, exergames may be advantageous to aid motivation for exercise by connecting the fun of electronic games with physical activity (199, 200), in the home environment. The study findings align with previous research conducted in non-pregnant populations, which also demonstrated that playing exergames leads to increased enjoyment, enhanced motivation for future play (54, 201-203), and improved adherence (37). The mean adherence rate in our study of 67.2 ± 16.3% was higher than observed in research consisting of a structured, home based 16-week stationary cycling program with 3-5 weekly sessions for pregnant women, which reported an average of 33% of exercise sessions completed (204). It could be speculated that use of exergaming may be a method to increase adherence, due to the fun and motivating nature of gameplay. However, the adherence in our study was not as high as that reported in a study that used supervised aerobic exercises on a treadmill and resistance exercises conducted twice per week, in which an average of 83.7% of exercise sessions were completed (197). The supervised nature of the intervention in the previous study may have contributed to a higher adherence rate. However, another RCT study that used supervised 12-week exercise programs reported that only 60% of women participants were able to attend at least 50% of prescribed exercise sessions (99). The program involved aerobic exercise (treadmill) and strength training exercises performed three times per week. Similarly, a previous study that involved supervised exercise programs (aerobic and strength training exercises) performed twice per week found that only 16. 3% of the women participants attended at least half of the prescribed training sessions (205). Hence, exergaming could be a method to improve adherence to exercise during pregnancy. Future research should aim to compare levels of supervision required and identify suitable types of exergame exercises for pregnant women to achieve an optimal level of adherence to exergame programs. In particular, women with pregnancy-related illnesses or other underlying conditions require greater attention, which entails more frequent supervision and tailored exercise programs to meet their specific needs.

The results of the current study indicate that women participants experienced favourable pregnancy and birth outcomes, with no reports of severe complications or adverse outcomes for both the mothers and babies. Acknowledging the small scale of this feasibility study, our finding is supported by evidence from the recent systemic review and meta-analysis, which demonstrated that regular exercise during pregnancy has positive effects on pregnancy and birth outcomes (11, 19, 31, 206-209). Studies involving exergames have also demonstrated that exergames are a promising approach for promoting various health benefits (116, 210-213), although these studies did not include pregnant women. However, evaluation of pregnancy and birth outcomes in the current study was expected to be limited by the nature of the study design, as it could be influenced by several factors and participation biases. This study included low-risk, motivated pregnant women in a high-income setting, who had access to regular prenatal care, which may have contributed to better pregnancy and birth outcomes. Further randomised controlled trials with a larger group of participants in a clinical setting is required to investigate the effect of exergame exercise programs on pregnancy and birth outcomes.

In this study, participating pregnant women exhibited optimal weight gain in accordance with the IOM recommendations for pregnancy weight gain (191). Whilst recognising the lack of control group and small sample size in this feasibility study, these findings conform with evidence from an RCT study conducted in postpartum women (36), in which the exergaming group experienced a greater weight reduction and more significant decrease in Body Mass Index (BMI) and body fat compared to the control group, following 40 days of exergaming (36). Similarly, a home-based 12-week exergaming programme among postpartum women showed that exergaming can prevent the retention of gestational weight gain, and reduce body mass and BMI (214). Further supporting this, recent systematic reviews have demonstrated that structured exercise interventions can decreases excessive gestational weight gain during pregnancy (10, 215). Larger scale randomised controlled trials are warranted to further investigate the effect of exergame exercise programs in weight management during pregnancy.

An important outcome was the lack of injuries or adverse events reported in relation to the exergame exercise programs, for which no discontinuation of the exergaming program was required. The absence of such incidents in this study may be attributed to the design of the exercise programs, which were carefully aligned with the guidelines for physical activity during pregnancy (79, 104, 174). Furthermore, the familiarisation and training provided by the research team on the safe and effective use of the exergame equipment and exercise techniques may have made a positive contribution. Additionally, the regular support provided by the research team throughout the study, along with the individualised nature of the exercise programs, may have played a role in preventing injuries or adverse events. Although speculative, such an outcome is important to add to the support for the feasibility of exergaming programs for safe participation in physical activity by pregnant women. As further evidence, previous studies conducted on non-pregnant individuals have also demonstrated that exergames are generally considered safe for use (216, 217). However, soreness and mild muscle and joint injuries have been reported amongst postpartum participants using home-based active video games (Nintendo Wii console) (36). Hence, it is essential to choose exercises that are low-impact, provide stability, avoid excessive flexion and risk of falls, as the physiological changes that occur during pregnancy can potentially increase the risk of injury (90, 91, 101). The finding of the current study suggests that exergames could be a safe form of exercise option to encourage and engage pregnant women in regular exercise, if tailored according to individual pregnant women's needs and limitations.

A strength of this study was that we implemented individualised exergame programs specifically tailored for pregnancy, following the recommendations for physical activity during pregnancy (3, 90, 101). This study is the first to attempt to evaluate the feasibility, safety and potential benefits of exergame-based exercise programs during pregnancy. Another notable strength of this study was the ability to maintain a high retention rate among women participants. A limitation of this study might be recruitment via social media, which could introduce bias, as not all pregnant women use social media or actively engage with advertisements. The unsupervised nature of the intervention could be considered a limitation of the study, though this was a result of the constraints of geographical location of participants and the ongoing COVID-19 pandemic. However, one of the aims of the program was to enable home based exercise, to attempt to overcome some of the barriers to physical activity in pregnancy. This was a self- limiting factor in providing access to exercise supervision. Nevertheless, prior to commencement of the intervention, participants received instruction and training on all aspects of Nintendo Switch equipment, exercises programs and training techniques. Subsequently, the women participated in the exercise program with support from the research team once a fortnight throughout the intervention period. We believe that the current study findings provide valuable preliminary insights into the safety and feasibility of using exergames as part of pregnancy exercise routines, which may give directions to game designers and developers to create more effective and tailored exergame exercise programs for pregnant women in future.

4.5. Conclusions

The findings suggest that the Nintendo Switch exercise program developed in this study was a feasible and safe form of exercise to use during pregnancy, given that it was tailored according to individual pregnant women's needs and trimester of pregnancy. The study findings also indicated that exergame exercise programs have the potential to increase physical activity level and enhance adherence to exercise routine. Overall, the evidence from this study suggests that exergaming during pregnancy may offer numerous potential benefits. Further large-scale randomised controlled trials in the clinical setting are required to corroborate these findings and to investigate the effects of exergame exercise programs on pregnancy and birth outcomes. In the next phase of this study, we explore the views, experiences and acceptability of pregnant women involved in the current study regarding the use of exergame exercise programs during their pregnancy.

Chapter 5

Study 3

Pregnant women's views and experiences of antenatal exercise using an innovative exergaming program.

Abstract

Aims: The aim of this study was to explore pregnant women's views and experiences of the home-based exergaming intervention.

Methods: A qualitative study design was adopted to explore women's views and experiences of exergaming during pregnancy. Women participants completed a home-based exergaming intervention from 16 to 36 weeks of gestation and were interviewed post-intervention (at 36 weeks of gestation or near birth). Twelve pregnant women were interviewed. The study was conducted using a semi-structured interview technique. The interviews were audio recorded and transcribed verbatim. Data were analysed qualitatively using the thematic analysis methods of Braun and Clarke.

Results: The analysis revealed 4 main themes: 1) convenience of exergame, 2) motives for exergaming, 3) perceived game usability and 4) improvements for future game versions. The women found that the Nintendo Switch exercise programs were convenient, motivating and easy to use during pregnancy. They suggested that future exergames design and development for pregnant women should incorporate a variety of exercise programs that are specifically tailored for pregnancy.

Conclusion: The results of the study suggest that exergame exercise programs were found to be acceptable, enjoyable, and convenient to pregnant women in the study. Our findings suggest exergames as a promising approach for encouraging regular exercise and addressing barriers to physical activity during pregnancy. Future game design should take into account pregnant women's limitations and preferences.

5.1. Introduction

Regular exercise during pregnancy provides important health benefits for both the mother and her unborn baby (3, 90, 101, 146). Some of the benefits include better management of weight gain, improved physical fitness, and enhanced psychological well-being (11, 32, 100). Previous studies have also shown that regular exercise during pregnancy can potentially reduce the risk of adverse pregnancy and birth outcomes (10, 19, 31). However, the majority of pregnant women do not engage in regular physical activity, and others significantly reduce their physical activity participation during pregnancy (97, 218, 219). Hence, it is crucial to implement interventions that encourage regular physical activity during pregnancy.

The current pregnancy physical activity guidelines recommend that women aim for moderate-intensity physical activity for at least 30 minutes per day, unless there are specific contraindications (3, 90, 101, 146) . Despite the recommendations for regular physical activity during pregnancy, initiating exercise during this period may not be feasible for many women. This is in part related to perceived barriers to traditional forms of exercise for the pregnant woman, such as lack of motivation and enjoyment, time constraints, lack of access to a gym, and concerns about safety (219-222). To overcome many of these reported barriers, innovative approaches to engage pregnant women in regular and safe exercise in their own environments are critical. One such potential innovative approach is the use of exergames, which are emerging technologies that use interactive exercise games to enhance physical activity (223).

Exergames incorporate physical activity into computer-generated gameplay and are designed to have players interact through various body movements, thereby increasing their level of physical activity (38, 150, 224). Fittingly, the connection of physical activity with the fun of electronic games makes the exergames motivating and enjoyable, and they are a suitable option for use in a home setting (49, 224). Studies have shown that exergaming provides health benefits, including improved cardiovascular health, reduced stress and anxiety, and may be effective in encouraging physical activity in non-pregnant populations (47, 49, 54, 225, 226). However, it is uncertain whether current exergames can provide safe and appropriate exercise programs that cater to pregnant women's unique needs, limitations and preferences. Exergames, such as Nintendo Switch, may have the potential to provide a convenient way for pregnant women to exercise regularly in the privacy of their own homes.

Home-based exergaming has the potential to address some of the perceived barriers to physical activity during pregnancy, as it offers an opportunity to undertake physical activity in the safety, convenience and privacy at home (54). This is particularly meaningful for women who are inactive and above a healthy weight during pregnancy who may be less motivated to engage in regular physical activity. Exergame (Nintendo Switch) also provides the player with training, support and instructions on how to exercise using the console, and opportunities for online connection and social networking with other players.

As the exergames require constant interaction with the player/user, failure to design the game according to the needs of players can negatively affect users' experiences and the overall success of the game (227, 228). It is imperative to explore pregnant women's views and experiences of the acceptability of using exergames during pregnancy to inform usability, increase compliance with exercise programs, and ensure the safety of pregnant women. The views and experiences of using exergames during pregnancy have not yet been studied among pregnant women, hence, this study aims to fill this gap. The findings of this study will provide insights into pregnant women's motivations for using exergames, their perceptions of the benefits and drawbacks of exergames, and any challenges or barriers they encountered while using exergames. The data will inform future design of exergames that can be tailored to pregnant women's specific needs. The findings will also guide future implementation research and may provide evidence for designing health policies and recommendations on physical activity during pregnancy.

5.2. Methods

5.2.1. Study Design

A qualitative study design was adopted to explore women's views and experiences of exergaming during pregnancy by conducting individual interviews using a semi-structured interview guide. This approach was selected as it allowed flexibility in interview settings and times, which we deemed essential in being able to undertake the interview at a time and date convenient to the women.

5.2.2. Participants

Pregnant women between 18 and 40 years of age, with a singleton pregnancy of less than 16 weeks of gestation, were eligible for inclusion in the study. Pregnant women were considered ineligible if they had any of the following features: under 18 or over 40 year of age, multiple pregnancy, ongoing smoking during the current pregnancy, unable to understand the implications of participation, and any medical or obstetrical conditions for which participation in physical activity during pregnancy is contraindicated by Royal Australian and New Zealand College of Obstetricians and Gynaecologists (101).

5.2.3. Recruitment

Participants were recruited from four Australian regions (New South Wales, Victoria, Australian Capital Territory, and Queensland). Potential participants were identified via social media using advertisements containing a description of the study's purpose and inclusion and exclusion criteria. The study was advertised between January and December 2022 on different social media, including a large Facebook group dedicated to mothers and pregnant women. The advertisement contained a link to a web-based survey (Google Forms) where interested pregnant women gave their contact details. These women were then provided with detailed study information and invited to provide consent for an eligibility assessment. The absence of contraindications to physical activity was verified using a screening tool for exercise during pregnancy and by requesting that women provide Physician or midwife clearance to engage in physical activity. Eligible women were then invited to meet with the PhD researcher and a midwife at the university campus, or were given the option to communicate via Zoom.

5.2.4. Intervention

The intervention was a regular home-based exergaming (Nintendo Switch, Nintendo Co Ltd, Kyoto, Japan) program tailored for pregnant women, with follow up from 16 weeks of gestation to birth. The intervention (exergaming) was designed by a team with multidisciplinary expertise, in accordance with the physical activity guidelines for pregnant women (3, 90, 101). For example, it consisted of low impact aerobic exercises, strength training exercises and yoga. During an earlier phase of this project, our multidisciplinary research team evaluated the suitability and safety of Nintendo Switch exercise programs for use by pregnant women using an expert’s heuristic evaluation. Based on this initial exploratory work, the team developed Nintendo Switch exercise programs that are tailored specifically for pregnant women (Appendix 3).

Women participants were provided with the Nintendo Switch console and all necessary equipment to keep in their home for the duration of the intervention. Prior to commencement of the intervention, participants were fully familiarised with all equipment, exercises and training program in person or on Zoom. Subsequently, the women undertook the training program with support from the research team, in person or on Zoom, once a fortnight throughout the intervention period.

The intervention began with prescribed sessions on two days per week (20 minutes per session) in week 1, building to three days per week (25 minutes per session) by week 3. The duration and frequency of prescribed exergaming varied over the intervention period. Exergaming duration and frequency were progressively increased throughout the intervention period, with the aim of achieving three to four days per week (30-40 minutes per session) accomplished at moderate intensity by approximately 20-24 weeks of gestation. The duration and intensity of exergaming were progressively decreased again during late pregnancy. The exercise program was individualised for each woman considering her trimester of pregnancy, previous exercise experience, level of fitness, and exercise preferences and comfort. Each exergaming session began with a 5 minute warm-up period, and concluded with a 5 minute cool down period, with static stretching of all major muscle groups.

Women were encouraged to maintain their prescribed exergaming (exercise) programs until at least 36 weeks of gestation. They were also requested to record the frequency and duration of each exergaming session in an exercise diary. Regular contact was maintained with all participants throughout the intervention period to assess their progress, motivate and encourage them and to check whether they had any challenges with equipment, exercises and/or training programs. Throughout the intervention period, women were encouraged to continue their usual activities of daily living and physical activity routines. They also received standard antenatal care as per hospital protocol for the duration of their pregnancy. Women were advised to cease the intervention (exergaming) and contact their health care provider and research team immediately in the event that they felt unwell, or experienced any other problems with their pregnancy.

5.2.5. Interviews

Semi-structured interviews were used to explore participating women's views and experiences of exergaming during pregnancy (Appendix 11). Twelve pregnant women were interviewed at the end of the intervention (at 36 weeks of gestation, near to the estimated due date of birth). This time was selected deliberately to explore women's experiences across the trimester of pregnancy. The interviews were conducted face to face or virtually via Zoom at a time convenient to the women. Questions in this interview were concentrated on enjoyment and motivation, acceptability, benefits, barriers, challenges and difficulties of using exergame during pregnancy, and used to further refine future training programs and game selection. Women were also asked to provide feedback and suggestions on refining future exergame exercise programs for pregnant women. Additionally, notes were taken during the interviews to record nonverbal aspects and elaborated on as soon as possible after the interviews.

Before the interview, all women participants were informed that there were no “wrong” or “right” answers to any of the questions, and the research team was interested in their genuine experiences and views. At the end of the session, women were asked if they had any other experiences or thoughts not covered in the interview to ensure they had the opportunity to provide all relevant experiences and views. The sequence and wording of questions were the same for each interviewee. However, based on initial women’s responses to the semi-structured interview guide, follow-up questions were probed to validate the responses. All interviews were audio recorded with women’s permission and lasted between 15 and 35 minutes.

5.2.6. Data analysis

The interviews were audio recorded and transcribed immediately. The audio recordings were transcribed verbatim. Transcripts were checked for accuracy against the audio recordings, before formal data analysis. Transcripts with unclear sections were verified using the corresponding audio recordings. Data were analysed qualitatively using the thematic analysis methods of Braun and Clarke (229). The transcripts were thoroughly examined to gain familiarity with the data and to understand the experiences of the women participants. Each transcript was read and thoroughly reviewed multiple times by the PhD researcher (GK). Transcripts were coded line-by-line and analysed to identify patterns and differences among the women participants' experiences. Two investigators (GK and DF) coded the interviews. Any discrepancies in the codes were resolved through discussion until consensus was reached.

5.2.7. Ethical considerations

Ethical approval to conduct the study was obtained from the Human Research Ethics Committee of the University of Technology Sydney (ETH20-5283). All participants were provided with detailed written and verbal information about the study (Appendix 9). Participants were informed that their participation was voluntary and that they were free to withdraw from the study at any time, without giving reasons. They were also assured that they were not obliged to answer questions they didn't want to answer. Written informed consent was obtained from each study participant after explaining the full nature of the study to participants (Appendix 10). To maintain confidentiality, all data and interviews were stored securely in a locked office and in secure cloud storage software on a password-protected computer.

5.3. Results

The analysis revealed 4 main themes, including *'Convenience', 'Motives for exergaming', 'Game usability'* and *'Improvements for future game versions'*. These themes will be discussed in the following sections.

Theme 1: Convenience

The first theme, *'Convenience',* comprises the sub-themes, *'exercising at home', 'knowing the exergaming program was safe and suitable for pregnancy',* and *'finding the game easy to use'***.**

Exercising at home

'Exercising at home' was the most robust theme in relation to the convenience of exergame program for pregnant women. The women reported that the Nintendo Switch exercise

programs are very convenient during pregnancy because it gave them an opportunity to exercise in privacy at home, at a time when it is suitable for them. For example, the women mentioned:

> *You know, just having some tool inside your house to push yourself to move around is a lot of help in terms of physical health, and mental health as well… literally you just do it indoors. It's not like something that you have to go outside and risk yourself outside. It's safe, because you just have to do it indoors [Nancy].*

Exergaming was seen as a good option for women who don't enjoy going to the gym or classes. Being able to commence exercising in privacy at home was helpful way to increase physical activity, as 'Ella' described:

> *Especially for women who don't enjoy going to the gym or classes and things like that, who prefer to just exercise in their own time and pace; it's a really good option to at least get them started and always have the option to exercise at home [Ella].*

Another common view related to exercising at home was the perceived benefit of the exergame program in 'saving time'. For example, the following quotes illustrate why women believed the exergame program saved them time:

> *I think it's a really good idea [exergame], especially, when you do have a baby, don't have time to go to the gym, but you could just turn on the switch and do a quick kind of exercise. So, I do hope I can continue using it [after I have my baby] [Ella].*

If I lived in the city and could go to the gym, it would save me travel time. But where I live [in a rural area], it's either like a YouTube video or going for a walk [Kris].

The accessibility and flexibility of having the equipment at home meant they were more likely to exercise regularly. Women appreciated the ability to exercise at home at any time of the day or evening.

I find it really accessible anytime; like whenever I want to, that gives me the flexibility to exercise; it's really enjoyable as well [Nancy].

The Nintendo Switch exercise programs were seen as advantageous during pregnancy, particularly when feeling fatigued after a long day at work. The women noted that that such exercise programs are good because they can help to avoid making excuses to not to exercise due to tiredness.

