



Effectiveness of supporting lifestyle change in pregnant mothers with obesity through the wearable internet-of-things (SLIM) -intervention on self-efficacy in weight management in pregnant women: A quasi-experimental trial

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ABSTRACT

Background: Half of women with overweight gain excessive weight during pregnancy. Perceived self-efficacy plays a significant role in adherence to healthy behaviours, especially in turning points of life, such as a pregnancy.

Objectives: To assess the effectiveness of the Supporting lifestyle change in pregnant mothers with obesity through the wearable internet-of-things (SLIM)-intervention in terms of improving self-efficacy in eating and physical activity and preventing excessive weight gain of pregnant women with overweight. The second aim was to evaluate the fidelity of the intervention implementation.

Methods: Pregnant women with overweight ($N = 54$) attending maternity clinics in Southwest Finland between 2021 and 2023, were recruited using convenience sampling. The SLIM-intervention included: health technology, motivational interviewing, feedback, and goal setting. The intervention was implemented in prenatal visits in maternity clinics continuing to 12 weeks postpartum. The change in self-efficacy was measured with Weight Efficacy Life-Style Questionnaire (score 0–180) and Self-Efficacy for Physical Activity Scale (score 5–25) with repeated measures in three timepoints. Data on weight were collected from patient records.

Results: The levels of self-efficacy were high throughout the study period and there were no significant changes in self-efficacy in eating ($p = 0.650$) or physical activity ($p = 0.936$). Most of the women ($N = 9/10$), whose gestational weight gain was within recommendations or less, managed to lose weight during the postpartum period ($p < 0.001$).

Conclusions: Although the intervention was not effective in improving self-efficacy, the importance of recommended gestational weight gain on better postpartum weight management was highlighted. A long follow-up time was valuable for examination of changes over time and understanding trends, patterns, and outcomes of the study.

Registration: The trial was registered at the Clinicaltrials.gov register platform (ID NCT04826861) on March 17th, 2021.

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Problem: Excessive gestational weight gain is a global health concern and a threat to maternal and child health. Half of women with overweight gain more weight than recommended during pregnancy.

What is already known: Weight management interventions should consider psychosocial determinants of individualized perinatal weight-management.

What this paper adds: Although there was no change in self-efficacy or weight gain in this study, the importance of recommended gestational weight gain on better postpartum weight management was highlighted as well as the need for more support for women with depression symptoms and lower educational level.

Introduction

Obesity and excessive gestational weight gain among pregnant women is widely recognized for its short- and long-term adverse consequences for both mother and child (Goldstein et al., 2017). Recommendations of gestational weight gain for women with overweight (pre-pregnancy BMI ≥ 25) and obesity (BMI ≥ 30) are 7–11 kg and 5–9 kg, respectively (ACOG, 2023; IOM, 2009). Optimal gestational weight gain can reduce the risk of maternal complications as well as adverse birth outcomes and the latent risks on long-term child health outcomes (Goldstein et al., 2017; Zhou and Liu, 2021). However, half of women with overweight exceed the gestational weight gain recommendations (Catalano and Shankar, 2017; Goldstein et al., 2017). In Finland, pregnant women receive free care from public maternity clinics, where women usually visit a public health nurse a total 10–11 times during perinatal period. Public health nurses in maternity clinics provide support and guidance regarding weight, sleep, physical activity and nutrition and for pregnant women (Hakulinen et al., 2023). There is, however, a need to find effective strategies for supporting weight management in maternity care (Walker et al., 2018), identify more closely the problematic areas and find effective implementation strategies in collaboration with health care professionals working in maternity clinics (Grol et al., 2013; Michie et al., 2011).

Most of the weight management interventions for pregnant women with overweight have focused only on physical activity and diet, although we know, that pregnant women with lower self-efficacy are at higher risk of excessive gestational weight gain (Zhou et al., 2022). Weight management among pregnant women includes a strong psychosocial aspect that requires holistic approach and methods. Self-efficacy in both eating and physical activity, are a fundamental psychosocial factors influencing change in behaviour, and essential targets for interventions aimed at improving overall health and of physical activity and dietary intake (Bandura, 1977, 1997; Teixeira et al., 2015). Many studies have found that increases in self-efficacy over the course of an intervention are correlated with greater reductions in weight (Annesi and Powell, 2023; Gallagher et al., 2013). Consequently, there is a need to find methods to support and increase women's self-efficacy and effectiveness of the weight-management interventions during the perinatal period. In addition, the role of maternity care professionals in the implementation of intervention to improve self-efficacy and weight management needs to be emphasized.