I am not someone that usually [does] exercise. It was really useful…having this [Nintendo Switch] at home. So, if I came home, I wouldn't go out again to go to the gym or anything like that, especially after a hard day's work for a long day, like I just want to get home first. So then, having that already there and set up, reduces my excuse to not exercise, and reduces resistance [Ella].

Participants enjoyed the benefits of exergaming (Nintendo Switch) inside at home during poor weather. Exergaming was preferred when access to outdoor activities or training facilities was limited, due to poor weather and pandemic conditions such as Covid-19. The following quote reflects Kris' experience during winter, being pregnant and the mother of an older baby at home:

It's good to be able to do it whenever it no matter what the weather is…because once I had the diabetes and had to really pull back, I was really only managing to go for walks with the baby in the pram, but then that was quite weather dependent. So it's good; it's not weather dependent [exergame] [Kris].

In addition to cold weather, the COVID-19 pandemic impacted upon women's decision making about going outside their homes. Women were very aware of the risks of contracting COVID during pregnancy, and welcomed the opportunity to be physically active at home, as these women described:

During pregnancy, it was hard for me, just go outside, maybe because of COVID as well and because it's it was too cold. Especially during my third trimester, it was just really, crazy cold because I was due in August. So just waking up and, then just thinking 'I can exercise inside my home' is a lot of comfort for pregnant women [Nancy].

During COVID-19 period, people don't want to go out or to the gym. So, during this time, exergame (Nintendo Switch) is very suitable [Ella].

Perceived safety and suitability of exercise programs for pregnant women

All women were asked whether there was any aspect of the Nintendo Switch exercise programs that they thought/felt was not acceptable, safe, or suitable for pregnant women. All the participants felt that the exercise programs (provided by the research team) were safe and suitable to use during pregnancy. The following quote is an example of a response referring to this sub-theme.

The exercises are not really that complicated, [none of the exercises] involves jumping and stuff. It's just like floor exercise or just mild exercises that I think any pregnant women can do. You just have to maybe adjust the difficulty for each pregnant women depending on the condition of pregnant women [Nancy].

One participant appreciated being able to trust that the exercise programs were designed specifically for safety and suitability during pregnancy, and were tailor made for this purpose:

Excellent, I thought that is one of the most beneficial part of doing it this way. So, to have someone to be able to tailor it I thought was fantastic and the gradual increase of the load of the program is excellent, too. That's yeah, I would say one of the best things about it [Kris].

Finding the game easy to use

The women specifically commented on the aspects of the Nintendo Switch Ring Fit that made it easier for them to exercise appropriately as the game requires. The women found that the Nintendo Switch exercise programs were easy to perform, as the game itself provides players with instructions on how to exercise before playing the real game/exercise. For example, this is mentioned in the following quote.

The demonstrations before each of the games, were actually helpful for me to properly execute the exercise [Nancy].

Women liked the exergame program because the game doesn't require other tools or materials to exercise. The women found this helpful because it makes the game easy to use. For example, one woman said:

It was useful that the exercise didn't need any tools or other materials…that was helpful [Ella].

One woman commented on how the exergame did not require too much space at home, so was easy to accommodate. This could be an advantage to women living in small apartments or units. The following quote demonstrate this theme:

Ability to do it in my lounge room without much space around the house. I think that's really helpful for women living in a unit [small house] or who can't you know, always get out or get to the gym [Kris].

The women also highlighted the perceived benefits of exergame exercise programs in overcoming their uncertainty about how to exercise safely during pregnancy. They noted a lack of knowledge and experience regarding the safety of exercises during pregnancy (what exercise they should or should not undertake during pregnancy, and for each trimester); and what combination of exercises they should do during each session. The women highlighted that they needed an exercise program they can follow without thinking about the safety, procedures (how to perform the exercise) and what next exercise they have to do. They found that exergame exercise programs were helpful because they didn't have to worry about exercise safety, how to perform it and what exercise to do next. The women's quote provided below exemplifies some of the responses related to this sub-theme:

You know, even me, who has a degree in Exercise Science, when I got pregnant the first time around, I had no idea what exercise was and wasn't okay, and I had to do a lot of reading [Kris].

As someone who does not usually go to the gym or exercise, when you do go there, you are not sure how to do a whole body workout, or you don't know what the options are even. So, it was good to have a mix [of exercise] and different parts of my body kind of targeted [in Nintendo Switch] [Ella].

*You don't have to stop and pause and try to figure out the next exercise [Ella]***.**

Theme 2. Motivation

This theme reflected on pregnant women's motivations to use Nintendo Switch and the rationale behind their motivations. Within the theme *'Motivation,'* several sub-themes emerged. These sub-themes are presented in the following sections.

Enjoyable and Fun

It was apparent that the women found the Nintendo Switch exercise programs enjoyable, fun and motivating. The women mentioned a sense of increased motivation to exercise, as a result of the fun and enjoyable nature of the game. All women frequently used the words *"enjoyable," "fun,"* and *"entertaining"* to explain the way they felt about the Nintendo Switch exercise programs. The following quoted examples demonstrate the common responses of women participants:

It incorporates fun and entertainment in it, which is why I enjoyed it. So, it's a combination of entertainment and exercise. It is really enjoyable [Nancy].

The Minigames were pretty fun [Ella].

Even the women who had no previous gaming experience found the exergame exercise programs enjoyable and fun.

I've never really played any other games. It was enjoyable [Felicity].

The pregnant women particularly enjoyed and found fun and entertaining, exercise programs that involved music and jogging. The women's quotes provided below illustrate this:

They were fun. I enjoyed them, like a good variety of different ones each time, like you're jogging, sitting with the leg squeezes and then squats and jogging. It is a good combination [Felicity].

I really liked the music based exercises. I had a much higher kind of satisfaction or enjoyment and looked forward to it. If it is music based, it is a really strong motivator [Kris].

Novel and interactive

The '*novel and interactive'* nature of the game arose frequently, in relation to motivation to exercise during pregnancy. The women found that exergame exercise programs were quite novel and more interactive than other modes of exercise they used to use. For instance, women mentioned that exergame exercise programs would be preferable to other forms of exercise, such as treadmills or following you tube videos. The women consistently emphasised the interactive nature of the game. The game's interactive nature was the main reason the women preferred exergame exercise programs over other types of exercises. The following quotes exemplify the women's experiences:

It was certainly something that was quite novel [Kris].

> *Prior to doing the Nintendo Switch, I was doing YouTube videos for prenatal, like yoga or whatever. There is a tendency with that to just do the same videos. There's no increase in fitness [Kris].*
>
> *When you are just on a treadmill, you are kind of just staring, but at least this one [Nintendo Switch] made it a bit more interactive [Ella]**.***
>
> *It is not similar to just watching a YouTube video and then following the video. It is kind of interactive [Nancy].*

Perceived benefits of exergame to encourage pregnant women into regular exercise

The women found that exergame exercise programs were novel, encouraging and engaging. This helped pregnant women to participate in regular exercise and physical activity in their own environment. The overall sense was that as exergames were enjoyable, fun and interactive, the women participants believed that Nintendo Switch exercises could help engage and encourage pregnant women to exercise regularly. The following quotes are some examples:

> *The exergame gave me exercises that really helped me a lot in just pushing myself to move around…Just having some tool inside your house to just push yourself to move around is a lot of help in terms of physical health, and mental health as well [Nancy].*
>
> *I am not usually someone that exercises. It was really useful already having this at home. Having that already there and set up, kind of, reduce my excuse to not exercise… I think it is very useful for women who don't usually exercise often or not active. So, it's a really good alternative option [Ella].*

I think it's beneficial and I think it's really good to have something that just gets you to do a set amount of exercise regularly [Felicity].

All women were also motivated to continue using Nintendo Switch as a way of staying active or exercising after giving birth. The women were asked about their plans for using Nintendo Switch after giving birth, all responded positively and wanted to continue after giving birth. All women suggested that exergame exercise programs be used during pregnancy to encourage and engage women in regular exercise on an ongoing basis. The women mentioned that such kind of exercises could be used in the postpartum period as well, as they are a safe and simple way of staying active. For example, the women stated that:

I would definitely still continue to use the switch [after giving birth] [Nancy].

Definitely, I will continue [Ella].

I would actually [continue to use the switch after giving birth]. I feel like it is probably really good in the postpartum time. If it was a program that was tailored specifically to it [postpartum recovery], I would be quite interested in that [Kris].

Social support

The *'social support'* that was included in the program was a motivating factor for women, that made exergame exercise programs easier to execute and adhere to. This support involved encouragement from a spouse, family members and/or the research team. Such support gave them the motivation to stay active and adhere to the exercise programs. The women also mentioned that the availability of professional advice and support from the research team further encouraged them to stay active and adhere to the exercise programs. The following quote illustrates some of the responses related to the sub-theme of social support:

> *You guys [research team] really pushed me in just keeping myself motivated, keeping me active because you know, it can get really difficult during pregnancy. You just sit and stare at the bank window and it can be a bit depressing… during the third trimester [it] was hard for me to move around because the baby was really heavy. So, in terms of support, I had to have my husband beside me 24/7. Because, like I say, just picking up something from the floor is a huge chore. Just setting up the [Nintendo] Switch, for me was a huge chore as well. Just bending and putting the… controller at my thigh is a huge array. So, in terms of support, I needed someone who can help me in terms of my mobility [Nancy].*

> *My husband was very supportive in doing the technology thing. Without him, I don't think it would have been as smooth either [Kris].*

> *I think it was helpful for me with my partner who just feel like oh, he'll remind me being like, do you need to do your exercise tonight? And having that support person to motivate you and remind you as well or to make you feel guilty is a very helpful tool as well [Ella].*

Theme 3: Game usability

This theme reflects pregnant women's perceived challenges of using the Nintendo Switch during pregnancy. Overall, women found the Nintendo Switch was straightforward and easy to use. To comprehend the usability issues (user-game interaction) associated with the

Nintendo Switch, all women were asked about their perceived challenges of using the game. The women highlighted aspects of the Nintendo Switch that they found challenging. For instance, some women participants mentioned that they had difficulty using the Joy-con control buttons to start the game, navigate through it, select the exercises and go forward and backward. All women stated that the reported challenges were minor and not persistent; they happened only at the beginning or the first time they used the game. Once they were familiar with the game, these challenges were no longer an issue. The quote provided below illustrates some of the responses related to game usability and challenges:

> *I think the struggle was only because there are a lot of varieties of exercise. But once you have already done, got the hang of it and played it multiple times, it's already easy from there. So, it's only at the beginning; like how do I properly execute this exercise? But as you go on, it gets easier [Nancy].*
>
> *I think they were all kind of, they were easy to understand…I think it was easier for me because I already had a switch. So, using it and setting it up wasn't as much of a challenge to me. Even before I played Wii, Wii Sports and things like that. So having experience was a bit more of an advantage [Ella].*
>
> *It was tricky to sometimes choose games or move back and forth [Ella].*
>
> *I don't have a lot of experience with those type of things [playing games]. It was very straightforward. It was easy to set up; was easy to use. Just the control buttons were stuck sometimes. The buttons were very sensitive [the thumb stick]. So, I couldn't select things [play modes and exercises] very easily [Felicity].*

Connecting the Nintendo Switch to her TV and charging the Joy-con controllers were challenges to using the game for one woman. She stated that these issues were minor and happened only the first time she used the game.

> *Like anything, it just takes a little bit to get used to it. Charging the switch* [Joy-con controllers] *and even trying to change my TV from the usual viewing to the Nintendo side of things was a lot of little troubleshooting, which I don't think is a big problem [Kris].*

Further, one woman stated that the game does not always inform the player that they may be doing some exercises incorrectly.

> *I think the only thing with having on a game is if you're doing some of them [exercises] incorrectly, it doesn't always pick up on it [Ella].*

The availability of exercises that can be used during pregnancy was highlighted by some women as a limitation of the Nintendo Switch. For instance, one woman implied that the game offers numerous exercises, but there were few exercises in the game that were appropriate for pregnant women.

> *It was enjoyable, but it could get a bit repetitive because there were only a certain number of exercises we [pregnant women] could do on the game. I think it's hard because not all of the games were tailored to pregnant women [Ella].*

Theme 4: Improvements for future game versions

Participating women made suggestions and recommendations for the game's future modification and improvement. Some women suggested that for effective use of the game, the game must provide a variety of exercise programs that are safe to use during pregnancy and that target different body parts. A repetition of exercise programs from one week to another may de-motivate pregnant women to adopt this exercise program. For example, one woman noted that:

> *I would say, maybe there shouldn't be any repetition from one week to the other. So, it should probably be completely, or it could be potentially completely different exercises. I felt like, it could have done with more variety [Kris].*

Other women highlighted that the game should have an option or specific mode that is tailored only for pregnant women.

> *I don't know if there is, maybe, an option that they could turn on like <u>a pregnancy mode</u> because then they would have, like, warnings on how you can do this exercise faithfully or according to your pregnancy because there could be some exercises you could do that there might be some kind of, you just have to be aware of how to do it a bit safer [Ella].*

The women suggested that the game should provide tutorials and detailed information on how to use the game to improve game usability. For example, one woman participant described:

Potentially like in the actual game itself, they could have some tutorials on like, how to charge or that kind of thing [Kris].

Further, the woman commented that individualized support during pregnancy is helpful. For instance one woman stated that:

My shifts are different every day. So it was hard to find a routine that works every single week if I had a different finish time or start time at work. So depending on someone's occupation as well, they might also need different levels of support and exercise routines [Ella].

5.4. Discussion

The aim of this qualitative study was to explore women's views and experiences of using exergame (Nintendo Switch) exercises during pregnancy. The current study presented data on the acceptability, suitability, perceived benefits, and possible barriers of using exergame exercises during pregnancy. The women participating in the study described several reasons that motivated them to use exergame exercise programs during pregnancy. They also found that the exercise programs were convenient and suitable for use during pregnancy. Additionally, the women mentioned that the game was easy to use, although they did mention experiencing some challenges that could be addressed in future versions of the game. Overall, the results of the study suggest that exergame exercise programs were acceptable, enjoyable, and convenient to this sample of women.

The Nintendo Switch exercise programs were found by pregnant women to be enjoyable, fun, and motivating. Evidence demonstrates that enjoyment and motivation are crucial for the effectiveness of exercise-promoting lifestyle interventions (124, 125, 230, 231). These factors are important because it is known that most pregnant women do not meet the recommended levels of physical activity, and some even significantly decrease their physical activity during pregnancy (97, 218, 219). Exercise behaviours are often attributed to a lack of motivation and enjoyment (230, 232). Exergames may offer a promising and enjoyable new approach to increase physical activity and improve exercise adherence (150, 223) in pregnant women, who may be less likely to engage in regular physical activity and exercise (97, 218). Exergames can motivate regular exercise during pregnancy due to their interactive and enjoyable nature. Additionally, they offer feedback on progress and accomplishments, which keep users motivated and encourage continued participation (39, 41). These findings suggest that exergames may be an effective way to motivate and engage pregnant women in regular exercise.

The women participants reported that Nintendo Switch exercises were convenient and suitable to use during pregnancy. The convenience of exercising at home using exergames was highly appreciated, as it allowed them to adjust their workout according to their own schedule and comfort, making it easier to incorporate/fit physical activity into their daily routines/busy lifestyle. For example, they suggested the use of exergame was found to be particularly convenient as it provided them with a private and flexible workout environment, allowing them to engage in physical activity at a time that best suits their needs. These views are supported by guidelines for physical activity during pregnancy, which suggest that the types of exercise prescribed during pregnancy is probably best informed by the woman’s personal preferences, circumstances, available resources, and the setting (3, 32, 101).

Exergaming provides a valuable alternative for pregnant women who may have limited access to outdoor activities or training facilities, and this was highlighted in the responses in relation to fatigue after work, poor weather and pandemic-related restrictions due to COVID-19. These responses align with previous research highlighting barriers to exercise in pregnant women (220, 222), and suggest exergaming may also a favourable alternative for women who don't enjoy going to the gym or group classes. The current findings suggest that pregnant women perceive exergames to be an ideal approach to encourage regular exercise and address barriers to physical activity during pregnancy, as they offer a safe, suitable, and easily accessible form of exercise that can be completed in the home environment. This indicates that exergames may help to overcome the challenges faced by pregnant women in maintaining regular physical activity, which could lead to better adherence to physical activity (104, 233, 234).

Our study found that a sample of women perceived the exercise programs on the Nintendo Switch as user-friendly (easy to use) as the game offers instructions on both how to use the game and perform the exercises. The women mentioned that they didn’t have to worry about exercise safety, how to perform it and what exercise to do next, as the game provides instruction and encouragement for proper technique and progression. These instructions, provided within the game, may assist pregnant women in alleviating uncertainty about what types and intensity of exercise are safe to engage in during pregnancy. This is particularly relevant if the game is specifically designed for pregnant women, as it could address the unique physical and safety considerations of this audience. Hence, exergame may have the potential to overcome the most commonly reported barrier to physical activity during pregnancy, which is uncertainty about the safety and proper execution of exercise during pregnancy (103, 104, 233). This highlights the potential for exergames to be an effective alternative method of exercise for pregnant women, especially if the game is specifically designed/tailored to meet their unique needs and preferences.

Some women mentioned issues with the game's usability, such as having difficulty in using the Joy-Con control buttons to navigate easily through the game and setting up the game, which is not uncommon in game design concerns (235, 236). The women highlighted that the difficulties they faced while using the game were minor and occurring only at the beginning, during their initial experience with the game. These challenges were no longer a problem once they were familiar with the equipment and game. This implies that that future versions of the game should be designed to be more user-friendly and easier to use for the target audience. The other drawback of the Nintendo Switch Fit ring, as noted by some women, is the limited number of exercises available for use during pregnancy. Revising the game's design to address these usability issues reported by the women is salient to improve the game's usability, enhance adherence to exercise programs, and ensure the safety of pregnant women.

Some women suggested that for effective use of the game, it should provide a variety of pregnancy-safe exercise programs targeting various body parts, as currently the game has limited exercise options available for pregnant women. This is in line with guidelines for physical activity which recommend that pregnant women should incorporate a variety of aerobic exercise, resistance training activities, and pelvic floor muscle training to achieve greater benefits (3, 90, 101). This implies that game developers should aim to include a diverse range of exercises, such as yoga, resistance training, and low-impact aerobics that are engaging, motivating, and enjoyable for pregnant women to play (3, 101). In addition, the game should take into consideration their unique needs and limitations, and offer a range of exercises that are safe and suitable for all stages of pregnancy (3, 90, 101). This could potentially provide pregnant women with more options to choose from and enable them to find exercises that are more suited to their needs and preferences.

The women participants also mentioned the requirement for more detailed tutorials. They suggested that the game could provide detailed information and instruction on how to play and use the game features, in order to enhance its ease of use. These views outlined by the women participants are supported the idea that players prefer games with clear instructions, and the presence of tutorials improved player's overall gaming experience (155, 237). Therefore, when creating games, game designers should consider incorporating more detailed information and instructions that are easy to follow on how to navigate and use game features effectively. This could make the game easy to understand and more user-friendly, with clear instructions and intuitive controls.