The Supporting lifestyle change in pregnant mothers with obesity through the wearable internet-of-things (SLIM)-intervention has been developed in close collaboration with public health nurses working in maternity clinics and pregnant women with overweight, and it focuses on supporting and refining existing prenatal services. The

SLIM intervention offers health data to be utilized in maternity care and it targets to enhance the participants' self-efficacy and to promote their weight management during perinatal period (Saarikko et al., 2023,

2021).

Objectives

The first aim of this study was to assess the effectiveness of the SLIM-intervention in terms of improving self-efficacy in eating and physical activity (primary outcome) and preventing excessive gestational weight gain and postpartum weight retention (secondary outcome) of women with overweight or obesity. The second aim was to evaluate the fidelity of the intervention implementation.

Methods

Study design and settings

This quasi-experimental (pre-post), non-randomized intervention trial was conducted in three public maternity clinics located in five municipalities in the wellbeing services county of Southwest Finland between April 2021 and May 2023. The study protocol for Supporting Lifestyle Change in Pregnant Mothers with Obesity through the Wearable Internet-of-Things (SLIM) -intervention for overweight pregnant women was published previously (Saarikko et al., 2023).

Study intervention

The SLIM intervention was created for pregnant women with overweight or obesity, with a goal to improve their self-efficacy in weight management. The core components of the intervention were *health technology, motivational interviewing, feedback, and goal setting*. Health technology included the smart ring (Oura, 2023), an electronic food diary (FatSecret, 2022) and a SLIM application, in which participants filled out questionnaires at three time points 12 weeks after the birth. Participants were instructed to wear the smart rings continuously starting from gestational week 20 or less and to continue until the postnatal visit 12 weeks after the birth. Participants completed a food diary for one week at three timepoints, 1: at recruitment, 2: gestational week 34 and 3: eight weeks after the birth. Public health nurses utilized the data monitored and collected with the smart ring and the food diary during routine maternity care visits to evaluate physical activity, sleep, and nutrition. Public health nurses gave feedback to the women based on the data, used motivational interviewing focusing on helping individuals to identify and resolve any ambivalence about changing behaviour, and created goals for changes of lifestyle, based on women's individual needs for weight management, in collaboration with women.

Implementation of the intervention

The Grol et al. (2013) five-step implementation-of-change model guided the development process of the intervention, which was conducted in collaboration with pregnant women with overweight and public health nurses working in maternity clinics (Saarikko et al., 2023, 2021). Before the recruitment began, educational meetings were conducted by researcher in each maternity clinic. In addition, educational materials were delivered during the meetings. During the data collection, researchers scheduled workshops with public health nurses every six months. In each maternity clinic, one local opinion leader was selected among the public health nurses to facilitate the implementation and Nurse Directors discussed about the importance of intervention and their determination to have it implemented in regular meetings of maternity clinic staff. The researchers also sent monthly email reminders to public health nurses. Public health nurses ($n = 9$) were recruited in the intervention development phase (Saarikko et al., 2021). However, there was a high turnover within the public health nurses and only three of them were involved throughout the study period.

Study participants

Eligible participants for the current study were pregnant women with overweight, attending maternity clinics as described in the ‘Study design and settings’ section. Women with overweight were recruited at their first prenatal visit using convenience sampling. The inclusion criteria were 1) pregnancy ≤ 15 weeks of gestation, 2) ≥ 18 years of age, 3) overweight or obesity ($BMI \geq 25 \text{ kg/m}^2$) and 4) adequate language skills in Finnish. After a year of recruitment, we decided to recruit pregnant women ≤ 20 weeks of gestation to be able to include also women who wanted to consider their participation. Women, who 1) did not have a mobile device to download applications and synchronize data, 2) had a diagnosis of severe mental illness, 3) were diagnosed diabetes type 1 before pregnancy and/or 4) had mobility limitations, were excluded. Due to different patient record systems, we didn’t have exact numbers of eligible women. Two maternity clinics reported BMI 25 kg/m^2 or more, and three maternity clinics BMI 27 kg/m^2 or more. The flow chart of the participants is shown in Fig. 1.

Sample size

The power analysis was calculated based on two scales, self-efficacy in eating and physical activity. Due to the scarcity of preliminary

information, the calculations were done with one-sided *t*-tests for the difference between two dependent means with an effect size of 0.50, a power level of 0.80 and a significance level of 0.05. A 20 % loss was included in the calculation (Faul et al., 2007). Based on both scales, a sample of 54 overweight pregnant women was needed to detect the difference in changes in eating self-efficacy or self-efficacy in physical activity.

Outcome measures and data collection

In the first prenatal appointment, the public health nurses provided a letter of information and confirmed permission for the researchers to contact the potential participants. The researchers explained the study purpose and procedures to the women in a scheduled appointment and gave a smart ring, and instructions on how to use it and other applications to each participant.

The primary outcomes for the effectiveness of the intervention were self-efficacy in eating and self-efficacy in physical activity which were measured with Weight Efficacy Life-Style Questionnaire (WEL) and Self-Efficacy for Physical Activity Scale (PASE) questionnaires, respectively. WEL consists of 20 items relating to negative emotions, food availability, social pressure, physical discomfort, and positive activities, which are scored on a Likert-type scale from 0 to 9 (0: Not confident, 9: Very

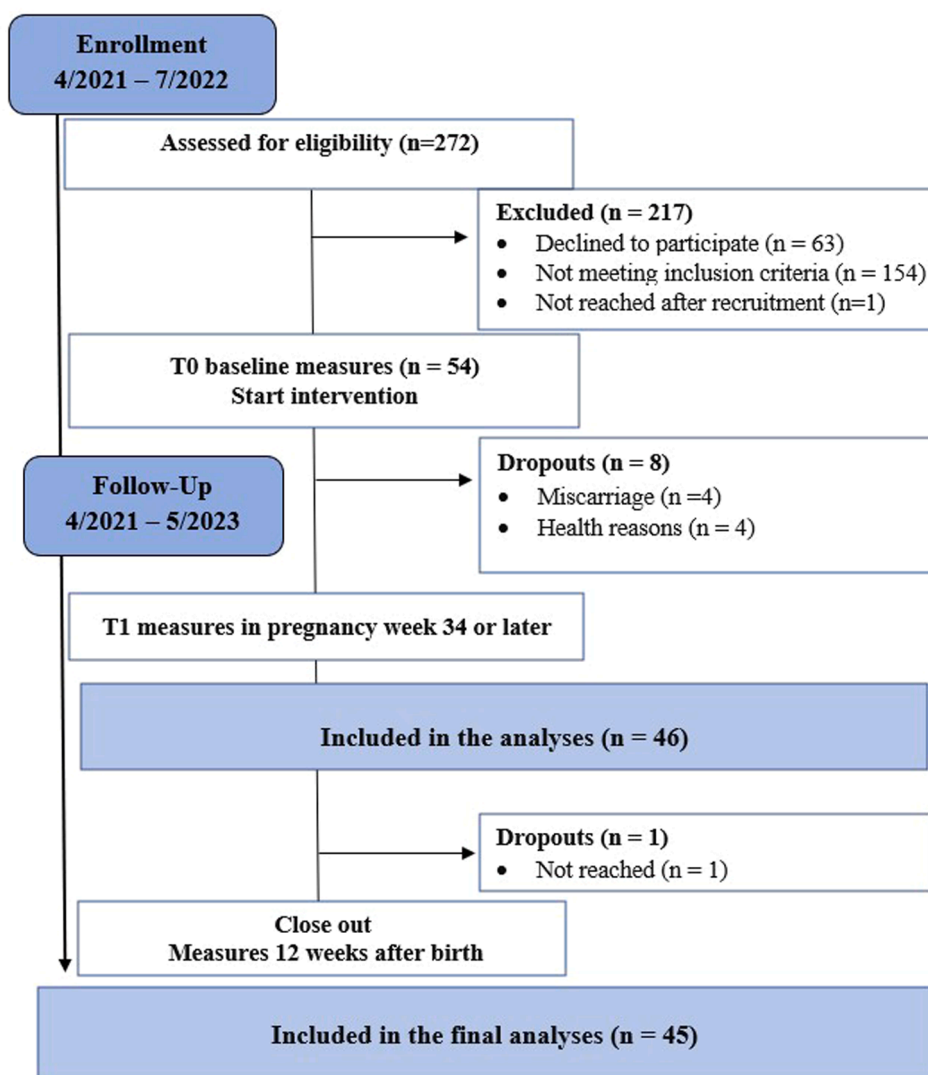


Fig. 1. Flow diagram of the study.

confident). Total scores of WEL range from 0 to 180. The validation studies reported an internal consistency for Cronbach's α ranging from 0.70 to 0.90 in an overweight Caucasian population (Clark et al., 1991). PASE consists of five items on confidence in the ability to exercise. Responses of PASE are measured on a Likert scale ranging from 1 to 5 (1 = not at all confident, 5 = extremely confident). The PASE score is calculated by taking the sum of the 5 items, total score ranging from 5 to 25. The internal consistency for Cronbach's α ranged from 0.70 to 0.78 in a sample of Latino women (Marcus et al., 1992). In both scales, higher score indicated stronger perceived self-efficacy.

A secondary outcome, weight gain during pregnancy, was measured by public health nurses at every prenatal appointment, on average eight times. The women's weight before birth was compared to the national recommendations based on their BMI before pregnancy (IOM, 2009). Postpartum weight retention or lost was assessed by comparing the weight measured in 12 weeks after the birth to pre-pregnancy weight.