The strength of this study was its diverse sample, comprising women with various backgrounds, characteristics and exercise experiences, which could provide deeper understanding of pregnant women's experiences and views of using exergame during pregnancy. A possible limitation might be the study's small sample size, which could limit the generalizability of the results to the wider pregnant women population. Nevertheless, we believe that the sample was adequate to describe the variation in the women's experiences and to answer the research question. Additionally, unsupervised nature of the intervention could be a limitation of the study, though was also a result of the constraints of the pandemic and geographical location of participants. However, prior to commencement of the intervention, participants were thoroughly familiarised with all equipment, exercises and the training program. Subsequently, the women were then closely supported once a fortnight by the research team throughout the intervention period, adding further support to the use of this exercise modality. This study is the first to attempt to explore women's experiences and views of exergame use during pregnancy as a tool for exercise. We believe that our study findings provide valuable insights into the pregnant women's experiences, as well as the potential benefits and barriers of using exergames during pregnancy, which may give directions to game designers to develop more effective and tailored exergame exercise programs for this population in future.

5.5. Conclusion

Our findings suggest that Nintendo Switch exercises are enjoyable, fun, and motivating for pregnant women to use. In addition, these findings suggest that exergames may be a convenient, safe, and suitable option for pregnant women looking to incorporate exercise into their routine. The women participants also found the Nintendo Switch easy to use. However, they suggested that the game should include a wider range of exercise programs customized specifically for pregnant women, in order to meet their unique needs. Overall, our study shows that exergames may be a promising approach to encouraging physical activity and addressing barriers to antenatal exercise. The findings suggest that game designers and developers may consider incorporating a variety of exercise programs that are specifically tailored to meet pregnant women's limitations and preferences, which could make the game more effective and acceptable for this cohort. Future postdoctoral work is planned in this area.

Chapter 6

Discussion

6.1. Overview, aims and key findings

In this chapter the main findings from all three studies are interpreted and discussed in reference to the alignment with existing literature. The strength and limitations of the studies are also discussed. Finally, this chapter presents implications for practice, directions for future research, and an overall conclusion of this thesis.

Regular physical activity during pregnancy is shown to be crucial to the health and wellbeing of pregnant women and their unborn babies (31, 208, 215). Studies have shown that regular exercise during pregnancy is as an important modifiable factor to reduce the risk of certain adverse pregnancy and birth outcomes (238-241). The current guidelines for physical activity during pregnancy recommend that all women without contraindications should engage in moderate-intensity physical activity for at least 30 minutes per day on most or all days of the week (3, 90, 101). However, many pregnant women find it challenging to meet physical activity recommendations during pregnancy, and decrease their physical activity participation as pregnancy progresses (74, 75). Of concern, only 3 in 10 Australian pregnant women meet the recommendation for physical activity during pregnancy (147). Despite physical activity guidelines recommending regular exercise throughout pregnancy, initiating exercise during this period may not be feasible for most women due to perceived barriers to physical activity, such as safety concerns, lack of motivation and enjoyment, fatigue, time constraints, and lack of suitable facilities (102, 168-170). Hence, innovative exercise methods to overcome these barriers and promote physical activity are required.

One such novel approach to encourage regular exercise during pregnancy may be via exergames. Recent studies have shown that exergames were found to encourage regular physical activity (110, 174, 242), and have the potential to improve adherence to exercise among sedentary and high-risk populations (37, 49, 243). Moreover, the connection of physical activity with the fun of electronic games can make exergames motivating and enjoyable for populations who otherwise do not undertake exercise (46, 48, 242). However, exergames may carry potential risk of injury and adverse events if the physiological adaptations to pregnancy are not considered (3, 90, 101). Hence, evaluating the feasibility, safety and acceptability of exergame exercise programs is crucial to improve ease of use, ensure safety of pregnant women and achieve anticipated benefits for pregnant women, given the current lack of evidence.

Accordingly, this thesis aimed to evaluate the suitability and safety of exergame exercise programs (the Nintendo Switch) as a tool for pregnant women to exercise (Study 1). Secondly, this thesis aimed to investigate the feasibility, safety and potential benefits of an exergaming intervention for pregnant women to increase physical activity and improve pregnancy outcomes (Study 2). Thirdly, this thesis aimed to explore pregnant women's views and experiences of the acceptability, benefits and potential barriers to the home-based exergaming program (Study 3).

Summary Findings

Study 1 provides the foundation of this thesis. By conducting a heuristic evaluation of the exergame (Nintendo Switch) exercise programs from multidisciplinary experts' perspectives, we focussed on the suitability and safety of exergaming for pregnant women as a potential tool for promoting physical activity. This evaluation focused primarily on the structure of the game, user interaction with the game, and the intensity and mode of the exercise programs for pregnant women. These aspects of evaluation are essential to identifying usability issues that might arise in a real-world context. This study suggested that exergames could be a potential tool for encouraging pregnant women to exercise, provided that the specific exercises are used that are safe for each trimester and tailored according to pregnant women's needs and physiological adaptations to pregnancy. Moreover, this study highlights usability concerns related to the intensity and mode of some of the exercises contained in the Nintendo Switch, as the game is not designed specifically for a pregnant population. Due to the physiological changes of pregnancy, pregnant women might be unable to safely perform all the movements, balance and positioning that the game requires. These findings provide support for the subsequent studies (Study 2 and Study 3) by underlining the need for tailored exercise programs for pregnancy to enhance safety and efficacy.

Study 2 builds on the implications derived from the findings of Study 1. Providing a quantitative perspective, the design complements the more observational approach of the first study. While Study 1 provides experts' perspectives, Study 2 expands on these findings by investigating the feasibility, safety, and potential benefits of home-based exergaming programs for pregnant women. It provides a more detailed look at the acceptability and usability of the game for pregnant women in real-world circumstances. The findings suggest that home-based exergame programs can be a feasible and safe exercise option to encourage regular exercise during pregnancy, provided they are tailored according to individual pregnant women's needs and trimester of pregnancy. Study 2 corroborates the findings of Study 1, highlighting the need for tailoring exercise programs based on pregnant women's needs and physiological changes. The study findings indicate exergaming resulted in a significant increase in physical activity level from trial entry to the mid-intervention period (p=0.01). A positive correlation was observed between physical activity levels (Mets) and adherence to the prescribed exergaming sessions (r=0.83, p=0.02). Importantly, no injuries or other safety concerns related to the exergaming program for either mother or baby were reported. This study provides empirical evidence supporting the potential of exergaming to increase physical activity levels and improve adherence to exercise during pregnancy.

Study 3 is a qualitative study exploring the experiences, views, and acceptability of the exergame programs of the end users - the pregnant women themselves. The exergame programs used in this project were found to be enjoyable, and convenient for pregnant women to integrate into their daily lives. The study findings suggest that exergames are a promising approach for encouraging regular exercise and addressing barriers to physical activity during pregnancy. This qualitative study supports the findings of the first two studies by confirming that the pregnant women found the game enjoyable, motivating, and easy to use. This can be interpreted as an indication of the game's feasibility and acceptability, further addressing the usability issues highlighted in Study 1. Women participants suggested that a wider range of exercise programs specifically designed for pregnant women would be beneficial. The inclusion of user experience further confirms that tailored exercise programs are crucial, reaffirming the need for customisation highlighted in the earlier studies (study 1 & 2).

In summary, this thesis provides a comprehensive understanding of the usability, feasibility, acceptability, and potential benefits of a home-based exergaming program as a tool for promoting regular physical activity during pregnancy. Each study contributes a unique perspective: the initial experts' viewpoint through heuristic evaluation (Study 1), the empirical evidence from a feasibility study (Study 2), and the qualitative insights from the end-user perspective (Study 3). These studies suggest that exergaming programs hold promise in promoting regular exercise and overcoming barriers to physical activity during pregnancy. However, it is crucial to tailor the game design to accommodate for the physiological changes, limitations, and preferences of pregnant women. These findings establish a strong foundation for future investigations in this field.

6.2. Heuristic Evaluation of the safety and suitability of exergame exercise programs for pregnant women.

Study 1 showed that the Nintendo Switch offers exercise programs that are engaging, enjoyable and fun to play. It also offers a range of exercise options that target different body parts, including aerobic, resistance training and yoga exercises that can be prescribed for pregnant women. However, not all available exercises or movements are appropriate, as the game is not designed specifically for pregnant women, hence, it includes exercise that could be considered contraindicated for pregnant women. Consequently, the expert panel identified a list of appropriate exercises for pregnant women to be considered for exercise prescription, considering the unique needs of pregnant women and physiological changes of pregnancy (3, 90, 101).

The findings of the Heuristic Evaluation showed that some Nintendo Switch exercises have the potential for excessive intensity or inappropriate movement patterns that provide stress and strain that could be considered a risk for pregnant women. This raises concerns for pregnant women, as they have high resting heart rates, and require lower workloads to reach the target heart rates (90, 101). Further, studies have shown that excessive exercise intensity during pregnancy could potentially cause a decrease in utero-placental blood flow (244). Hence, exercises with potential for excessive intensity may be best avoided, or individualised and undertaken with close supervision that is not suitable for the unsupervised nature of exergaming. The current guidelines for physical activity during pregnancy recommend that exercise during pregnancy is safe as long as it is performed at moderate intensity (90, 101, 166). However, it is recommended that pregnant women should discuss the exercise intensity with their maternity care provider prior to participation (90, 101). For example, the Royal Australian and New Zeeland College of Obstetricians and Gynaecologists (RANZCOC) recommend that women aim for moderate-intensity physical activity on most days of the week for at least 30 minutes at a time (101). A simple measure of exercise intensity that can be used by pregnant women is the 'talk test' (3, 101). The talk test implies that the intensity of exercise is considered 'moderate' if the pregnant woman can comfortably maintain a conversation during physical activity. The woman should reduce the intensity if this is not possible (that is, if she needs to pause for breath during a conversation) (3, 101). Women with sedentary lifestyles prior to pregnancy, or those who were above a healthy weight at conception should commence with lower intensity and volume of exercise followed by a gradual increase (90, 146). Physical activity guidelines recommend that the intensity of exercise in pregnancy should depend on baseline fitness level and previous exercise routine (101). In line with this, recommendations we developed for exergame exercise programs were tailored for pregnancy with the aim of three to four days per week (30-40 min/session) accomplished at moderate intensity (pregnant woman should comfortably hold a conversation while exercising). A critical aspect of particular exergames for populations like pregnant women is the regulation of the intensity and difficulty of exercises/gameplay; and it should be customised according to the capabilities of the user. If the intensity and difficulty of the exercise programs are too high, it may pose risks to the safety of pregnant women users (3, 90), resulting in adverse events or reduction in acceptability and adherence to the exercise program. As a result, modifying future versions of the game to adjust exercise intensity according to pregnant women's needs and physiological changes that occur during pregnancy is salient to achieve the expected benefits, maximise compliance to exercise programs, and ensure the safety of pregnant women.

The Heuristic Evaluation also showed that some Nintendo Switch exercises involve positioning or movement patterns that may be inappropriate for pregnant women. While some minigames, rhythm games, structured exercises and yoga are safe to use during pregnancy, other exercises were deemed unsuitable. For example, some included inappropriate positioning, compression on the abdomen, excessive flexion, back stress or fast movement. The current guidelines for physical activity during pregnancy suggest that exercises that involve excessive flexion, jumping, inherent risk of falling, rapid changes in posture, pressure to complete a movement quickly or unstable movements may be avoided, or undertaken with serious consideration of the potential risks (3, 90, 101, 166). Pregnant women might be unable to perform all the movements, balance, flexion and gaming techniques as the game requires, due to the limitations and physiological adaptation resulting from pregnancy (90, 101, 245, 246). Hence, gaming techniques that require exercise flexion and fast movements, increase lower back stress or create uncontrolled time pressure to complete the game were deemed inappropriate for pregnant women.

The physiological changes that occur during pregnancy have implications for game designers and developers who must consider these adaptations during pregnancy while designing exercise programs for pregnant women. An increase in ligament laxity, due to the endogenous production of the hormone relaxin during pregnancy, may have impact on the range of movement, and an adjusted range of motion or type of movement is required (3, 245, 246). Given the implications for the potential risk of injury, exercises that require jumping and frequent changes in direction are best avoided (3, 90, 101). Additionally, an increase in body weight as pregnancy advances may also increase load at the joints. Hence, weight-supported exercises may be more preferable in the later stages of pregnancy (90, 101). Furthermore, change in centre of gravity due to change in weight distribution in later stages of pregnancy may impact balance (3, 146, 246). For this reason, in later stages of pregnancy, exercises that require rapid changes in direction or a high degree of balance are best avoided or accomplished with close supervision. The weight of enlarged uterus may also occlude venous blood return, hence, exercises that require supine position should be avoided during the second and third trimester of pregnancy (90, 101). The experts suggested that rhythm games (legs and arms) and Minigames such as Crate crasher, Robo-wrecker, Thigh Rider, Bootstrap tower, Squattery wheel and Squat goals are suitable for pregnant women as they offer stable lower body position, limited overhead movement, and exercises that minimise the potential for over-exertion, excess flexion or compression on the abdomen (3, 146). Further, structured lower and upper body exercises such as: Squat, Thigh Press, Side Step, Front Press, Triceps

Kickback, and Bow Pull can be used safely during pregnancy as they offer exercises with controlled intensity and number of repetitions, whilst offering a stable postural positioning and less likelihood of over exertion (90). However, Rhythm Games (core/abdomen), some Minigames and structured exercises were deemed unsuitable for this population, as they include compression on the abdomen, inappropriate supine positioning, excessive flexion, lower back stress and exercises that have the potential for overexertion.

In summary, the expert evaluators were unanimous in their conclusions from the Heuristic Evaluation, suggesting that the exergame (Nintendo Switch) exercise programs could be used for pregnant women, provided that specific exercises are used that are safe for each trimester and tailored according to the needs of individual pregnant women. These findings have significant implications for using exergames as a promising way to encourage and engage pregnant women in regular exercise. Although the Heuristic Evaluation showed some usability issues from experts' perspectives, further analyses should be undertaken by pregnant women - end users. The purpose of this is to identify critical usability issues that pregnant women may encounter and to ensure that the exercise programs meet the unique needs of pregnant women. Consequently, the expert panel developed an exercise program for this audience using the lists of appropriate exercises for pregnant women. We then investigated the feasibility and acceptability of exergaming among the end users, pregnant women, using exercise programs specifically tailored for this audience (Study 2 and Study 3).

6.3. Feasibility and potential efficacy of exergaming program during pregnancy

6.3.1. Physical activity levels

Study 2 findings indicate exergaming resulted in a significant increase in physical activity level from trial entry to the mid-intervention period (p=0.01), highlighting the potential benefits for pregnant women. This evidence implies that such interventions could be feasibly employed as an approach to mitigate sedentary behaviour/inactive lifestyle often associated with pregnancy. In agreement, a RCT study that implemented an individualised exercise program twice per week during pregnancy, showed that pregnant women in the exercise group had a higher energy expenditure, especially in light intensity activities, compared to the control group. The exercise sessions consisted of aerobic exercises on a treadmill, resistance exercises, stretching and relaxation, for a total of 50–55 min/session (197). The increase in physical activity levels observed in this study align with previous studies that have indicated the potential for exergame interventions to encourage physical activity in various populations, such as children, adolescents and older individuals (115, 172, 174, 194). Additionally, prior studies also highlighted the potential of exergaming in improving fitness levels (175, 195), and attitudes towards participating in other forms of physical exercise (60, 196). This aspect is of particular importance as it suggests that exergaming can be used as an approach for promoting a sustainable active lifestyle, even beyond gaming. As further evidence, a recent systematic review examined the effectiveness of different exercise interventions during pregnancy, finding that structured aerobic and strength training exercise program enhance physical activity levels among pregnant women. Accordingly, a range of research supports the current findings, demonstrating that the level of physical activity among the intervention group at post intervention was significantly higher compared to control counterparts (198).

The increase in physical activity observed in our study encompassed a broad range of activity types. The Pregnancy Physical Activity Questionnaire (PPAQ) that we asked women to complete provides a comprehensive assessment of various activities including household/caregiving, occupational, sports/exercise, transportation, and sedentary activities (185, 186). It is interesting to note that slow walking was the most dominant sport/exercise activity reported by participants in our study. This finding is consistent with earlier studies, demonstrating that walking is a commonly reported physical activity during pregnancy due to its lower intensity and safety considerations (92, 97, 247). Moreover, walking is aligned with the safest exercise suggestions outlined by the guidelines for physical activity during pregnancy, further substantiating its suitability for pregnant women (3, 90, 91, 101). Since walking is a low-impact physical activity, and easily accessible form of exercise that doesn't require special equipment, it may be a feasible recommendation for pregnant women, particularly when combined with exergaming.

An important finding in Study 2 was the positive correlation that was observed between physical activity levels (Mets) and adherence to the prescribed exergaming sessions ($r=0.83$, $p=0.02$). This implies that those pregnant women who adhered more to the exergaming programs were more likely to report higher physical activity outcomes. The positive correlation between physical activity and adherence to the exergame program implies the potential role of exergaming in motivating physical activity during pregnancy. This finding aligns with previous studies showing that exergaming can facilitate adherence to regular physical activity in non-pregnant populations who may have difficulty with traditional exercise (37). Further supporting this finding, a recent systematic review reported that exergaming has the potential to address barriers to traditional physical activity such as lack of enjoyment and motivation thus improving adherence to exercise in older adults (114). Future research should explore this relationship further to assess the long-term effects of such interventions on physical activity levels during pregnant women and the postpartum period.

Based on the findings from our study and supporting literature, exergaming may be a feasible and innovative exercise option to promote an active and healthy lifestyle during pregnancy. Exergaming offers a flexible and adaptable form of exercise that can be tailored to the individual's needs, enhancing the likelihood of long-term engagement. Large-scale randomised controlled trials are required to further corroborate the effect of exergaming on physical activity levels during pregnancy.

6.3.2. Adherence to exergaming program

Our findings indicated a considerable level of adherence to home-based exergaming programs among pregnant women, with a mean adherence rate of 67.2 % (range 41.2 - 92.1%). Apart from one pregnant woman, all participants managed to undertake more than 50% of the prescribed exercise sessions. Notably, half of the women participants were able to perform more than 70% of the prescribed exergaming sessions, with adherence rate ranging from 71.4 % to 92.1 %, indicating the feasibility and potential acceptance of exergaming as a strategy to promote regular exercise during pregnancy. This adherence rate is promising, considering the physical and physiological challenges associated with pregnancy, which may cause barriers to maintaining regular exercise (102, 168).

Prior studies in non-pregnant populations indicate that participating in exergames results in increased enjoyment and motivation for future engagement (46, 48), while also improving adherence (37). In agreement with this, our study demonstrated higher adherence levels than an earlier study involving pregnant women, which reported that an average of 33% of prescribed exercise sessions were completed (204). The exercise program consisted of a structured 16-week stationary cycling program performed at home with a frequency of 3-5 sessions per week. Similarly, the adherence rate observed in our study was higher than observed in previous study among pregnant women, which found that only 16. 3% of the women participants attended half of the prescribed training sessions (205). The exercise program consisted of aerobic and strength exercises performed twice per week. Hence, it could be speculated that use of exergaming may improve adherence, considering the engaging and interactive nature of the gameplay. The adherence rate observed in our study may be attributed to the innovative nature of exergames, which makes exercise more interactive, engaging, and enjoyable, thereby enhancing motivation and adherence (37, 46, 48). Furthermore, exergames provide an accessible and flexible form of exercise that can be played in the comfort of a woman's own home, reducing barriers to exercise such as travel, weather, time constraints or lack of childcare, which can often limit adherence to regular exercise during pregnancy (168, 170).