Patient records provided the data on pregnancy and birth (pregnancy complications, birth outcomes and newborn data). Well-being data was collected as follows: the smart ring recorded physical activity and sleep parameters, electronic food diary collected the dietary intake, total calories per day, and a validated questionnaire, Edinburgh Postnatal Depression Scale (EPDS) measured the depression symptoms, with a higher score indicating more depression symptoms (0 to 30). The reliability values of the Edinburgh Depression Scale, as indicated by Cronbach's α coefficient, were 0.82, 0.83, and 0.84 for the first, second, and third trimesters, respectively, in an unselected sample of 845 pregnant women. In this study we used a cut-off score 10 for indicating possible depression (Cox et al., 1987).

To assess the fidelity of the intervention, overweight women's daily non-wear time of a smart ring was evaluated. In addition, the days that women filled food diaries were assessed. Public health nurses were also asked to complete a logbook of those contents of the participant's maternity care appointments that are related to the SLIM intervention.

Data analysis

Data concerning physical activity levels were accepted as valid for analyses if the participant wore the smart ring for at least 10 hours per day while awake (McCarthy and Grey, 2015) at least 4 days per week (Khan et al., 2016). Sleep measurements were considered successful if there was non-wear time during the sleep period and at least 4 sleep periods measured per week (Reid et al., 2017). All smart rings non-wear time data were accepted for analysis, but miscarriages were excluded. Data of food diaries were considered valid when the participant documented at least three separate eating occasions at least 3 days per week (Goldstein et al., 2019; Payne et al., 2022).

Given that primary outcomes were collected at three distinct timepoints, it was necessary to average smart rings data. Mean values were calculated for each participant around these specific weeks. For the baseline assessment, mean values during gestational weeks 10–12 were calculated. Pregnancy timepoint T1 was determined by considering the mean values during gestational weeks 33–35. Finally, for postpartum timepoint T2, the mean values during postpartum weeks 10–12 were utilized. Furthermore, to enhance the interpretability of smart ring results, we categorized them using median values as "low" and "high". The filled days of food diaries were categorized in two groups based on the number of days they filled food diaries: 5 days or more and less than 5 days.

Appropriate descriptive statistics were calculated for the background variables, WEL, PASE, weight change, well-being data (EPDS, calories consumed, sleep and PA), smart ring's non-wear time and the days, those women filled food diaries based on their distribution. Normally distributed variables were summarized using means with standard deviations (SD) or 95 % confidence intervals [95 % CI], while skewed distributions were presented with medians and interquartile ranges (IQR).

Due to the longitudinal design with three measurements per participant of WEL, PASE and weight and the expected correlation of measurements within individuals, hierarchical linear mixed effects models for repeated measures were used to evaluate changes over time as well as their associations with well-being data. For ease of interpretation, continuous well-being variables were stratified into two groups based on median values. Models included one within-factor variable (time), one between-factor variable (group/ category defined by median), and their interaction (time \times group). An unstructured covariance structure was utilized for time and Kenward-Roger correction for degrees of freedom was applied. Also, variables like the EPDS, baseline BMI and smart rings wear time were tested for their association with changes in WEL and PASE using hierarchical linear mixed effect models for repeated measures. Using log-binomial models, we evaluated factors associated with meeting weight change recommendations (weight change: within or less than recommended; weight loss: yes or no). All tests were performed as two-sided tests with a significance level set at 0.05 using SAS (Version 9.4) for Windows. The graphs were created in R version 4.2.1, utilizing ggplot2 package.

Ethical approval

The Joint Ethics Committee of the Hospital District of Southwest Finland (113/1801/2020) and the maternity clinics approved the study design. The study was conducted in accordance with the Helsinki Declaration and all participants gave a written informed consent before data collection. The study was registered on the Clinicaltrials.gov website with the registration number (NCT04826861) on March 17th, 2021.

Results

Characteristics of participants

A total of 55 pregnant women with overweight or obesity were enrolled in the study. Only 54 participants were included in the baseline analysis because one participant was lost immediately after recruitment. Refusal rate was at least 53 %. Common reason for refusal was the lack of strength or resources for anything other than necessary. More than 70 % of participants ($n = 39$) entered the study in the first trimester (gestational week 12 or before). A total of four ($n = 4$) participants had a miscarriage during early pregnancy. Four ($n = 4$) participants dropped out during pregnancy because of health reasons (Fig. 1.) Median BMI of participants was 30 (IQR 27, 33). Almost half of the participants went through induction of birth for various reasons, e.g., post term pregnancy, rupture of membranes, suspected macrosomia of the fetus, cholestasis of pregnancy, hypertension, or fear of childbirth. Table 1 presents the background characteristics and perinatal outcomes of the women participating in this study.

Effectiveness of the intervention on self-efficacy in eating and physical activity

The SLIM intervention was not effective in increasing self-efficacy over time ($p = 0.650$). The mean total score of eating self-efficacy at baseline was 125 [115, 135], indicating a good perceived level of self-efficacy. At 34 gestational weeks, the level of eating self-efficacy was even higher (mean 130 [119, 140]) and 12 weeks after birth it decreased back to baseline level (mean 125 [114, 136]). The mean total score of self-efficacy in physical activity at baseline was 15 [14, 16], which also indicated a good perceived level of self-efficacy. The mean score of self-efficacy in physical activity did not change over the time ($p = 0.936$). It was 15 [13, 16] at both 34 gestational week and 12 weeks after birth.

Altogether nine participants with obesity ($n = 9/24$, 38 %) and five ($n = 5/30$, 17 %) with overweight had EPDS score 10 or more at baseline indicating possible depression. These women had statistically significantly lower scores on eating self-efficacy compared to women with no

Table 1
Descriptive statistics for maternal background characteristics and perinatal outcomes.

CHARACTERISTICS	PARTICIPANTS (N = 54)
Age (years), mean (SD)	30 (5)
BMI before pregnancy (kg/m ²), n (%)	
25.0–29.9	24 (44 %)
30.0–34.9	30 (56 %)
Highest educational qualification, n (%)	
Secondary education or below	30 (56 %)
College or university	24 (44 %)
Employment status, n (%)	
Working	49 (91 %)
Unemployed	5 (9 %)
Marital status, n (%)	
Married or living with a partner	53 (98 %)
Single	1 (2 %)
Previous children n (%)	
No	18 (33 %)
1 or more children	36 (67 %)
Planned pregnancy, n (%)	
Yes	48 (89 %)
No	6 (11 %)
Capable of using smart ring at work, n (%)	
Yes	44 (81 %)
No	10 (19 %)
PERINATAL OUTCOMES	PARTICIPANTS (N = 46)
Gestational age at birth (week), median (IQR)	40 (38.8, 40)
Gestational diabetes, n (%)	13 (28 %)
Induced birth, n (%)	21 (46 %)
Length of birth (min), median (IQR)	362 (223.5, 539)
Length of birth stage 2 (min), median (IQR)	10.5 (6, 20.3)
Means of birth, n (%)	
Vaginal	34 (74 %)
Vacuum-assisted	1 (2 %)
Caesarian section	11 (24 %)
Birth weight (g), M [95 % CI]	3690 [3540, 4030]

BMI: body mass index.

IQR: interquartile range.

depression symptoms ($p = 0.009$). Daily intake of calories, median 1880 kcal/day or more was statistically significantly associated with higher self-efficacy in physical activity ($p = 0.003$). Higher educational level was also statistically significantly associated with higher scores in self-efficacy in physical activity ($p = 0.044$). Mean values and change across time of well-being data and smart rings non-wear time are described in Fig. 2.

Reporting the fidelity of the SLIM intervention during perinatal appointments was not possible due to the unavailability of accurate log-books. Smart ring's non-wear time, a marker of intervention fidelity of pregnant or postpartum women, was statistically significantly associated with self-efficacy in physical activity. Participants with non-wear time of smart ring less than 237 minutes/day had 1.5 higher score in self-efficacy in physical activity compared with participants with more than median non-wear time ($p = 0.05$). Non-wear-time of smart ring was not associated with self-efficacy in eating ($p = 0.493$). We also used the number of days when food diaries were filled at each time point as a measure of fidelity, but results were not statistically significant. Table 2 presents the association of self-efficacy in eating and physical activity with background variables, wellbeing data, smart ring wear time and filled days of food diaries.

Effectiveness of the intervention for weight change during perinatal period

The SLIM-intervention was not effective on limiting weight gain during perinatal period. Altogether 17 out of 21 women with overweight (81 %) and 15 out of 25 women with obesity (60 %) gained more weight than recommended during pregnancy ($p = 0.277$). Median gestational weight gain among women with overweight was 12.8 kg [11.6, 19.3] while median of women with obesity was 10.9 kg [5, 13.7] ($p = 0.039$),

both groups exceeding gestational weight gain recommendations. Median weight change during the whole study period (pre-pregnancy weight compared to weight 12 weeks postpartum) was 3.7 kg [−0.4, 7.5] in women with overweight and 0.3 kg [−2.1, 3.0] in women with obesity ($p = 0.033$). Nine out of ten women who gained weight within recommendations or less, managed to lose weight during the postpartum period, while only every fifth of women with excessive gestational weight gain achieved the same result ($N = 6/27$) ($p < 0.001$). Women over 30 years of age were almost eight times likely to achieve optimal gestational weight gain compared to younger women ($p = 0.017$). Other variables were not associated with gestational weight gain within recommendations (Table 3).