While adherence to the exergaming programs was relatively high, adherence levels decreased to 20.8% after 35 weeks of gestation, which was expected to occur due to the common discomforts of late pregnancy, rather than the exergame program itself. The decreased adherence to the prescribed exergaming sessions in late pregnancy align with a previous study, which showed similar decrease in adherence to physical activity interventions during the later stages of pregnancy (204). Women participants in our study cited common pregnancy-related discomforts such as increasing pelvic pressure, lower back pain, and fatigue as the main reasons for reduced adherence. This is consistent with previous studies which has also identified such discomforts as significant barriers to physical activity during pregnancy (102, 248). This highlights the need to consider additional support and/or adaptation of the program to maintain adherence in the later stages of pregnancy, particularly after 35 weeks of gestation.

Our study finding suggests that home-based exergaming programs could be an innovative and appealing way to increase adherence to regular physical activity among pregnant women. Future research could focus on adapting exergame programs to better accommodate for the changing physical conditions, preferences and capabilities of pregnant women as pregnancy advances.

6.3.3. Safety of the exergaming programs for pregnant women

Safety of the exergaming program was another crucial aspect examined in the study. No injuries or other safety concerns related to the exergaming program occurred, suggesting that exergaming can be safe for pregnant women and their unborn babies when tailored appropriately and prescribed under appropriate guidance and monitoring. This is a significant outcome to note, as safety is a critical aspect to consider when promoting physical activity during pregnancy (90, 101). The absence of negative safety events observed in the current study could be attributed to the individualised nature of the exercise programs, which were designed in align with the guidelines for physical activity during pregnancy (3, 90, 101) and the needs of each individual woman. Moreover, the familiarisation, training and regular support provided by the research team on the safe and effective use of the exergame equipment and exercise techniques could have had a positive impact. A systematic review and meta-analysis of randomised controlled trials has shown that aerobic exercise for 35-90 minutes 3-4 times per week during pregnancy can be safely performed by a woman with a healthy pregnancy without obstetric contraindication to physical activity, as it is not associated with adverse outcomes (249). Similarly, studies which implemented structured exercise programs tailored for pregnant women didn't detect injuries or adverse effects of such exercise programs for either pregnant women or their unborn babies (99, 197, 204, 250). As further evidence, earlier studies have demonstrated that exergames are generally considered safe for use (216, 217), although these studies did not include pregnant women. However, it is crucial to customise exergame programs for pregnant women using exercise that provide stable position and controlled intensity, as the physiological changes that occur during pregnancy can potentially increase the risk of injuries (90, 146, 166). Accordingly, the Heuristic Evaluation undertaken in study 1 was important to provide adaptable and appropriate exercises for use in the feasibility project of Study 2 and should be considered in future training programs for safe outcomes. Accordingly, evidence from the current study suggests that appropriately designed exergaming program, adapted to individual pregnant women's unique limitations, preferences, and physiological changes, can be a safe form of exercise option to promote regular exercise during pregnancy.

6.3.4. Pregnancy and birth outcomes

Women participants in our study had positive pregnancy and birth outcomes, with no reports of complications or adverse outcomes for either the mothers or their babies. Acknowledging the small sample size and the nature of the study design in the current feasibility study, our finding is supported by evidence from a systemic review and meta-analysis, which showed that regular physical activity during pregnancy has positive effects on maternal and neonatal outcomes (11, 19, 31). Another systematic review and meta-analysis of randomised controlled trials showed that an aerobic exercise regimen performed 3-4 times per week during pregnancy was not associated with adverse pregnancy or birth outcomes. This aerobic exercise regimen was associated with a significantly higher incidence of vaginal birth, and significantly lower incidence of caesarean birth, gestational diabetes mellitus and hypertensive disorders (249). Similarly, a recent meta-analysis showed that exercise interventions during pregnancy effectively reduce the risk of preterm birth (251). Further, a recent meta-analysis of randomised trials showed that structured exercise programs was associated with reduced odds of macrosomia (abnormally large babies) (31). Supporting the findings of our study, this meta-analysis also demonstrated that structured exercise programs tailored for pregnant women was not associated with neonatal complications or adverse outcomes (31). However, the pregnancy and birth outcomes reported in the current study was expected to be limited by the nature of study design. Further large-scale randomised controlled trials in a clinical setting are required to investigate the effect of exergame exercise programs on women's pregnancy and birth outcomes.

6.4. Pregnant women's views and experiences of exergaming during pregnancy

Study 3 explored the views and experiences of pregnant women, to evaluate the end user acceptability of the exergaming program. The women participants in the study reported the exergaming programs to be convenient, enjoyable and motivating to use during pregnancy. They found the game was easy to use and they appreciated that they didn't require any additional tools or exercise equipment. They highlighted the benefits of requiring minimal space at home and the ease of accommodating the program. This qualitative study supports the findings of the Study 1 and Study 2 by confirming that the pregnant women found the game enjoyable, motivating, convenient and easy to use.

Participants found that the exergaming program gave them an opportunity to undertake physical activity in privacy at home, at a time that was convenient to them. Given the perceived barriers to traditional physical activity that pregnant women face (102, 168, 170, 234, 252), exergaming may offer an opportunity to integrate a home-based, safe exercise program with an enjoyable experience for pregnant women. The advantage of being able to exercise at home is particularly significant during poor weather (extreme heat or cold) and an ongoing pandemic, like COVID-19, that may make traditional physical activity less appealing. Previous studies have found that the COVID-19 pandemic has negatively impacted women's physical activity levels during pregnancy (253-255). Similarly, the study has shown that poor weather (such as cold weather) was perceived as a barrier to undertaking physical activity outdoors during pregnancy (256). Hence, exergames may be convenient option to exercise at home during poor weather and pandemic conditions, as also noted by women participants in our study.

Exergaming may provide an option for pregnant women who have limited access to training facilities, such as for women living in isolated areas. A lack of access was mentioned as a barrier to physical activity during pregnancy in earlier studies (107, 257). Similarly, it is also important to note that having other young children can affect participation in physical activity during pregnancy, as the demands of caring for children may affect the time available for outdoor physical activity. The findings of this qualitative study exploring end-user perspectives suggest that exergames are a promising approach to overcome some of the barriers to physical activity during pregnancy and promote regular exercise, further supporting the findings of Study 1 and Study 2.

The women participants in our study found the exergame (Nintendo Switch) exercise programs to be user-friendly (easy to use) as the instructions on how to use the game and perform the exercises are embedded in the game itself. They mentioned that they didn't have to worry about exercise safety, how to perform it or what exercise to do next. Previous studies have reported that uncertainty about the exercise safety and proper execution of exercise during pregnancy as common barrier to physical activity during pregnancy (107). Hence, exergames have the potential to overcome these barriers especially if they are specifically designed for pregnant women and address their unique physical and safety needs.

The women in our study reported that the fun and interactive nature of the exergame program helped to keep them motivated and engaged, mentioning that exergaming was novel and more interactive than other modes of exercise they had used, such as treadmills or following YouTube videos. Our findings are aligned with previous studies conducted in non-pregnant populations, demonstrating that exergames are enjoyable and motivating (46, 48, 54). Given lack of enjoyment and motivation are common barriers to physical activity during pregnancy identified in previous studies (107, 257), exergames may provide fun and interactive exercise options for pregnant women. Physical activity guidelines during pregnancy suggest that types of exercise prescribed during pregnancy is best informed by the woman's personal preferences (3, 90, 101). Moreover, exergames can be adjusted to meet pregnant women's preferences and limitations, such as by adjusting the level of difficulty or providing alternatives for certain exercises. This make exergames more enjoyable and inclusive for pregnant women of all fitness levels. Additionally, they offer feedback on progress and accomplishments, which keep users motivated and encourage continued participation. These findings suggest that exergames may be an effective way to motivate and engage pregnant women in regular exercise, provided that games are designed according to pregnant women's needs and preferences.

In summary, this thesis demonstrated the feasibility and acceptability of the exergame exercise program for pregnant women. Moreover, our program shows promise in increasing levels of physical activity and resulted in moderate-high adherence among pregnant women. The findings contribute to the body of evidence that exercise during pregnancy is advantageous, and can be encouraged using innovative approaches such as exergaming. Considering the observed benefits on levels of physical activity and adherence, as well as its acceptance among end-users, pregnant women, exergame exercise programs could be potentially integrated into antenatal care as an option to assist women in meeting the recommended 150 minutes of physical activity per week.

6.5. Strengths of the studies

This thesis evaluated the feasibility, acceptability and potential benefits of a home-based exergaming program designed for use during pregnancy. The major strength of this thesis was that we used a multi-disciplinary team of experts with significant experience in public health, exercise physiology, midwifery, heuristic principles, and carrying out usability evaluation. Multi-disciplinary experts could identify critical usability problems and possible safety issues that an end user may not identify (160, 161). Additionally, we followed the recommendations for physical activity during pregnancy (3, 90, 101), to design and implement individualised exergaming programs specifically tailored for pregnancy. Another notable strength of the study was the ability to maintain a high retention rate. Moreover, the study comprised women with varying prior exercise experiences, fitness levels, BMI category, and from different regions across Australia. This diverse sample significantly contributed to a deeper understanding of pregnant women's experiences and views of using exergames during pregnancy.

The aim of this thesis addresses a key indicator identified by the NSW Health 'Get Healthy in Pregnancy Program', that women require multimodal support to meet national guidelines for physical activity and exercise goals throughout pregnancy. The thesis aimed to address this issue by investigating and evaluating different types of support (innovative exergame program), which could help pregnant women overcome the barriers to physical activity during pregnancy, and help them meet the national guidelines for physical activity and exercise.

Evidence garnered from this thesis could establish the foundation for the use of exergames as an approach to engage and encourage pregnant women into regular exercise. The findings will also guide future implementation research and may provide evidence for designing health policy and recommendations on physical activity during pregnancy.

6.6. Limitations of the studies

Despite the novel findings reported in this thesis, several limitations need to be considered. Firstly, a possible limitation might be the small sample size in Study 2, which could limit the generalisability of the findings to the wider pregnant women population. A feasibility study serves as a preliminary investigation to assess the practicality, acceptability, and potential challenges that may arise during the implementation of a full-scale RCT. Unlike the larger-scale randomised controlled trials, feasibility study approaches often utilise smaller sample sizes (258). This smaller sample size enabled us to test the safety and feasibility of the exergaming for pregnant women prior to a larger-scale implementation. In addition, we conducted qualitative interviews with 12 pregnant women, generating meaningful insights into their experiences of exergaming during pregnancy. This was a necessary component of feasibility testing, to evaluate the acceptability of exergaming programs by the end users - pregnant women. We believe that the sample was adequate to describe pregnant women's views and experiences of exergaming during pregnancy. Further, the Heuristic Evaluation part of this thesis (Study 1) did not require women participants, as this study focuses on experts' perspectives.

A further limitation is the possibility that the recruitment of women participants via social media might introduce participation biases. As not all pregnant women use social media or actively engage with advertisements, the sample may exclude those who do not have access to or choose not to use social media. Women who are more likely to engage with social media and its advertisements may be more comfortable with technology, more open to new experiences and more aware about their health, which could cause bias. Recruitment via social media was necessary, as the NSW Health Human Research Ethics Committee required a feasibility study and safety run-in to be conducted outside the health service, prior to approval for a clinical trial in a health service/clinical setting. Future studies will recruit women participants from clinical settings, such as hospitals and antenatal clinics.

Furthermore, the intervention was not fully supervised, which could be considered a limitation of the study. However, the aim of the project is to create a program that women can use in the privacy and comfort of their homes, hence, we trialled the feasibility of the program in a real-world context. Prior to commencement of the intervention, participants were thoroughly familiarised with all equipment, exercises and training program by the PhD researcher. Subsequently, he closely supported the women once a fortnight throughout the intervention period; adding further support to the use of this exercise modality. We did not employ objective measures of physical activity such as accelerometer to measure the level of physical activity. The subjective measures of Physical activity using tools such as PPAQ might be less accurate than directly/objectively measured Physical activity (259).

These limitations may limit the strength and generalisability of our findings, calling for further large scale randomised controlled trials in a clinical setting to fully validate the finding of this thesis. We believe that the current study findings provide valuable preliminary insights into the safety, feasibility and acceptability of exergaming as an option for exercise during pregnancy, which may provide direction to game designers and developers in creating tailored exergame exercise programs for pregnant women in future.

Chapter 7

Summary, Implications for practice and

Future research

7.1. Implications for practice

Several implications, that can be used to inform the design and implementation of future exergaming interventions aiming to increase physical activity during pregnancy, emerge from this thesis, including;

- To ensure safe and effective use of exergames during pregnancy, pregnant women appreciate being thoroughly familiarised on the use of exergame equipment, exercise programs and training techniques. Healthcare facilities (for example, antenatal clinics and hospitals) play a crucial role in advising pregnant women on physical activity.
- The safety of the exergame programs highlighted in this study emphasises its suitability for use in pregnancy. However, continuous guidance and monitoring should be an integral part of the exergaming program to ensure the safety of pregnant women. The absence of injuries or adverse events related to the exergaming programs in our study indicates the importance of adequate precautions, training and support provided during the intervention. The findings of this thesis have implications that, when appropriately tailored, exergaming can be a safe exercise options for pregnant women to stay active.
- To ensure safety, exergaming programs for pregnant women should be designed in accordance with guidelines for physical activity during pregnancy (90, 91, 101). These guidelines are designed to optimise the health benefits of exercise for both mother and baby, while minimising potential risks that may occur due to the unique physiological changes during pregnancy.
- Pregnant women may need support and familiarisation in setting up the game, connecting the game to home televisions, the proper use of control buttons and exercise techniques.

- Given the increased physical activity levels and acceptable adherence level observed in our study, exergaming could be offered to women as an option during antenatal care, as an alternative or supplement to traditional exercise recommendations, particularly for those who face barriers to traditional forms of exercise such as lack of motivation, safety concerns, and time constraints. More research in a larger sample is required before exergaming can be widely recommended as an option for women in standard antenatal care.
- For pregnant women looking for home-based exercise options due to various constraints, exergames could provide a feasible alternative that can be tailored to individual pregnant women's needs and could reduce the need for outdoor activities or attending training facilities such as gyms.
- The women participants in our study highlighted that family support gave them the motivation to stay active and adhere to the exergame program. Hence, involving her partner and/or family members in exergaming sessions could be useful to enhance adherence and make exergaming more motivating and enjoyable for the pregnant woman.

7.2. Implications for pregnant women

- Before using any exergaming programs pregnant women should consult with their health care providers or exercise physiologist to ensure the exergame exercise programs are safe and appropriate for their fitness level, current health status, individual needs and trimester of pregnancy.
- While exergaming at their homes, pregnant women should ensure that their surrounding is free from obstacles that could potentially lead to trips or falls. This could include chairs, tables, toys, rugs, any other small objects, as well as wet or slippery surfaces/floor. In addition, they should wear supportive shoes to reduce the risk of slipping or trips.
- As some exergames may collect user health or personal data, pregnant women may wish to review the game's privacy policy to ensure how their data will be used and stored.
- While exergaming, pregnant women should listen to their bodies. They should stop exergaming and contact their healthcare providers immediately in the event that they feel unwell (for example, chest pain, persistent excessive shortness of breath, severe headache, persistent dizziness/feeling faint, regular painful uterine contractions, vaginal bleeding, and persistent loss of fluid from the vagina), or perceive reduced fetal movements or any other problems with their pregnancy.

7.3. Implication for the game industry

This findings of this thesis have implications for the game industry in designing safe and effective exergames for pregnant women in future, including;

- Our study findings underline the importance of designing exergames that consider the specific needs and physiological changes that occur during pregnancy. Thus, the game industry may consider creating or adapting exergames tailored to specific groups such as pregnant women.
- Our findings highlight the usability issues related to the intensity and mode of some exercises/gameplay that may have the potential for injury or adverse events for specific groups such as pregnant women. The intensity and mode of some exercises in the game need to be modified to accommodate physical limitations and physiological changes that occur during pregnancy. Game designers and developers should incorporate adjustable intensity levels in exergames to cater to a range of fitness levels, trimester of pregnancy and limitations of specific populations like pregnant women. For this reason, exercises that require excessive flexion, jumping, risk of losing balance, and unstable and fast movements are best avoided, or included with an indication of the potential risks. Additionally, exercises to be incorporated in exergames for pregnant women should align with the latest guidelines for physical activity during pregnancy to ensure safety and effectiveness.
- As indicated in this thesis, even though the Nintendo Switch has a variety of exercises/gameplay, the game has limited pregnancy-safe exercise options available for pregnant women. Hence, game designers and developers should include a wider

range of exercises, considering pregnant women's needs and physiological changes that occur during pregnancy. This would allow pregnant women to choose from options that are appropriate for their pregnancy stage, and personal preferences.

- Integrating information related to pregnancy and prenatal exercise into the game would provide additional value to pregnant women. In addition, proper instructions and warnings should be incorporated into the games to inform pregnant women about potential risks and how to exercises safely.

7.4. Implications for future research

The findings of this thesis demonstrate the potential for the use of exergaming in pregnant women, providing the foundation for further evidence from large-scale studies. Specifically, outcomes from randomised controlled trials are needed before exergaming can be widely recommended as a standard option during antenatal care. Such studies can inform policy, guide healthcare providers, and help game designers and developers to create games that are more appealing and effective.

This thesis aimed to achieve evidence for the safety, feasibility, and potential efficacy of exergaming during pregnancy and its acceptability by end users, pregnant women. In the next phase of this project, we will conduct RCT in a clinical setting to investigate the effect of exergaming programs on pregnancy and birth outcomes. This RCT will provide evidence on the impact of the exergaming program on: (1) physical activity levels during pregnancy; (2) birth and neonatal outcomes; (3) mental health and wellbeing during pregnancy and post birth; (4) barriers and facilitators to implementation; and (5) longer term maternal and perinatal health outcomes. This work will progress us closer to new, validated individualised exergaming interventions that can be integrated into maternity care.

Furthermore, we have commenced the co-design of a bespoke exergame prototype with exercise scientists, midwives, exergame design experts and consumers to demonstrate proof-of-concept. The implementation of Project Natal, as the project is called, was informed by the findings of this thesis. The prototype features a progression system, quests, goals, and a well-defined interaction that received positive initial responses from consumers. Work is ongoing to develop a fully functional bespoke game. Our ultimate goal is to produce a pregnancy specific exergame that can be scaled up in health services at reasonable cost, without the need for pregnant women to purchase expensive equipment.

Based on the current thesis findings and possible limitations, future research is suggested in the following areas:

- Large-scale randomised controlled trials in the clinical setting are warranted to corroborate the findings of this thesis. This could include investigating the effects of exergaming programs on pregnancy and birth outcomes such as hypertensive disorders in pregnancy, gestational weight gain, mode of birth, gestational diabetes and other health outcomes.
- The effects of exergaming programs during pregnancy on newborn outcomes (for example, gestation at birth, birth weight, Apgar scores).
- Evaluating the effectiveness of exergames for promoting postpartum recovery/weight management and pre-conception preparation for subsequent pregnancies in the intra-partum period.
- Impacts of an exergaming program on the mental health and well-being of pregnant women.
- Barriers and facilitators to exergaming programs for pregnant women, and strategies for enhancing adherence.
- Cost-effectiveness and equity of exergaming programs as a tool for exercise during pregnancy, to provide insights to guide policy and implications for practice.
- Development of a bespoke exergame for pregnancy that would not require the purchase of expensive kit.