Fidelity of the intervention in terms of smart rings non-wear time was not associated with gestational weight gain ($p = 0.844$) or weight change postpartum ($p = 0.954$). In addition, gaining weight within or less than recommended, was not associated with the days that participant filled food diaries during pregnancy ($p = 0.298$) or postpartum ($p = 0.948$).

Discussion

The SLIM intervention was developed in collaboration with target groups and is, to our knowledge, the first study to examine the effect of a lifestyle intervention on the self-efficacy in implementing lifestyle changes and weight changes during the perinatal period among women with overweight or obesity. A long follow-up time allowed the examination of changes over time within the participants. This longitudinal perspective was valuable for understanding trends, patterns, and outcomes of the study. Although we did not see a change in self-efficacy nor weight gain in this study, we were able to highlight the importance of recommended gestational weight gain on better postpartum weight management and the need for more support for women with depression symptoms and lower educational level.

Participant's self-efficacy was at a high level already in baseline as well as throughout the study period compared to previous studies of participants with overweight and obesity (De Jersey et al., 2017; Nezami et al., 2016; Oikarinen et al., 2023). Therefore, without a control group, the effects of the intervention are difficult to prove. One previous study reported a significant decrease in self-efficacy during pregnancy (Yu et al., 2023), so it is possible that with usual care, self-efficacy would have decreased during pregnancy in this study participants as well. Self-efficacy in eating and physical activity were not associated with weight change on the contrary to previous studies with overweight adults (Nezami et al., 2016) or overweight women aged 20–60 years (Oikarinen et al., 2023). However, these studies did not include pregnant participants. Although pregnancy is a motivating period to undertake positive lifestyle changes, pregnant women usually have difficulties in perceiving the immediate benefits of behaviour changes during a relatively short-term intervention (Saarikko et al., 2021). Pregnant women with overweight or obesity might face additional anxiety or concerns about their health or the health of their unborn child. Emotional factors could hinder their ability to commit to behaviour changes. This was evident in the low levels of self-efficacy among women with depression symptoms also in our study (Christenson et al., 2019a; Lagadec et al., 2018). Social norms and low education levels can also influence a pregnant woman's behaviour, such as lower physical activity levels among women with lower education. These patient groups should receive more precise care.

Although the intervention was not effective on limiting excessive gestational weight gain, it is notable that most of the women who gained weight within recommendation or less managed to lose weight below the initial weight before pregnancy. Interestingly, women over 30 years old were more likely to achieve optimal gestational weight gain compared to younger women. Previous meta-analysis found similar results (OR 1.14; 95 % CI, 1.10–1.19) (Zhou et al., 2022), although opposite results have also been reported (Dolatian et al., 2020; Ebrahimi

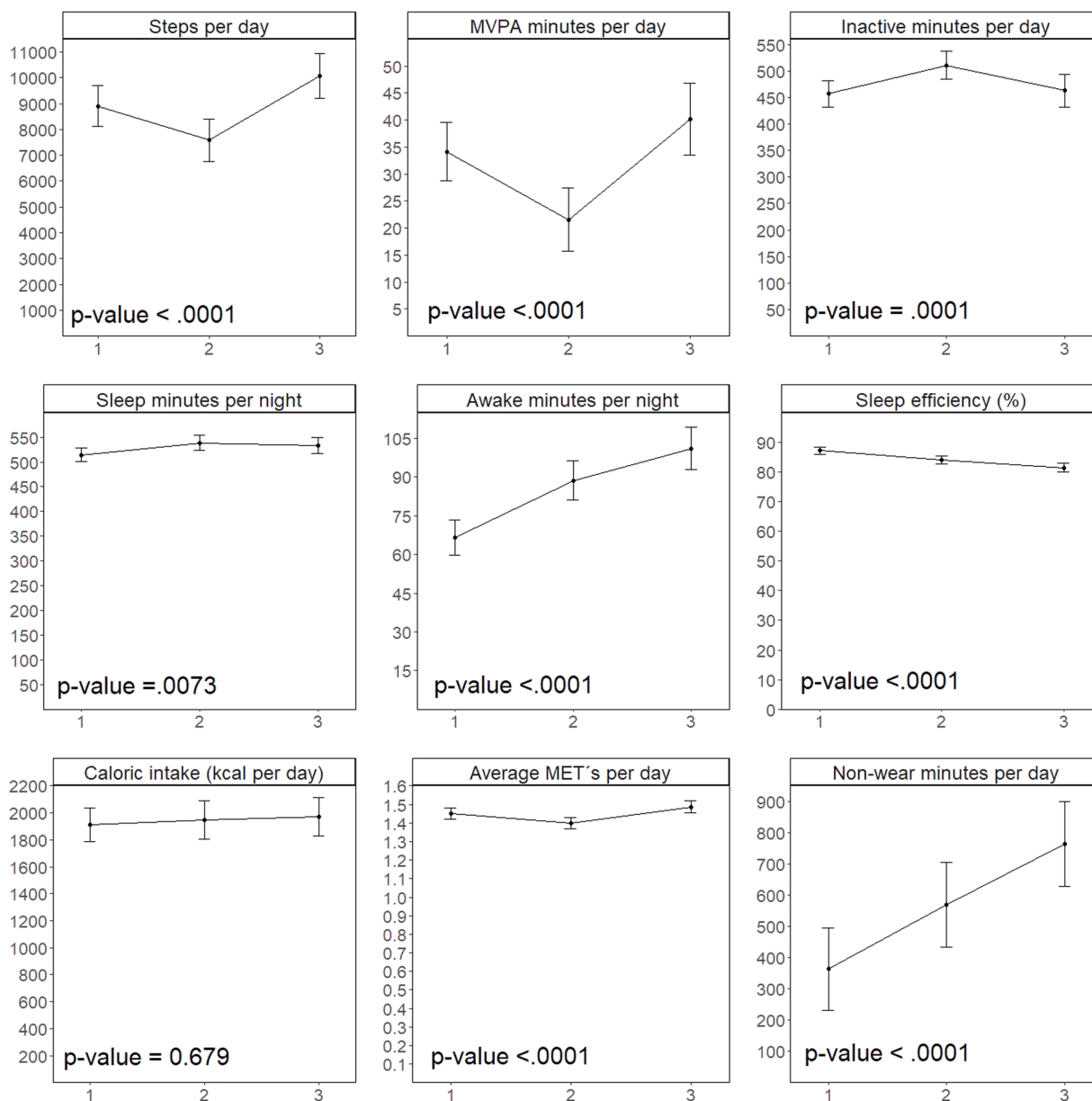


Fig. 2. Mean values of well-being data and smart rings non-wear time across the three timepoints.

et al., 2015). Older women might have a poorer anabolic response to pregnancy than younger women. Another possibility is that older women could be more disciplined regarding lifestyle choices (Restall et al., 2014). According to a meta-analysis, excessive gestational weight gain can lead to higher risk of postpartum weight retention and long-term weight imbalance (Mannan et al., 2013; Rong et al., 2015). This highlights the need for individualized information about weight management during pregnancy, which requires adequate information from maternity care professionals (Lavender and Smith, 2016; Saarikko et al., 2020). Although this intervention was developed in collaboration with target groups to address these potential challenges, we can assume that intervention did not address these individual differences adequately or consider the unique needs and concerns of all pregnant women with overweight.

Public health nurses working in maternity clinics have only a limited time for each perinatal visit, which means they need to prioritize various aspects, and they might take precedence over additional weight management interventions. Implementing comprehensive weight management interventions requires time for counselling, education, and

support, which can be challenging within the constraints of prenatal care appointments (McCann et al., 2018). This deficit might have hindered successful implementation of our intervention. Support from the management and providing adequate resources is a vital prerequisite to integrate weight management seamlessly into normal prenatal care and to create a supportive and non-judgmental environment for pregnant women with overweight or obesity (McCann et al., 2018). Systemic approach with more effective training for public health nurses working in maternity clinics is required to make effective use of the intervention to the individualized guidance of perinatal women with overweight or obesity.

Strengths and limitations

The SLIM intervention was conducted in real-life settings, on maternity clinic appointments. Therefore, the intervention did not cause extra burden to the participants, and the intervention was easier to integrate as a part of the maternity care. Intervention included assessment of a range of parameters to establish the associations to the

Table 2
Factors associated with self-efficacy in eating and physical activity in a Univariate Approach examined in the baseline sample.