7.4. Conclusion

In conclusion, exergaming was found to be a safe and feasible approach for encouraging physical activity during pregnancy, given that safe exercises that were appropriate for each trimester were designed and tailored according to individual pregnant women's needs and preferences. The study findings also demonstrated that exergaming programs have the potential to increase physical activity levels and enhance adherence to exercise. Our study findings suggest that exergaming is enjoyable, fun, and motivating for pregnant women. In addition, these findings imply that exergames could provide a convenient, safe, and suitable option for pregnant women looking to incorporate exercise into their routine. In particular, exergames could be a useful exercise option for pregnant women who face barriers to physical activity, such as lack motivation, limited access to outdoor activities or training facilities, limited time, or uncertainty how to exercise safely. Providing familiarisation and training on the safe and effective use of the exergame equipment and exercise techniques is essential for ensuring the safety of pregnant women. Additionally, pregnant women should consult with their health care provider before using exergames and adhere to guidelines for safe and suitable physical activity during pregnancy. Overall, our findings support the potential of exercise interventions like exergames in promoting physical activity and addressing barriers to physical activity during pregnancy. As such, further larger-scale studies, preferably randomised control trials, are warranted to further investigate the effect of exergaming during pregnancy. In summary, this thesis provides promising evidence that could be a valuable addition to public health strategies aimed at promoting physical activity during pregnancy.

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Appendices

Appendix 1. Expert's evaluation of Nintendo Switch exercise programs for use for pregnant women.

1. Minigames

Legs

Exercises/game play	Pros	Cons	Preference
Squattery Wheel	You can control time, effort and gameplay. You can be creative	Risk of holding deep asymmetric squats Range of motion might not be possible	Yes
Squat Goals	Depending on fitness Advanced and taxing exercise, but probably too much for this population	Risk of holding deep asymmetric squats Nature of powerful movement for jumping Lack of time (too many squats) Time pressure	Yes (with precaution)
Thigh Rider	Seated Stability technique not an issue Interesting game mechanics	Heavy load on isolated muscle group (abductors) Game duration for this muscle group	Yes
Dreadmill	High load	Extensive physical activity	NO

	Cardiovascular	Intensity required to do the game	

Arms

Exercises/gameplay	Pros	Cons	Preference
Robo-Wrecker	Good upper body exercise Good stability Predominantly for shoulders and forearms Not above head lifting	Time-pressure and speed of movement Not big issue for those muscles	YES
Aerochute		Overhead lifting Flexion of spine Inappropriate positioning	NO
Crate Crasher	Good stability Good technique Controlled time Controlled intensity Limited overhead lifting		YES
Bootstrap Tower	Fine motor control	Too based on technique Questionable physical training stimulus	YES

Stomach/Abdomen

Exercises/gameplay	Pros	Cons	Preference
Bank Balance		Concerns regarding lateral flexion Press against the abdomen Lower back stress High Risk for pregnant population	NO
Core Crushing		Concerns regarding lateral flexion Press against the abdomen Lower back stress High Risk for pregnant population	NO
Gluting Gallery		Overhead lifting Excessive lateral flexion Time pressure	NO
Smack Back		Excessive rotation Torsion of hips Fast movements Time pressure uncontrolled	NO

Jogging

Exercises/gameplay	Pros	Cons	Preference
Beginnia	Gentle on the spot walking Good lower body exercise	Nothing stops you from overloading the intensity Inappropriate knee lifting	Yes (if can put a time limit)

Transient Temple	Gentle on the spot walking Good lower body exercise	Nothing stops you from overloading the intensity Inappropriate knee lifting	Yes (if can put a time limit)
Sportan highway		Concerns regarding lateral flexion Press against the abdomen Technique and lower back stress High Risk for pregnant population	NO
Starting Block Bridge	Better game mechanics Gentle on the spot walking Good lower body exercise	Nothing stops you from overloading the intensity Inappropriate knee lifting	Yes (if can put a time limit)
Trotter Grove	Good lower body exercise	Potential for over exertion Risk of holding deep asymmetric squats Time pressure uncontrolled	NO
Monster Den	Good lower body exercise	Potential for over exertion Excessive rotation Press against the abdomen Time pressure	NO

Dragaux Stadium 11	Good lower body exercise	Potential for over exertion	NO

2. Rhythm Games

Arms and Legs			
Exercises/ gameplay	**Pros**	**Cons**	**Preference**
Fit battle	Stable base No twisting and torsion of Spine No pressure on abdomen Good upper body exercise	Isolated muscle groups Repetitive	YES
Boss battle	Stable base No twisting and torsion of Spine No pressure on abdomen Good upper body exercise	Come too regularly so, no time to control the gap then pause Time pressure Constant contraction all the time Isolated muscle groups	YES
Four Masters battle	Stable base No twisting and torsion of Spine No pressure on abdomen	Come too regularly so, no time to control the gap then pause Time pressure Constant contraction all the	YES

	Good upper body exercise	time Isolated muscle groups	
Battle Gym	Stable base No twisting and torsion of Spine No pressure on abdomen Good upper body exercise	Come too regularly so, no time to control the gap then pause Time pressure Constant contraction all the time Isolated muscle groups	YES
Dragaux Battle	Stable base No twisting and torsion of Spine No pressure on abdomen Good upper body exercise	Come too regularly so, no time to control the gap then pause Time pressure Constant contraction all the time Isolated muscle groups	YES
Grassland	Stable base No twisting and torsion of Spine No pressure on abdomen Good upper body exercise	Come too regularly so, no time to control the gap then pause Time pressure Constant contraction all the time Isolated muscle groups	YES
Riverside	Stable base No twisting and torsion	Come too regularly so, no time to control the gap then pause	YES

	of Spine No pressure on abdomen Good upper body exercise	Time pressure Constant contraction all the time Isolated muscle groups	
Snow Mountain	Stable base No twisting and torsion of Spine No pressure on abdomen Good upper body exercise	Come too regularly so, no time to control the gap then pause Time pressure Constant contraction all the time Isolated muscle groups	YES
Night Road	Stable base No twisting and torsion of Spine No pressure on abdomen Good upper body exercise	Come too regularly so, no time to control the gap then pause Time pressure Constant contraction all the time Isolated muscle groups	YES
Athletic 1	Stable base No twisting and torsion of Spine No pressure on abdomen Good upper body exercise	Come too regularly so, no time to control the gap then pause Time pressure Constant contraction all the time Isolated muscle groups	YES

Athletic 2	Stable base No twisting and torsion of Spine No pressure on abdomen Good upper body exercise	Come too regularly so, no time to control the gap then pause Time pressure Constant contraction all the time Isolated muscle groups	YES
Draguax Stadium	Stable base No twisting and torsion of Spine No pressure on abdomen Good upper body exercise	Come too regularly so, no time to control the gap then pause Time pressure Constant contraction all the time Isolated muscle groups	YES
Jump up, Superstar	Stable base No twisting and torsion of Spine No pressure on abdomen Good upper body exercise	Come too regularly so, no time to control the gap then pause Time pressure Constant contraction all the time Isolated muscle groups	YES
Ground Theme	Stable base No twisting and torsion of Spine No pressure on abdomen	Come too regularly so, no time to control the gap then pause Time pressure Constant contraction all the	YES

	Good upper body exercise	time Isolated muscle groups	
Breath of Wild	Stable base No twisting and torsion of Spine No pressure on abdomen Good upper body exercise	Come too regularly so, no time to control the gap then pause Time pressure Constant contraction all the time Isolated muscle groups	YES
Splatoon 2 Medley	Stable base No twisting and torsion of Spine No pressure on abdomen Good upper body exercise	Come too regularly so, no time to control the gap then pause Time pressure Constant contraction all the time Isolated muscle groups	YES
Wii Fit Medley	Stable base No twisting and torsion of Spine No pressure on abdomen Good upper body exercise	Come too regularly so, no time to control the gap then pause Time pressure Constant contraction all the time Isolated muscle groups	YES

Core and Legs			
Exercises/ gameplay	**Pros**	**Cons**	**Preference**
Fit battle	Upper body contraction	Press against the abdomen Inappropriate positioning(supine) Length/duration of contraction Torsion of spine Twisting of spine Time pressure uncontrolled	NO
Boss battle	Upper body contraction	Press against the abdomen Inappropriate positioning(supine) Length/duration of contraction Torsion of spine Twisting of spine Time pressure uncontrolled	NO
Four Masters battle	Upper body contraction	Press against the abdomen Inappropriate positioning(supine) Length/duration of contraction	NO

		Torsion of spine Twisting of spine Time pressure uncontrolled	
Battle Gym	Upper body contraction	Press against the abdomen Inappropriate positioning(supine) Length/duration of contraction Torsion of spine Twisting of spine Time pressure uncontrolled	NO
Dragaux Battle	Upper body contraction	Press against the abdomen Inappropriate positioning(supine) Length/duration of contraction Torsion of spine Twisting of spine Time pressure uncontrolled	NO
Grassland	Upper body contraction	Press against the abdomen Inappropriate positioning(supine) Length/duration of contraction	NO

		Torsion of spine Twisting of spine Time pressure uncontrolled	
Riverside	Upper body contraction	Press against the abdomen Inappropriate positioning(supine) Length/duration of contraction Torsion of spine Twisting of spine Time pressure uncontrolled	NO
Snow Mountain	Upper body contraction	Press against the abdomen Inappropriate positioning(supine) Length/duration of contraction Torsion of spine Twisting of spine Time pressure uncontrolled	NO
Night Road	Upper body contraction	Press against the abdomen Inappropriate positioning(supine) Length/duration of contraction	NO

		Torsion of spine Twisting of spine Time pressure uncontrolled	
Athletic 1	Upper body contraction	Press against the abdomen Inappropriate positioning(supine) Length/duration of contraction Torsion of spine Twisting of spine Time pressure uncontrolled	NO
Athletic 2	Upper body contraction	Press against the abdomen Inappropriate positioning(supine) Length/duration of contraction Torsion of spine Twisting of spine Time pressure uncontrolled	NO
Draguax Stadium	Upper body contraction	Press against the abdomen Inappropriate positioning(supine) Length/duration of contraction	NO

		Torsion of spine Twisting of spine Time pressure uncontrolled	
Jump up, Superstar	Upper body contraction	Press against the abdomen Inappropriate positioning(supine) Length/duration of contraction Torsion of spine Twisting of spine Time pressure uncontrolled	NO
Ground Theme	Upper body contraction	Press against the abdomen Inappropriate positioning(supine) Length/duration of contraction Torsion of spine Twisting of spine Time pressure uncontrolled	NO
Breath of Wild	Upper body contraction	Press against the abdomen Inappropriate positioning(supine) Length/duration of contraction	NO

		Torsion of spine Twisting of spine Time pressure uncontrolled	
Splatoon 2 Medley	Upper body contraction	Press against the abdomen Inappropriate positioning(supine) Length/duration of contraction Torsion of spine Twisting of spine Time pressure uncontrolled	NO
Wii Fit Medley	Upper body contraction	Press against the abdomen Inappropriate positioning(supine) Length/duration of contraction Torsion of spine Twisting of spine Time pressure uncontrolled	NO

3. Fit skills (structures exercises)

Arm

Exercises/gameplay	Pros	Cons	Preference
Front Press	Good upper body exercise No overhead lifting Stable postural positioning Less likelihood of overexertion	Positioning for pregnant women	YES
Overhead Arm Twist	Good stability	Overhead lifting Isolated muscle group	NO
Overhead Arm Spin		Overhead lifting Torsion on spine Unsupported lumbar spine	NO
Triceps Kickback	Good exercise for triceps muscle Stable position(despite flexion) Controlled lunge	Single isolated muscle group	YES
Bow Pull	Stable base		YES

	Safe position for working shoulder and biceps No twisting No overhead lifting Multi muscle group Full upper body exercise		
Back Press		Isometric contraction above the head Hyperextension of the shoulders Blood pressure response Pressure on cervical and lumbar area	NO
Shoulder Press	Good stability Good exercise for biceps	Single isolated muscle group Misnamed (all about biceps, not shoulders) Above shoulder contraction	NO
Overhead Press	Limited spinal movement Stable base	Overhead lifting Inappropriate spinal position	NO

	Controlled contraction and relaxation Upper body strength exercise Intensity can be controlled	High blood pressure responses to consider	

Abdomen/core

Exercises/gameplay	Pros	Cons	Preference
Standing Twist		Twisting motion Torsion of spine Speed of movement is inappropriate	NO
Overhead side Bend		Overhead lifting Time pressure uncontrolled Inappropriate Lateral flexion	NO
Overhead Bend		Spinal flexion with overhead lifting (inappropriate) Lack of external support Increased risk of losing balance	NO

		Time pressure uncontrolled	
Pendulum Bend		Combination of spinal flexion with torsion Inappropriate position Unsupported Risk of lumbar injury Isometric contraction Time pressure uncontrolled	NO
Overhead Lunge Twist	Lunge base isometric	Overhead movement Spinal torsion Time pressure uncontrolled	NO
Overhead Hip Shake	Hip motion	Overhead lifting	NO
Knee to Chest	Controlled base Controlled support	Limited range of motion in later stages	NO
Seated Ring Raise	Stability is not issue Controlled posture Easy Technique	Overhead lifting Weaken core strength	No
Leg Raise	Good abdominal exercise	Lack of support for upper body	NO

		Risk of inappropriate loading to the spine	
Open and Close Leg Raise		Unsupported Inappropriate positioning Inappropriate sprain	NO
Russian Twist	Seated(stable position) Reduces weight bearing	Inappropriate twisting Inappropriate torsion Speed of the movement is inappropriate Postural concerns for the load through the spine (lumbar)	NO
Seated Forward Press	Stability is not an issue Upper body press is good	Potential for too much forward flexion and compression on the abdomen	YES
Flutter Kick	Reduce load on spine Works abdominal muscles	Inappropriate positioning Full straight leg Resistance for untrained	NO
Plank		Inappropriate position	NO

		Weight in wrong spot Unsupported Difficult when carrying a fetus Load on elbow Huge load on the hamstring	
Leg Scissors	Good exercise for load bearing through groin	Unsupported weight Inappropriate positioning for pregnant population Load through low spine Unstable movements Requires sufficient strength	NO

Leg

Exercises/gameplay	**Pros**	**Cons**	**Preference**
Squat	Good exercise for lower body (glutes and quads muscles) Can be done safely Timing is appropriate	Needs refined technique to do it effectively Deep squat to the game timing is an excessive load	YES

Overhead squat	Good exercise for lower body exercise for major muscle groups	Overhead isometric hold Overhead lifting places excessive load on the lumbar spine Holding deep squats to the game timing is an excessive load	NO
Wide Squat	Assuming feet are not too wide it is: Good Lower body exercise Mimics elements of positioning for pregnant woman Important exercise for Glutes and Quads muscles Can be done safely Timing is appropriate	Pressure through pelvic region Need refined technique to do it effectively Full squat to the game timing is an excessive load	NO
Knee lift		Overhead lifting Requires balance Too much bouncing	NO

		Speed of movement dedicated by the game Potential for over exertion	
Side Step	Good low body exercise Easy movement Requires cardiovascular load	Overhead movement not appropriate Fast movement	YES (without overhead)
Ring Raise Combo	Simple movement technique from stable posture base	Excessive overhead movement Limited lower body range of motion Pattern/speed of movement is too fast	NO
Knee Lift Combo	Good advanced exercise High physical demand Whole body exercise (lower, upper)	Excessive overhead movement Speed of movement is too fast Increased risk of losing balance	YES (if limited overhead movement, slow movement)

		Requiring one-legged balance Possibility of over exertion	
Thigh Press	Nice and controlled posture Stable positioning Focus on pelvic region and groin Appropriate for pregnant women Well timed (gradual build up)		YES
Hip lift	Common exercise for pregnant women Nice and controlled posture Stable positioning Focus on pelvic region and groin Appropriate for pregnant women Good timing	Requires hip strength, which needs to be developed	YES (not in late stages of pregnancy)

	Step up from thigh press		
Mountain Climber		Fast movement Inappropriate positioning, posture, speed Difficult movement pattern Potential for over exertion	NO

Yoga

Exercises/gameplay	**Pros**	**Cons**	**Preference**
Tree Pose	Slow and controlled	Requires single leg balance Possibility of losing balance (risk of fall) Lateral flexion of the spine Overhead lifting Time pressure uncontrolled Inappropriate positioning for pregnant women	NO

Chair Pose	Stable lower body position Isometric contraction of major lower body muscles	Overhead movement Pressure on lumbar spine	NO OR With restricted body movement
Warrior 1 Pose	Lunge position is good Provides stable postural position	Overhead arm position Lateral flexion Time pressure uncontrolled Lateral flexion	NO
Warrior II Pose	Good lower body position Isometric contraction Stable base Upper body is used but below the shoulder	Requires development of technique and strength	YES
Revolved Crescent Lunge Pose	Good launch position Stable base Isometric contraction of large	Potentially too much torsion of spine and twist (But slow and controlled)	YES Dependent on individual

	muscle groups in lower body Speed is well controlled Works abdominis muscle		(for later on)
Warrior III Pose		Too advanced Too technical Requires single leg balance Overhead movement Unstable base Excessive load through lumbar spine Risk of falling or losing balance	NO
Hinge Pose		Inappropriate load on lumbar spine Difficult posture Too much above head work Very technical exercise requiring extensive flexibility Risk of fall or losing balance	NO

		Time pressure Uncontrolled	
Standing Forward Fold		Inappropriate load on lumbar spine Difficult posture Too much above head work Risk of falling or losing balance	NO
Boat Pose		Supine position Extra pressure on pelvic floor Too advanced exercise Positioning is difficult for pregnant women Stress through lumbar spinal Inappropriate abdominal flexion	NO
Fan Pose	Seated with stable postural base Targets obliques and back muscles	Potentially too much lateral flexion of the spine Too much work above the head	NO

Dynamic Stretches

Exercises/gameplay	Pros	Cons	Preference
Alternate Bringing Your Knees Up to Touch the Ring-Con		Inappropriate knee lifting Overhead lifting Risk of falling or losing balance	NO
Heel Lift Stretch		Inappropriate knee lifting Overhead lifting Risk of falling or losing balance	NO
Back Straightening Stretch		Overhead lifting Extra pressure on pelvic floor	NO
Lean Stretch		Excessive flexion	NO

Static Stretches

Exercises/gameplay	**Pros**	**Cons**	**Preference**
Hand Stretches	Good stability		YES
Arm Stretches	Good stability		YES

Forward Bend Stretch		Potential for losing balance	NO
Hip Stretches		Add extra load to the pelvic floor	May be

Appendix 2. Screening tool for physical activity/exercise during pregnancy

UTS HREC Approval number: ETH20-5283

Section 1 – General contraindications to physical activity/exercise

This section explores general health prior to pregnancy.

1. Has your Doctor ever told you that you have a heart condition or have you ever suffered a stroke?

1. Yes   2. No

2. Do you ever experience unexplained pains or discomfort in your chest at rest or during physical activity/exercise?

1. Yes   2. No

3. Do you ever feel faint, dizzy or lose balance during physical activity/exercise?

1. Yes   2. No

4. Have you had an asthma attack requiring immediate medical attention at any time over the last 12 months?

1. Yes   2. No

5. If you have diabetes (type I or type 2) have you had trouble controlling your blood sugar (glucose) in the last 3 months?

1. Yes   2. No

6. Do you have any diagnosed muscle, bone or joint problems that you have been told could be made worse by participating in physical activity/exercise?

1. Yes 2. No

7. Do you have any other conditions that may require special consideration for you to exercise?

1. Yes 2. No

IF YOU answered 'NO' to all 7 questions above, please proceed to Section 2, which specifically considers your health during pregnancy.

Section 2: Absolute contraindications to physical activity/exercise during pregnancy.

Have you ever been told, or diagnosed by your doctor that you have any of the following contraindications to physical activity/exercise?

1. Incompetent cervix (cervix opens or dilates too early during pregnancy)

1. Yes 2. No

2. Ruptured membranes, premature labour

1. Yes 2. No

3. Persistent second or third trimester bleeding

1. Yes 2. No

4. Placenta previa (low lying placenta)

1. Yes 2. No

5. Pre-eclampsia

1. Yes 2. No

6. Evidence of intrauterine growth restriction

1. Yes   2. No

7. Multiple gestation (e.g.: triplets or higher number)

1. Yes   2. No

8. Poorly controlled Type I diabetes, hypertension or thyroid disease

1. Yes   2. No

9. Other serious cardiovascular, respiratory or systemic disorder

1. Yes   2. No

IF YOU answered 'NO' to all 9 questions above, please proceed to section 3, which considers relative contraindications physical activity during pregnancy.

Section 3: Relative contraindications to physical activity/exercise during pregnancy.

Have you ever been told, or diagnosed by your doctor that you have any of the following contraindications to physical activity/exercise?

1. History of spontaneous miscarriage, premature labour or fetal growth restriction.

1. Yes   2. No

2. Mild/moderate cardiovascular or chronic respiratory disease

1. Yes   2. No

3. Pregnancy-induced hypertension

1. Yes 2. No

4. Poorly controlled seizure disorder

1. Yes 2. No

5. Type 1 diabetes

1. Yes 2. No

6. Symptomatic anaemia

1. Yes 2. No

7. Malnutrition, significantly underweight or eating disorder

1. Yes 2. No

8. Twin pregnancy

1. Yes 2. No

9. Other significant medical condition/s

1. Yes 2. No

IF YOU answered NO to all 9 questions above, please proceed section 4.

Section 4: Current lifestyle

1. Do you smoke during the current pregnancy?

1. Yes 2. No

2. Do you drink alcohol during the current pregnancy?

1. Yes   2. No

Thank you for taking the time to fill this form.

Appendix 3: Exergame (Nintendo Switch) exercise programs tailored for pregnant women

UTS HREC Approval number: ETH20-5283

Name of participant: ____

Research team contact details: Phone: 0452354055

Email: deborah.fox@uts.edu.au or gemechu.kumera@student.uts.edu.au

Exergaming/training procedures

- The exergaming training program is designed by a team of midwives, exercise scientists and an exergame expert to ensure your safety and enjoyment.
- The training programs are designed so that initial exercise volume and intensity is low and will progressively increase according to your ability.
- Prior to commencement of the exergaming program you will be provided with familiarization sessions by a research team to show you how to use the games.
- You may experience some post-exercise muscle soreness and fatigue during the first few weeks of the training sessions.

Please Note: The inappropriate application of training programs carries an increased risk of injury or adverse events.

Warm-up Sessions: (5 min)

1. Standing march - 1min and 30sec
2. Shoulder rotations - 30sec
3. Kneeling wall push-ups - 30sec
4. Seated calf raises - 30sec
5. Side Steps with arm movements - 1min and 30sec
6. Forearm stretch - 30sec

Week 1

Training program/ Fitness List A

Exercises	Repetition (Reps)	Session 1 (Total duration 20 min)	Session 2 (Total duration 20 min)
		Time/duration	Time/duration
Warm up	1	5 min	5 min
Crate crasher Thigh Rider Crate crasher Transient Temple	1	10 min	10 min
Cool down	1	5 min	5 min

Week 2

Training program/ Fitness List B

Exercises	Repetition (Reps)	Session 1 (Total duration 25 min)	Session 2 (Total duration 25 min)
		Time/duration	Time/duration
Warm up	1	5 min	5 min
Robo-Wrecker Thigh Rider Beginnia Robo-Wrecker Squattery Wheel Beginnia	1	15 min	15 min
Cool down	1	5 min	5 min

Week 3

Training Program/Fitness List C

Exercises	Reps	Session 1 (total duration 25 min)	Session 2 (total duration 25 min)	Session 3 (total duration 25 min)
		Time/Duration	Time/Duration	Time/Duration
Warm up	1	5 min	5 min	5 min
Crate crasher Squat goals Starting Block Bridge Crate crasher Squattery Wheel Starting Block Bridge	1	15 min	15 min	15 min
Cool down	1	5 min	5 min	5 min

Week 4

Training Program/Fitness List D

Exercises	Reps	Session 1 (Total duration 30 min)	Session 2 (Total duration 30 min)	Session 3 (Total duration 30 min)
		Time/Duration	Time/Duration	Time/Duration
Warm up	1	5 min	5 min	5 min
Squat Front press Side Step Triceps Kickback Thigh Press Robo-Wrecker Thigh rider Fit battle Starting block bridge Seated forward press	1	20 min	20 min	20 min
Cool down	1	5 min	5 min	5 min

Week 5

Training Program/Fitness List E

Exercises	Reps	Session 1 (Total duration 35 min)	Session 2 (Total duration 35 min)	Session 3 (Total duration 35 min)
		Time/Duration	Time/Duration	Time/Duration
Warm up	1	5 min	5 min	5 min
Squat Bow Pull Side Step Triceps Kickback Crate Crasher Thigh rider Four Masters battle Beginnia	2	25 min	25 min	25 min
Cool down	1	5 min	5 min	5 min

Week 6

Training Program/Fitness List F

Exercises	Reps	Session 1 (Total duration 35 min)	Session 2 (Total duration 35 min)	Session 3 (Total duration 35 min)	Session 4 (Total duration 35 min)
		Time/Duration	Time/Duration	Time/Duration	Time/Duration
Warm up	1	5 min	5 min	5 min	5 min
Squat Front Press Side Step Triceps Kickback Robo-Wrecker Squat goals Boss battle Transient Temple	2	25 min	25 min	25 min	25 min
Cool down	1	5 min	5 min	5 min	5 min

Week 7

Training program/ Fitness List G

Exercises	**Reps**	**Session 1** (Total duration 40 min)	**Session 2** (Total duration 40 min)	**Session 3** (Total duration 40 min)	**Session 4** (Total duration 40 min)
		Time/Duration	**Time/Duration**	**Time/Duration**	**Time/Duration**
Warm up	1	5 min	5 min	5 min	5 min
Squat Bow Pull Side Step Triceps Kickback Thigh Press Robo-Wrecker Thigh rider Dragaux Battle Starting block bridge	2	30 min	30 min	30 min	30 min
Cool down	1	5 min	5 min	5 min	5 min

Week 8

Training Program/Fitness List H

Exercises	Reps	Session 1 (Total duration 40 min)	Session 2 (Total duration 40 min)	Session 3 (Total duration 40 min)	Session 4 (Total duration 40 min)
		Time/Duration	**Time/Duration**	**Time/Duration**	**Time/Duration**
Warm up	1	5 min	5 min	5 min	5 min
Transient Temple Boss battle Squat Side Step Bow Pull Front Press Thigh Rider Crate crasher Warrior II pose	2	30 min	30 min	30 min	30 min
Cool down	1	5 min	5 min	5 min	5 min

Week 9

Training program/ Fitness List I

Exercises		**Session 1** (Total duration 40 min) **Time/Duration**	**Session 2** (Total duration 40 min) **Time/Duration**	**Session 3** (Total duration 40 min) **Time/Duration**	**Session 4** (Total duration 40 min) **Time/Duration**
Warm up	1	5 min	5 min	5 min	5 min
Starting block bridge Fit battle Thigh Press Side Step Front press Bow Pull Squat goals Robo-Wrecker Warrior II pose	2	30 min	30 min	30 min	30 min
Cool down	1	5 min	5 min	5 min	5 min

Week 10

Training Program/Fitness List J

Exercises	Reps	Session 1 (Total duration 40 min)	Session 2 (Total duration 40 min)	Session 3 (Total duration 40 min)	Session 4 (Total duration 40 min)
		Time/Duration	Time/Duration	Time/Duration	Time/Duration
Warm up	1	5 min	5 min	5 min	5 min
Beginnia Battle Gym Squat Side Step Bow Pull Front Press Squattery Wheel Crate crasher Warrior II pose	2	30 min	30 min	30 min	30 min
Cool down	1	5 min	5 min	5 min	5 min

Week 11

Training program/ Fitness List G

Exercises	Reps	Session 1 (Total duration 40 min)	Session 2 (Total duration 40 min)	Session 3 (Total duration 40 min)	Session 4 (Total duration 40 min)
		Time/Duration	**Time/Duration**	**Time/Duration**	**Time/Duration**
Warm up	1	5 min	5 min	5 min	5 min
Squat Bow Pull Side Step Triceps Kickback Thigh Press Robo-Wrecker Thigh rider Dragaux Battle Starting block bridge	2	30 min	30 min	30 min	30 min
Cool down	1	5 min	5 min	5 min	5 min

Week 12

Training Program/Fitness List H

Exercises	**Reps**	**Session 1** (Total duration 40 min)	**Session 2** (Total duration 40 min)	**Session 3** (Total duration 40 min)	**Session 4** (Total duration 40 min)
		Time/Duration	**Time/Duration**	**Time/Duration**	**Time/Duration**
Warm up	1	5 min	5 min	5 min	5 min
Transient Temple Boss battle Squat Side Step Bow Pull Front Press Thigh Rider Crate crasher Warrior II pose	2	30 min	30 min	30 min	30 min
Cool down	1	5 min	5 min	5 min	5 min

Week 13

Training program/ Fitness List I

Exercises		**Session 1** (Total duration 40 min)	**Session 2** (Total duration 40 min)	**Session 3** (Total duration 40 min)	**Session 4** (Total duration 40 min)
		Time/Duration	**Time/Duration**	**Time/Duration**	**Time/Duration**
Warm up	1	5 min	5 min	5 min	5 min
Starting block bridge Fit battle Thigh Press Side Step Front press Bow Pull Squat goals Robo-Wrecker Warrior II pose	2	30 min	30 min	30 min	30 min
Cool down	1	5 min	5 min	5 min	5 min

Week 14

Training Program/Fitness List J

Exercises	Reps	Session 1 (Total duration 40 min)	Session 2 (Total duration 40 min)	Session 3 (Total duration 40 min)	Session 4 (Total duration 40 min)
		Time/Duration	**Time/Duration**	**Time/Duration**	**Time/Duration**
Warm up	1	5 min	5 min	5 min	5 min
Beginnia Battle Gym Squat Side Step Bow Pull Front Press Squattery Wheel Crate crasher Warrior II pose	2	30 min	30 min	30 min	30 min
Cool down	1	5 min	5 min	5 min	5 min

Week 15

Training Program/Fitness List K

Exercises	Reps	Session 1 (Total duration 35 min)	Session 2 (Total duration 35 min)	Session 3 (Total duration 35 min)	Session 4 (Total duration 35 min)
		Time/Duration	Time/Duration	Time/Duration	Time/Duration
Warm up	1	5 min	5 min	5 min	5 min
Squat goals Front Press Side Step Triceps Kickback Robo-Wrecker Thigh Press Boss battle Transient Temple	2	25 min	25 min	25 min	25 min
Cool down	1	5 min	5 min	5 min	5 min

Week 16

Training Program/Fitness List L

Exercises	**Reps**	**Session 1** (Total duration 35 min)	**Session 2** (Total duration 35 min)	**Session 3** (Total duration 35 min)	**Session 4** (Total duration 35 min)
		Time/Duration	**Time/Duration**	**Time/Duration**	**Time/Duration**
Warm up	1	5 min	5 min	5 min	5 min
Beginnia Bow Pull Squat Front press Thigh press Crate Crasher Thigh rider	2	25 min	25 min	25 min	25 min
Cool down	1	5 min	5 min	5 min	5 min

Week 17

Training Program/Fitness List M

Exercises	Reps	Session 1 (Total duration 35 min)	Session 2 (Total duration 35 min)	Session 3 (Total duration 35 min)	Session 4 (Total duration 35 min)
		Time/Duration	**Time/Duration**	**Time/Duration**	**Time/Duration**
Warm up	1	5 min	5 min	5 min	5 min
Beginnia Front press Squat Bow Pull Thigh press Robo-Wrecker Thigh rider	2	25 min	25 min	25 min	25 min
Cool down	1	5 min	5 min	5 min	5 min

Week 18

Training Program/Fitness List L

Exercises	**Reps**	**Session 1** (Total duration 35 min)	**Session 2** (Total duration 35 min)	**Session 3** (Total duration 35 min)	**Session 4** (Total duration 35 min)
		Time/Duration	**Time/Duration**	**Time/Duration**	**Time/Duration**
Warm up	1	5 min	5 min	5 min	5 min
Beginnia Bow Pull Squat Front press Thigh press Crate Crasher Thigh rider	2	25 min	25 min	25 min	25 min
Cool down	1	5 min	5 min	5 min	5 min

Week 19

Training Program/Fitness List M

Exercises	Reps	Session 1 (Total duration 35 min)	Session 2 (Total duration 35 min)	Session 3 (Total duration 35 min)	Session 4 (Total duration 35 min)
		Time/Duration	**Time/Duration**	**Time/Duration**	**Time/Duration**
Warm up	1	5 min	5 min	5 min	5 min
Beginnia Front press Squat Bow Pull Thigh press Robo-Wrecker Thigh rider	2	25 min	25 min	25 min	25 min
Cool down	1	5 min	5 min	5 min	5 min

Week 20

Training Program/Fitness List L

Exercises	Reps	Session 1 (Total duration 35 min)	Session 2 (Total duration 35 min)	Session 3 (Total duration 35 min)	Session 4 (Total duration 35 min)
		Time/Duration	**Time/Duration**	**Time/Duration**	**Time/Duration**
Warm up	1	5 min	5 min	5 min	5 min
Beginnia Bow Pull Squat Front press Thigh press Crate Crasher Thigh rider	2	25 min	25 min	25 min	25 min
Cool down	1	5 min	5 min	5 min	5 min

Cool down programs: (5 min)

1. Door way peck stretch
2. Hand Stretch
3. Cross body arm stretch
4. Forward bend stretch
5. Standing lunge stretch/calf stretch
6. Wall supported thigh stretch

Appendix 4: Guides to connecting Nintendo Switch to a home TV

UTS HREC Approval number: ETH20-5283

What you will need?

Gather these items to connect your Nintendo Switch to your TV.

1. Nintendo Switch console
2. Nintendo Switch dock
3. Left Joy-Con
4. Right Joy-Con
5. Leg Strap
6. Ring-Con
7. AC adapter
8. HDMI cable
9. HDMI-compatible TV

Once you have all the materials above, connecting your Nintendo Switch to your television takes only a minute.

Step 1. Open the back cover of the Nintendo Switch Dock.

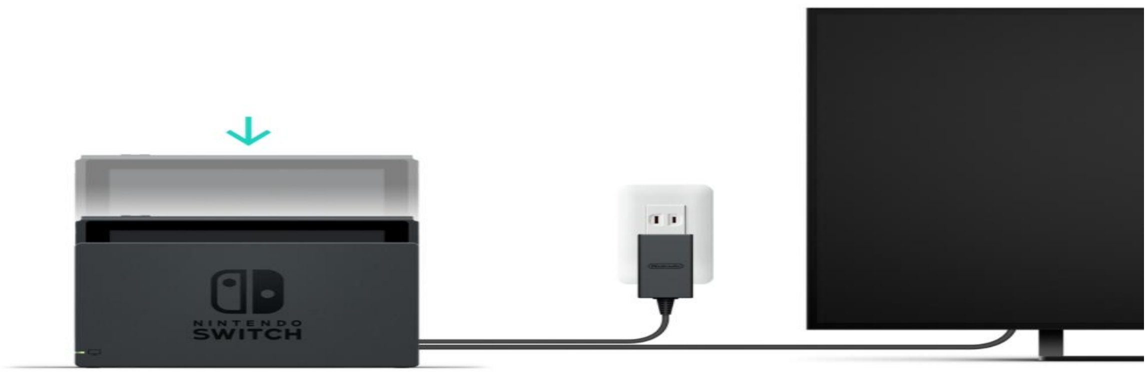
Step 2. Connect the USB plug from the Nintendo Switch **AC adapter** into the top terminal of the dock labelled "AC ADAPTER," then connect the other end of the AC adapter to a wall outlet.

Step 3. Connect one end of the **HDMI cable** into the bottom terminal of the dock labelled "HDMI OUT," then connect the other end into an HDMI port on your television.

Step 4. Close the back cover of the **Nintendo Switch dock** routing the cables through the opening.

Step 5. Remove/detach the **left** and **right Joy-Con** controllers from the console. Press the button on the back of a Joy-Con and slide it upward to remove it.

Step 6. Put or insert your **Nintendo Switch console** into the **dock**. Make sure the console screen faces the front of the dock where you see the Nintendo Switch logo. Place your Nintendo Switch dock on a stable surface close to the television.

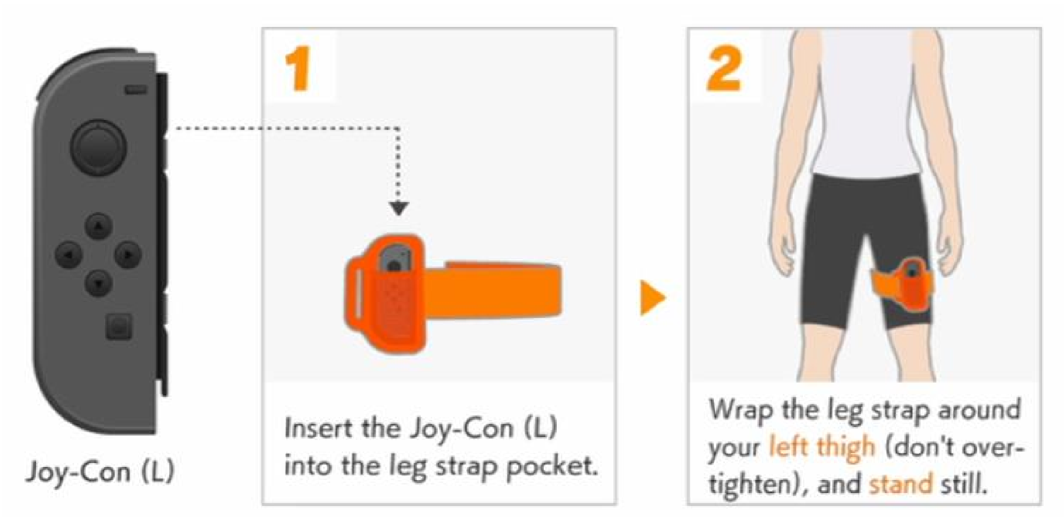


Step 7. Power on the **Nintendo Switch** and your **television**. Adjust the input on your TV for the corresponding HDMI port you used.

The screen on the Switch turns off when it's in the dock, but you should now see the Switch's screen on your television.

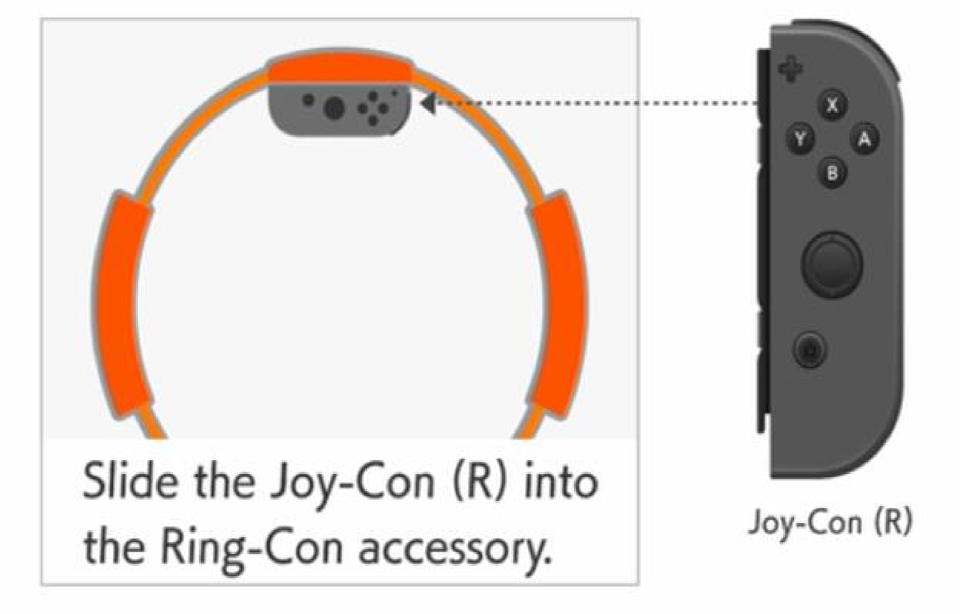
Step 8. Insert the **left Joy-con** (the one with the minus '-' symbol) in to the leg strap pocket with the thump stick at the top, facing outward.

Step 9. Wrap the **leg strap** around your left thigh (don't over-tighten). Stand still until the game registers that the strap is in place.



Be mindful of how tight you wrap this - you want it firm so it doesn't slip but it shouldn't need to be overly tight. The clothes you're wearing may make this more difficult so consider clothing that won't move too much or be too bulky under the strap.

Step 10. Insert the **right Joy-con** (the one with the minus '+' symbol) in to the Ring-Con. Align the (+) symbols on the Joy-Con (R) and the Ring-Con, then slide the Joy-Con (R) into the rail on the Ring-Con until you hear a click. So, you should be ready to play!



Step 10. Review the Ring-Con basic controls, then squeeze the Ring-Con to continue.

Step 11. Review the health and safety information, then squeeze the Ring-Con to continue.

Step 12. Tilt the Ring-Con or use thump stick to highlight the mode you want to play (**Adventure**, **Quick Play**, **Rhythm Games**, **Custom**, or **Multitask Mode**), then squeeze the Ring-Con to begin!

Please Note: You are recommended to play only **Custom Mode**. Playing **Adventure**, **Quick Play**, **Rhythm Games** or **Multitask Mode** carries an increased risk of injury or adverse events for pregnant women.

Appendix 5: A guide for women participants on the training/exergaming programs

UTS HREC Approval number: ETH20-5283

Introduction

Being active during pregnancy is essential for the good health and wellbeing of both you and your baby.

Staying active during pregnancy has many benefits for the health of both mother and baby, including:

- Improve strength for staying active in labour and birth
- Recovering after the birth of your baby
- Lower risk of gestational diabetes
- Less back and pelvic pain
- Lower risk of incontinence
- Better mental health, including a lower risk of postnatal depression.

Intensity (effort or how hard) and duration (how long) of training/exergaming

The training program is designed to provide moderate-intensity exercise for at least 30-40 minutes per day over 3-4 days per week.

Physical activity during pregnancy doesn't have to be vigorous to be beneficial. For a simple way to measure intensity, try the '**talk test'**.

You should be able to carry on a conversation during moderate intensity activities, but in vigorous intensity activities you would find this difficult.

Note: Training/exergaming above moderate intensity can pose safety risk.

Safety precautions/considerations

- Drink plenty of water and ensure you meet your nutrition and energy needs.
- Avoid exercising in hot weather, especially in high humidity. Physical activity should preferably be done in a cool environment.
- Always wear appropriate shoes, non-restrictive clothing, and a supportive pregnancy-safe bra.
- If it is hot, wear loose clothing made from ‘breathable’ fabric.

Listen to your body and speak with your doctor or the research team for more help or ways to adapt the training.

Contraindications to training/exergaming programs

If you have pregnancy complications contact your doctor and a research team before starting, continuing or returning to training/exergaming.

If you have been told by your doctor/midwife that you have any of the following you are **advised not to take part** in **training/exergaming programs:**

- Shortened cervix
- Ruptured membranes, preterm labour
- Persistent vaginal bleeding
- Placenta previa
- Pre-eclampsia
- Evidence of intrauterine growth restriction

- Multiple gestation (twins or higher)
- Type 1 diabetes, hypertension or thyroid disease
- Other serious cardiovascular, respiratory or systemic disorders

Contact your doctor and a research team before starting or continuing **training/exergaming** if you have a history of, or develop, any of the following:

- Spontaneous miscarriage
- Preterm labour
- Fetal growth restriction
- Mild/moderate cardiovascular or chronic respiratory disease
- Pregnancy induced hypertension
- Seizure disorder
- Type 1 diabetes mellitus
- Severe anaemia
- Malnutrition, significantly underweight or eating disorder
- Other significant medical conditions.

Warning signs to stop exercising/exergaming

If you experience any of the following symptoms during training/exergaming, stop the training/exergaming and contact your midwife, doctor or hospital immediately before continuing with any activity. Please also notify our research team after you have received care and advice from your midwife, doctor or hospital.

- Chest pain
- Persistent shortness of breath that does not get better with rest

- Severe headache
- Persistent dizziness/feeling faint that does not get better with rest
- Regular painful uterine contractions
- Vaginal bleeding
- Persistent loss of fluid from the vagina

Appendix 6. Recommendations of the Institute of Medicine (IOM) of the National Academy of Sciences (USA) on gestational weight gain.

Pre-pregnancy BMI, Kg/m²	**Recommended gestational weight gain, Kg**
Underweight (< 18.5)	12.5-18
Normal weight (18.5-24.9)	11.5-16
Overweight (25-29.9)	7.0-11.5
Obese (>=30)	5.0-9.0

Appendix 7. Pregnancy Physical activity Questionnaire (PPAQ)

UTS HREC Approval number: ETH20-5283

It is very important you tell us about yourself honestly. There are no right or wrong answers.

We just want to know about the things you are doing during this trimester.

Code Number_____________

Today's Date: DD/MM/YY_______________

During this trimester, when you are not at work, how much time do you usually spend:

1. Preparing meals (cook, set tables, wash dishes)?

- o None
- o Less than ½ hour per day
- o ½ hour to almost 1 hour per day
- o 1 hour to almost 2 hours per day
- o 2 hours to almost 3 hours per day
- o 3 or more hours per day

2. Dressing, bathing, feeding children while you are **sitting**?

- o None
- o Less than ½ hour per day
- o ½ hour to almost 1 hour per day
- o 1 hour to almost 2 hours per day
- o 2 hours to almost 3 hours per day
- o 3 or more hours per day

3. Dressing, bathing, feeding children while you are **standing**?

- None
- Less than ½ hour per day
- ½ hour to almost 1 hour per day
- 1 hour to almost 2 hours per day
- 2 hours to almost 3 hours per day
- 3 or more hours per day

4. Playing with children while you are **sitting or standing**?

- None
- Less than ½ hour per day
- ½ hour to almost 1 hour per day
- 1 hour to almost 2 hours per day
- 2 hours to almost 3 hours per day
- 3 or more hours per day

5. Playing with children while you are **walking or running**?

- None
- Less than ½ hour per day
- ½ hour to almost 1 hour per day
- 1 hour to almost 2 hours per day
- 2 hours to almost 3 hours per day
- 3 or more hours per day

6. Carrying children

- None
- Less than ½ hour per day
- ½ hour to almost 1 hour per day
- 1 hour to almost 2 hours per day
- 2 hours to almost 3 hours per day
- 3 or more hours per day

7. Taking care of an older adult

- None
- Less than ½ hour per day
- ½ hour to almost 1 hour per day
- 1 hour to almost 2 hours per day
- 2 hours to almost 3 hours per day
- 3 or more hours per day

8. Sitting and using computer or writing, while **not at work**

- None
- Less than ½ hour per day
- ½ hour to almost 1 hour per day
- 1 hour to almost 2 hours per day
- 2 hours to almost 3 hours per day
- 3 or more hours per day

9. Watching TV or a video

- None
- Less than ½ hour per day
- ½ hour to almost 2 hours per day
- 2 hours to almost 4 hours per day
- 4 hours to almost 6 hours per day
- 6 or more hours per day

10. Sitting and reading, talking, or on the phone, while **not at work**

- None
- Less than ½ hour per day
- ½ hour to almost 2 hours per day
- 2 hours to almost 4 hours per day
- 4 hours to almost 6 hours per day
- 6 or more hours per day

11. Playing with pets

- None
- Less than ½ hour per day
- ½ hour to almost 1 hour per day
- 1 hour to almost 2 hours per day
- 2 hours to almost 3 hours per day
- 3 or more hours per day

12. Light cleaning (make beds, laundry, iron, put things away)

- None
- Less than ½ hour per day
- ½ hour to almost 1 hour per day
- 1 hour to almost 2 hours per day
- 2 hours to almost 3 hours per day
- 3 or more hours per day

13. Shopping (for food, clothes, or other items)

- None
- Less than ½ hour per day
- ½ hour to almost 1 hour per day
- 1 hour to almost 2 hours per day
- 2 hours to almost 3 hours per day
- 3 or more hours per day

During this trimester, when you are not at work, how much time do you usually spend:

14. Heavier cleaning (vacuum, mop, sweep, wash windows)

- None
- Less than ½ hour per day
- ½ hour to almost 1 hour per day
- 1 hour to almost 2 hours per day
- 2 hours to almost 3 hours per day
- 3 or more hours per day

15. Moving lawn while on rider mower

- None
- Less than ½ hour per day
- ½ hour to almost 1 hour per day
- 1 hour to almost 2 hours per day
- 2 hours to almost 3 hours per day
- 3 or more hours per day

16. Moving lawn using a walking mower, raking, gardening

- None
- Less than ½ hour per day
- ½ hour to almost 1 hour per day
- 1 hour to almost 2 hours per day
- 2 hours to almost 3 hours per day
- 3 or more hours per day

Going places

During this trimester, how much time do you usually spend:

17. Walking **slowly** to go places (such as to bus, work, visiting). **Not** for fun or exercises.

- None
- Less than ½ hour per day
- ½ hour to almost 1 hour per day
- 1 hour to almost 2 hours per day
- 2 hours to almost 3 hours per day

- 3 or more hours per day

18. Walking **quickly** to go places (such as to bus, work, or school). **Not** for fun or exercises.

- None
- Less than ½ hour per day
- ½ hour to almost 1 hour per day
- 1 hour to almost 2 hours per day
- 2 hours to almost 3 hours per day
- 3 or more hours per day

19. Driving or riding in a car or bus

- None
- Less than ½ hour per day
- ½ hour to almost 1 hour per day
- 1 hour to almost 2 hours per day
- 2 hours to almost 3 hours per day
- 3 or more hours per day

For fun or exercises

During this trimester, how much time do you usually spend:

20. Walking **slowly** for fun or exercise

- None
- Less than ½ hour per day
- ½ hour to almost 1 hour per day

- 1 hour to almost 2 hours per day
- 2 hours to almost 3 hours per day
- 3 or more hours per day

21. Walking more **quickly** for fun or exercise

- None
- Less than ½ hour per day
- ½ hour to almost 1 hour per day
- 1 hour to almost 2 hours per day
- 2 hours to almost 3 hours per day
- 3 or more hours per day

22. Walking quickly up hills for fun or exercise

None

Less than ½ hour per day

½ hour to almost 1 hour per day

1 hour to almost 2 hours per day

2 hours to almost 3 hours per day

3 or more hours per day

During this trimester, how much time do you usually spend:

23. Jogging

- None
- Less than ½ hour per day

- ½ hour to almost 1 hour per day
- 1 hour to almost 2 hours per day
- 2 hours to almost 3 hours per day
- 3 or more hours per day

24. Prenatal exercise class

- None
- Less than ½ hour per day
- ½ hour to almost 1 hour per day
- 1 hour to almost 2 hours per day
- 2 hours to almost 3 hours per day
- 3 or more hours per day

25. Swimming

- None
- Less than ½ hour per day
- ½ hour to almost 1 hour per day
- 1 hour to almost 2 hours per day
- 2 hours to almost 3 hours per day
- 3 or more hours per day

26. Dancing

- None
- Less than ½ hour per day
- ½ hour to almost 1 hour per day

- 1 hour to almost 2 hours per day
- 2 hours to almost 3 hours per day
- 3 or more hours per day

Doing other thing for fun or exercise? Please tell us what they are?

27. Name of activity____

- None
- Less than ½ hour per day
- ½ hour to almost 1 hour per day
- 1 hour to almost 2 hours per day
- 2 hours to almost 3 hours per day
- 3 or more hours per day

28. Name of activity____

- None
- Less than ½ hour per day
- ½ hour to almost 1 hour per day
- 1 hour to almost 2 hours per day
- 2 hours to almost 3 hours per day
- 3 or more hours per day

Please fill out the next section if you work for wages, as a volunteer, or if you are student. If you are a homemaker, out of work, or unable to work, you do not need to complete this section.

At work

During this trimester, how much time do you usually spend:

29. Sitting at work or in class

- ○ None
- ○ Less than ½ hour per day
- ○ ½ hour to almost 2 hours per day
- ○ 2 hours to almost 4 hours per day
- ○ 4 hours to almost 6 hours per day
- ○ 6 or more hours per day

30. Standing or slowly walking at work while carrying things (heavier than a 1 galloon milk jug)

- ○ None
- ○ Less than ½ hour per day
- ○ ½ hour to almost 2 hours per day
- ○ 2 hours to almost 4 hours per day
- ○ 4 hours to almost 6 hours per day
- ○ 6 or more hours per day

31. Standing or <u>slowly</u> walking at work **<u>not</u>** carrying any thing

- ○ None
- ○ Less than ½ hour per day
- ○ ½ hour to almost 2 hours per day
- ○ 2 hours to almost 4 hours per day

- 4 hours to almost 6 hours per day
- 6 or more hours per day

32. Walking <u>quickly</u> at work while <u>carrying</u> things (heavier than a 1 gallon milk jug)

- None
- Less than ½ hour per day
- ½ hour to almost 2 hours per day
- 2 hours to almost 4 hours per day
- 4 hours to almost 6 hours per day
- 6 or more hours per day

33. Walking <u>quickly</u> at work <u>**not**</u> carrying any thing

- None
- Less than ½ hour per day
- ½ hour to almost 2 hours per day
- 2 hours to almost 4 hours per day
- 4 hours to almost 6 hours per day
- 6 or more hours per day

Thank you for taking the time to fill this questionnaire.

Appendix 8. Exercise Diaries

UTS HREC Approval number: ETH20-5283

It is very important you tell us about the duration and frequency of exergaming session you did honestly. Please, fill this form at the end of each session.

Study participant name__________________

Code Number______________

Duration and Frequency of exergaming/exercise sessions

Weeks	**Number of sessions**	**Duration of sessions (in minutes)**					
		Session 1	**Session 2**	**Session 3**	**Session 4**		
Week 1							
Week 2							
Week 3							
Week 4							
Week 5							
Week 6							
Week 7							
Week 8							

Week 9							
Week 10							
Week 11							
Week 12							
Week 13							
Week 14							
Week 15							
Week 16							
Week 17							
Week 18							
Week 19							
Week 20							

Appendix 9. Participant Information Sheet

UTS HREC Approval number: ETH20-5283

WHO IS DOING THE RESEARCH?

My name is Gemechu Kumera and I am a PhD student at UTS. My supervisors are:

1. Dr Deborah Fox (Associate Professor in Midwifery)

Centre for Midwifery, Child and Family Health at the University of Technology Sydney

2. Professor Rob Duffield (Professor of Sport and Exercise Science**)**

School of Sport, Exercise and Rehabilitation, Faculty of Health at the University of Technology Sydney

3. Dr Jaime Garcia Marin (Lecturer in Games Development**)**

School of computer science, Faculty of Engineering and IT at the University of Technology Sydney

4. Ms Justine Salisbury (Senior Midwife and Project Officer**)**

Clinical Policy and Engagement, NSW Centre for Population Health, NSW Ministry of Health

Before you decide whether or not you wish to participate in this study, it is important for you to understand why the research is being done and what it will involve. Please take the time to read the following information carefully and discuss it with others if you wish.

WHAT IS THIS RESEARCH ABOUT?

This research will find out about the feasibility, safety and acceptability of using exergaming in promoting regular physical activity for pregnant women.

Exergame or active video game is an emerging technology that incorporates entertainment and lower and/or upper body movement (e.g. walking, jogging and other low impact aerobic exercises) and differs from traditional videogames, which are played from a seated position. It is believed that exergame intervention may be an approach to promote regular physical activity. Exergame is a beneficial tool for encouraging individuals to exercise, because the connection of physical activity with the fun of electronic games makes the exercise motivating and enjoyable. Exercise in pregnancy is good for women and their babies because it lower a risk of a number of complications during pregnancy and birth, including, diabetes, high blood pressure, excessive weight gain, delay during labour, preterm baby, large baby and the need for caesarean section.

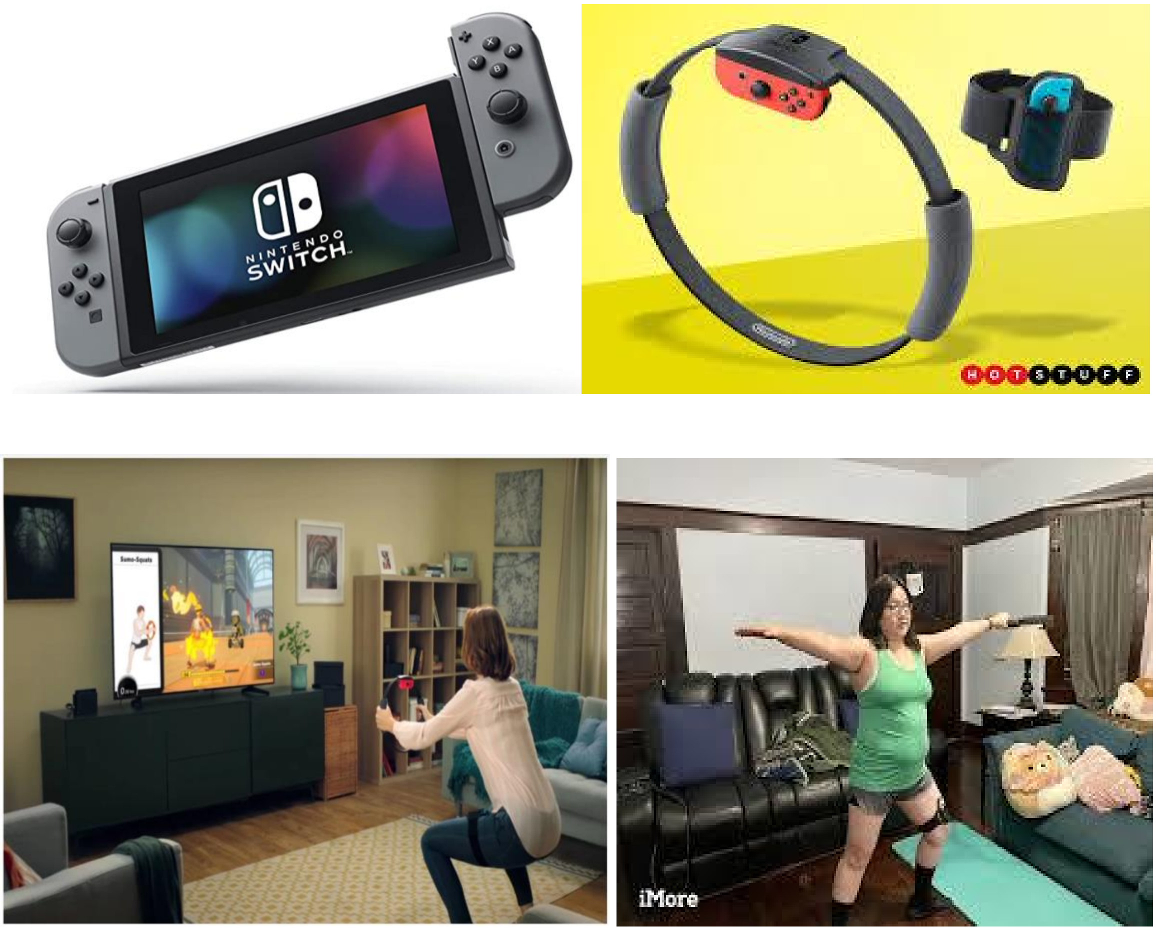


Figure 1: Images of exergame (Nintendo Switch and Fit ring).

The information obtained from this research will be used to design and implement interventions to encourage regular physical activity for pregnant women, and to improve health outcomes of pregnant women and their babies.

FUNDING

Funding for this project has been received from the SPHERE Maternal, Newborn and Women's Health Clinical Academic Group.

WHY HAVE I BEEN ASKED?

You have been invited to participate in this study because you identified yourself as being pregnant. This research project is testing a new 'exergame' intervention for promoting regular physical activity for pregnant women with sedentary/inactive lifestyles. Your participation would be invaluable in contributing to our understanding of the subject matter.

IF I SAY YES, WHAT WILL IT INVOLVE?

If you decide to participate in this study, you will be asked to undergo the following procedures:

❖ You will be assessed/screened for eligibility. This will determine if you are eligible to take part in the research. The screening will involve asking you about your history of number of live births, caesarean section, and existence of hypertension, diabetes mellitus, heart disease, and any medical condition for which participation in physical activity during pregnancy is contraindicated. Completing the screening measures will take approximately 10 minutes. If there are no reasons that make intervention (exergaming) unsuitable for you, you will be asked to participate in this research.

- If you decide to take part in this research, you will be provided with the exergame (Nintendo Switch) and all necessary equipment to keep in your home for the duration of the intervention (20 weeks). You will be provided with an instruction on how to use the exergame equipment, how to connect the exergame equipment to your home TV system, and the duration, frequency and intensity of exergaming.
- At the beginning of the study (16 weeks of pregnancy), and at mid-intervention (24-28 weeks of pregnancy) you will be asked to complete a short questionnaire that describes your level of physical activity. This takes only 15 minutes each time.
- You will attend UTS City Campus (61 Broadway, Ultimo NSW 2007) once a week or once a fortnight for a personalised training session. In the event of COVID-19 restrictions a familiarisation/training sessions will be held by Zoom.
- This study will be conducted over 20 weeks period. The intervention starts at 16 weeks of pregnancy, and ends at 36 weeks of pregnancy. The exergaming training program will begin with two days per week (15-20 min/session) in week 1 and three days per week (20-25 min/session) by week 3. Exergaming duration and frequency will progressively increase throughout the intervention period according to your ability, with the aim of achieving three to four days per week (30-40 min/session) accomplished at the moderate intensity (should be able to maintain a conversation). The duration and intensity of exergaming will progressively decrease again after 6 months of pregnancy. *Each session will include warmup, upper body exercise, lower body exercise, yoga, low impact aerobic exercises, minigames and cool down.
- You will also be interviewed about your views and experiences of intervention (exergaming) at the end of intervention (36 weeks of your pregnancy). This interview can take between 45 minutes and 1 hour. The interview will take place at a time that is

convenient to you. The interview will be audio-recorded with your permission in order for the data to be transcribed.

❖ The research team will follow you throughout the intervention period via phone, email or Zoom.

In addition, the researchers would like to ask you about the contents of your antenatal hand held record (yellow card) and hospital discharge report, to obtain information relevant to the study.

ARE THERE ANY RISKS/INCONVENIENCE?

Clinical guidelines recommend pregnant women without contraindication engage in regular exercise throughout pregnancy. However, certain medical conditions warrant a modification or cessation of exercise due to potential health risks. We will ask that you check with your midwife, obstetricians or GP to ensure that you have no contraindications for participating.

By participating in this research project the likelihood of risk to you and your unborn baby is minimal. The only disadvantage may be post-exercise fatigue and muscle soreness, and you will need to give up some of your time in order to perform exercise (exergaming) prescribed for you, to travel to UTS City Campus once a week or once a fortnight, to fill the questionnaires and to be interviewed. There may also be risks associated with this trial that are presently unknown or unforeseeable.

Exercise is considered to be safe if performed at light to moderate intensity and approved by a health professional. The exergame program has been developed by a team of midwives, exercise physiologists in collaboration with an exergame expert. All the exergame/exercise sessions are aligned with Royal Australian and New Zealand College of Obstetricians and Gynaecologists as safe in pregnancy. However, exercise performed above moderate intensity (vigorous) can pose safety risk, so it is important that exercise is not performed at vigorous intensity. If at any time you feel unwell or any other problems with your pregnancy, cease the intervention (exergaming) and contact your health care provider and research team immediately.

DO I HAVE TO SAY YES?

Participation in this study is voluntary. It is completely up to you whether or not you decide to take part.

WHAT WILL HAPPEN IF I SAY NO?

If you decide not to participate, it will not affect your relationship with the researchers, the University of Technology Sydney, or the treatment/care you receive now or in future at your hospital.

If you wish to withdraw from the study once it has started, you can do so at any time without having to give a reason, by contacting Dr Deborah Fox (Phone: 0295147982 or Email: *deborah.fox@uts.edu.au*) or Mr Gemechu Kumera (Email: *gemechu.kumera@student.uts.edu.au*).

However, it may not be possible to withdraw your data from the study results if these have already had your identifying details removed.

If you decide to leave the research project, we will not collect additional personal information from you, although personal information already collected will be retained to ensure that the results of the research project can be measured properly and to comply with law. You should be aware that data collected up to the time you withdraw will form part of the research project results. If you do not want them to do this, you must tell them before you join the research project.

CONFIDENTIALITY

By signing the consent form you consent to the research team collecting and using personal information about you for the research project. All this information will be treated confidentially. Your information will only be used for the purpose of this research project and it will only be disclosed with your permission, except as required by law.

Any identifiable information that is collected about you in connection with this study will remain confidential. Only the researchers involved in this study will have access to your details and results that will be held securely at the University of Technology Sydney. To maintain confidentiality, all data will be stored securely in a locked office and in a password-protected computer. All audio-recorded data will be destroyed following data analysis. All other data will be also destroyed after the completion of the research. All names and/or locations will be removed and substituted with a code.

It is anticipated that the results of this research project will be published and/or presented in a variety of forums. In any publication and/or presentation, information will be provided in such a way that you cannot be identified, except with your permission. No identifiable details will be included in any research reports.

The results of this research project will be shared more broadly through publication in peer-reviewed journals, presentation at conferences, or other professional forums.

The results of this research project will be communicated to interested participants directly by members of the research team upon completion of the project.

In accordance with relevant Australian and/or NSW privacy and other relevant laws, you have the right to request access to your information collected and stored by the research team. You also have the right to request that any information with which you disagree be corrected or removed.

In accordance with relevant Australian and/or NSW privacy and other relevant laws, you have the right to request access to your information collected and stored by the research team. You can choose not to answer any particular question, and what data to disclose. You will be offered the opportunity to confirm information you provided to us before the process of data analysis. You also have the right to request that any information with which you disagree be corrected or removed.

WHAT IF I HAVE CONCERNS OR A COMPLAINT?

If you have any concerns or queries about the research that you think my supervisor or I can help you with, please feel free to contact us to discuss it with you.

You will be given a copy of this form to keep.

NOTE: This study has been approved in line with the University of Technology Sydney Human Research Ethics Committee [UTS HREC] guidelines. If you have any concerns or complaints about any aspect of the conduct of this research, please contact the Ethics Secretariat on ph.: +61 2 9514 2478 or email: Research.Ethics@uts.edu.au], and quote the UTS HREC reference number. Any matter raised will be treated confidentially, investigated and you will be informed of the outcome.

Thank you for taking the time to consider this study.

If you wish to take part, please sign the attached consent form.

Appendix 10. Consent Form

UTS HREC Approval number: ETH20-5283

1. I ____________________ agree to participate in the research project "Antenatal exercise using an exergame program to improve maternal and birth outcomes" being conducted by Mr Gemechu Kumera, PhD Candidate at UTS:

2. I understand that funding for this research has been provided by the SPHERE Maternal, Newborn and Women's Health Clinical Academic Group.

3. I have read the Participant Information Sheet or someone has read it to me in a language that I understand.

4. I understand the purposes, procedures and risks of the research as described in the Participant Information Sheet.

5. I have had an opportunity to ask questions and I am satisfied with the answers I have received.

6. I freely agree to participate in this research project as described and understand that I am free to withdraw at any time without affecting my relationship with the researchers or the University of Technology Sydney.

7. I agree that research data gathered from the results of the study may be published, provided that I cannot be identified in any way.

8. I agree to be audio recorded.

9. I understand that I will be given a signed copy of this document to keep.

10. I am aware that I can contact Dr Deborah Fox (Email: *deborah.fox@uts.edu.au*) and Mr Gemechu Kumera (Email: *gemechu.kumera@student.uts.edu.au*) if I have any concerns about the research.

____ ____/____/____

Name and Signature [participant] Date

____ ____/____/____

Name and Signature [researcher or delegate] Date

Appendix 11: Interview guide for qualitative study

UTS HREC Approval number: ETH20-5283

1. Thinking about your experience with playing exergame (Nintendo Switch), do you feel the exercise programs are enjoyable?
2. If yes, what did you find most enjoyable about NS exercise programs?
3. Do you think NS exercise programs are encouraging or motivating for pregnant women?
4. Do you feel NS exercise programs are suitable or convenient for you as a pregnant woman?
5. Do you think exercising using NS was beneficial to you? If yes, what benefits did you get? [What benefits PW can get from exercising use games like Nintendo Switch].
6. Is there anything you found challenging or difficult while using NS in terms of using the game or exercise programs?
    1. How did these affect your exergaming experience?
    2. Can you think of any possible solutions to these issues?
7. Do you think Nintendo Switch is easy to use? E.g. setting up the game, connecting to a TV, starting the game, playing the game, etc.
8. Were there any support you would like to receive while using Nintendo Switch? If yes, what are they?
9. Were there any barriers that prevented you from playing Nintendo Switch exercise programs regularly or as we prescribed for you?
10. Do you think Nintendo Switch exercise helped you to improve your fitness or physical activity level?

11. Do you think NS exercise programs could reduce stress and increase happiness and improve mood during pregnancy?
12. Do you think game like Nintendo Switch could help to overcome barriers to physical activity during pregnancy? Such as lack of enjoyment and motivation, lack of time, lack of child care, fatigue and lack of energy, lack of knowledge how to exercise:
13. Thinking about your experiences with playing NS, do you feel they have any impact on your pregnancy?
14. Do you have any feedback or suggestions on improvements or modifications that can be made to the Nintendo Switch exercise programs for pregnant women?
15. Were there any exercises you felt you could not do or would prefer to do differently?
16. Do you continue to use the NS after your baby is born? Why?
17. Which exercises or activities do you think you are most likely going to continue to do?
18. Do you recommend other pregnant women to use NS for exercise or to stay active during pregnancy?
19. Is there anything more you would like to add?

Appendix 12. A flyer for social media recruitment

UTS HREC Approval number: ETH20-5283

Are you in early pregnancy?

Try exergaming (Nintendo Switch) to stay active during pregnancy!

This is an initiative that aims to promote a regular physical activity during pregnancy.

This study involves playing with Nintendo switch 3-4 times per week (30-40 min/session), including once a week or fortnight at UTS at time that is convenient for you.

You will be provided with the exergame (Nintendo Switch) and all necessary equipment to keep in your home for the duration of the study.

You will attend UTS City Campus once a week or once a fortnight for a personalised training session.

Following completion of the study, upon request, you may keep the exergame equipment until birth of the baby.

We are looking for pregnant women with the following characteristics:

- Between 18 and 40 years of age
- Singleton pregnancy of less than 16 weeks of gestation

- ❖ Non-smokers
- ❖ Can provide Doctor or Midwife clearance to engage in physical activity

The study requires 20 weeks of engagement.

If you fulfil the above characteristics and are happy to join the project, please provide your details using the link provided here or simply email us at: Deborah.Fox@uts.edu.au or call us on: 0295147982.

Appendix 13. Emergency Contact Details

UTS HREC Approval number: ETH20-5283

While training/exergaming at UTS city Campus:

1. If any injury or adverse events occur while training/exergaming a member from the research team (research student) will **DIAL UTS SECURITY** on "**9514 1192**" and follow instructions. In the event of an emergency, security personnel will be the first point of contact and they have an up-to-date first aid certificate.

2. Ensure the women involved receives first aid and/or medical treatment.

3. As soon as possible following the event, report an adverse event to the research team.

4. Ensure Covid-19 infection prevention standard precautions:

- All shared equipment and a high-touch surfaces are cleaned and disinfected
- Physical distancing (at least 1.5 m)
- Hand hygiene
- Face mask
- Respiratory hygiene and cough etiquette

While training/exergaming at your home:

1. In the event of an emergency (if serious illness or injury occur) while training/exergaming call **triple zero (000)** for an ambulance and follow instructions or go to the emergency department of your local hospital.

2. As soon as possible following the event, contact your midwife, doctor or hospital.

3. As soon as possible following the event, report adverse event to the research team at Deborah.Fox@uts.edu.au or on **"0295147982"**.

4. If any non-emergency injury/event occurs, as soon as possible following the event, contact your midwife, doctor or hospital and report adverse event to the research team at Deborah.Fox@uts.edu.au or on **"0295147982"**.

If you have any concern during training/exergaming:

1. Nintendo switch is not working,
2. Cannot connect the Nintendo Switch with TV,
3. Adjust game setting/set up Nintendo Switch, or
4. Any technical difficulties

Contact research team at Deborah.Fox@uts.edu.au or on **"0295147982"**.

If you have any concerns or queries about the **training/exergaming** that you think the research team can help you with, please feel free to contact us on (Phone: 0295147982 or Email: *deborah.fox@uts.edu.au*) or Mr Gemechu Kumera (Email: *gemechu.kumera@student.uts.edu.au*).

Appendix 14. Ethics approval letter

From: research.ethics@uts.edu.au

Sent: Tuesday, 09 November 2021, 11:23 AM

To: Research Ethics; Deborah Fox; Gemechu Kumera; Karin Birkner

Subject: HREC Approval Granted - ETH20-5283

Dear Applicant

Re: ETH20-5283 - "Antenatal exercise using an innovative exergame program"

Thank you for your response to the Committee's comments for your project. The Committee agreed that this application now meets the requirements of the National Statement on Ethical Conduct in Human Research (2007) and has been approved on that basis. You are therefore authorised to commence activities as outlined in your application.

You are reminded that this letter constitutes ethics approval only. This research project must also be undertaken in accordance with all UTS policies and guidelines including the Research Management Policy.

Your approval number is **UTS HREC REF NO. ETH20-5283.**

Approval will be for a period of five (5) years from the date of this correspondence subject to the submission of annual progress reports.

The following standard conditions apply to your approval:

- Your approval number must be included in all participant material and advertisements. Any advertisements on Staff Connect without an approval number will be removed.
- The Principal Investigator will immediately report anything that might warrant review of ethical approval of the project to the Ethics Secretariat.
- The Principal Investigator will notify the Committee of any event that requires a modification to the protocol or other project documents, and submit any required

amendments prior to implementation. Instructions on how to submit an amendment application can be found here.

- The Principal Investigator will promptly report adverse events to the Ethics Secretariat. An adverse event is any event (anticipated or otherwise) that has a negative impact on participants, researchers or the reputation of the University. Adverse events can also include privacy breaches, loss of data and damage to property.
- The Principal Investigator will report to the UTS HREC or UTS MREC annually and notify the Committee when the project is completed at all sites. The Principal Investigator will notify the Committee of any plan to extend the duration of the project past the approval period listed above.
- The Principal Investigator will obtain any additional approvals or authorisations as required (e.g. from other ethics committees, collaborating institutions, supporting organisations).
- The Principal Investigator will notify the Committee of his or her inability to continue as Principal Investigator including the name of and contact information for a replacement.

This research must be undertaken in compliance with the Australian Code for the Responsible Conduct of Research and National Statement on Ethical Conduct in Human Research.

You should consider this your official letter of approval. If you require a hardcopy please contact the Ethics Secretariat.

If you have any queries about your ethics approval, or require any amendments to your research in the future, please don't hesitate to contact the Ethics Secretariat and quote the ethics application number (e.g. ETH20-xxxx) in all correspondence.

Yours sincerely,

The Research Ethics Secretariat

On behalf of the UTS Human Research Ethics Committees

C/- Research Office

University of Technology Sydney

E: Research.Ethics@uts.edu.au

Ref: E38

Appendix 15: Evidence of Research Integrity Modules completion

Graduate Research School

Research Integrity for Students

Certificate of Completion

This is to certify that

Gemechu Kumera

has successfully completed

Module 1: Research Integrity and Code of Conduct

Production Note:
Signature removed prior to publication.

Professor Lori Lockyer,
Dean, Graduate Research School

University of Technology Sydney

Date: 27/01/2020

Graduate Research School

Research Integrity for Students

Certificate of Completion

This is to certify that

Gemechu Kumera

has successfully completed

Module 2: Plagiarism and Misconduct
Module 3: Risk Assessment
Module 4: Risk Management and Health & Safety
Module 5: Project Management

Production Note:
Signature removed prior to publication.

Professor Lori Lockyer,
Dean, Graduate Research School

University of Technology Sydney

Date: 28/01/2020

Appendix 16. Details of grant awarded

Maridulu Budyari Gumal | Maternal, Newborn and Women's
Working together for good health and wellbeing | Clinical Academic Group

Dr Deborah Fox
Senior Lecturer in Midwifery
Faculty of Health, UTS
Deborah.Fox@uts.edu.au

Monday 10 August 2020

Project: *Innovative exergame program to increase physical activity for pregnant women with obesity*

Dear Dr Fox,

Thank you for your recent application to the Maternal, Newborn and Women's Clinical Academic Group (MNW CAG) for funds to support your research project, *Innovative exergame program to increase physical activity for pregnant women with obesity*.

We received a significant number of applications for funding projects in 2020–2021. All applications underwent a thorough peer review process that rated projects according to relevance (including alignment with MNW CAG), feasibility, quality, and significance and impact.

On this occasion, we are pleased to advise that the MNW CAG will support your application for funding for the *Innovative exergame program* project to the amount of $13,949, which is 94% of the amount requested. This will be paid at the end of October on receipt of a tax invoice from your organisation, forwarded to Teena.Clerke@uts.edu.au

Please acknowledge the support of the Maternal, Newborn and Women's CAG of Maridulu Budyari Gumal SPHERE in relevant publications and presentations.

Please also email me a brief progress report mid-way through the project, and an outcomes report at project end, as per advised on the application form.

If you would like any clarification or assistance, please do not hesitate to contact me.

Yours sincerely,

Production Note:
Signature removed prior to publication.

Dr Christine Catling
Director of Midwifery Studies,
Centre for Midwifery, Child and Family Health
Faculty of Health
University of Technology Sydney
MNW CAG Leader – SPHERE

MARIDULU BUDYARI GUMAL