Variable	WEL			PASE		
	Mean	[95 % CI]	<i>p</i>	Mean	[95 % CI]	<i>p</i>
Data collection point			0.650			0.936
Baseline T0 (n = 54)	125.1	[115.0, 135.3]		14.9	[13.7, 16.1]	
Pregnancy T1 (n = 46)	129.6	[118.8, 140.5]		14.7	[13.3, 16.0]	
Postpartum T2 (n = 45)	124.8	[114.1, 135.6]		14.8	[13.5, 16.1]	
BMI			0.288			0.565
Overweight (n = 24)	131.74	[118.8, 144.6]		15.1	[13.5, 16.7]	
Obese (n = 30)	122.65	[111.5, 133.8]		14.5	[13.1, 15.9]	
Age			0.677			0.840
Under 30 (n = 25)	128.3	[116.2, 140.4]		14.9	[13.4, 16.4]	
30 or more (n = 29)	124.8	[112.9, 136.7]		14.7	[13.2, 16.2]	
Education			0.275			0.044
Secondary education or below (n = 30)	122.6	[111.5, 133.6]		13.9	[12.5, 15.2]	
College or university (n = 24)	131.9	[119.0, 144.8]		16	[14.4, 17.6]	
EPDS			0.009			0.111
No depression (n = 38)	132.2	[123.5, 140.9]		15.3	[14.2, 16.4]	
Possible depression (n = 14)	114.4	[101.9, 127.0]		14	[12.4, 15.5]	
Previous children			0.986			0.278
No (n = 18)	126.6	[112.2, 141.1]		14	[12.2, 15.8]	
one or more (n = 36)	126.5	[116.0, 137.0]		15.2	[13.9, 16.5]	
Employment status			0.098			0.77
Working (n = 49)	124.4	[115.7, 133.1]		14.8	[13.7, 15.9]	
Unemployed (n = 5)	149.1	[121.0, 177.5]		14.3	[10.8, 17.8]	
Planned pregnancy			0.876			0.821
Yes (n = 48)	125.8	[116.6, 135.0]		14.7	[13.6, 15.9]	
No (n = 6)	127.9	[102.6, 153.2]		15.1	[11.9, 18.3]	
Kcal, median 1880			0.304			0.003
low (n = 24)	125.4	[114.8, 136.1]		13.7	[12.4, 14.9]	
high (n = 23)	131.1	[120.5, 141.6]		16.1	[14.9, 17.3]	
Steps per day (median 8674)			0.987			0.451
low (n = 24)	124.7	[112.6, 136.8]		14.2	[12.7, 15.7]	
high (n = 25)	124.8	[112.4, 137.2]		14.9	[13.4, 16.5]	
Rest minutes per day (median 521)			0.343			0.563
low (n = 25)	121.3	[109.5, 133.0]		14.8	[13.4, 16.3]	
high (n = 24)	128.1	[116.5, 139.7]		14.3	[12.9, 15.8]	
Inactive minutes per day (median 471)			0.551			0.269

Table 2 (continued)

Variable	WEL			PASE		
	Mean	[95 % CI]	<i>p</i>	Mean	[95 % CI]	<i>p</i>
low (n = 25)	127.2	[115.0, 139.4]		15.1	[13.6, 16.6]	
high (n = 24)	122.7	[111.1, 134.4]		14.1	[12.7, 15.5]	
MVPA minutes per day (median 29) (n = 49)			0.759			0.704
low (n = 25)	125.8	[114.2, 137.5]		14.4	[13.0, 15.9]	
high (n = 24)	123.4	[111.0, 135.9]		14.8	[13.2, 16.3]	
Sleep efficiency minutes per night (median 88)			0.578			0.705
low (n = 24)	126.2	[116.0, 136.4]		14.4	[13.1, 15.7]	
high (n = 25)	130.5	[116.0, 145.0]		14.8	[12.9, 16.7]	
Sleep duration minutes per night (median 511)			0.671			0.723
low (n = 25)	129	[116.9, 115.8]		14.7	[13.1, 16.3]	
high (n = 24)	126.3	[115.9, 136.7]		14.4	[13.1, 15.7]	
Sleep duration Less than 7.5 h (n = 3)	141.7	[101.6, 181.8]	0.465	13.3	[8.2, 18.3]	0.614
7.5 h or more (n = 46)	126.4	[117.0, 136.2]		14.6	[13.4, 15.8]	
Awake minutes per night (median 66)			0.546			0.646
low (n = 24)	130.5	[116.6, 144.3]		14.8	[13.0, 16.6]	
high (n = 25)	126.1	[116.0, 136.2]		14.4	[13.1, 15.6]	
Non-wear minutes per day (median 237)			0.493			0.05
low (n = 25)	128.5	[116.9, 140.1]		15.5	[14.1, 16.9]	
high (n = 25)	124	[113.8, 134.2]		14	[12.7, 15.2]	
Food diary (filled at least 5 days)			0.153			0.931
Yes (n = 42)	129	[119.3, 138.8]		14.6	[13.4, 15.8]	
No (n = 12)	118.4	[104.8, 132.0]		14.6	[12.9, 16.2]	

T0: at recruitment, T1: at 34 gestational weeks and T2:12 weeks after the birth.
WEL: Weight Efficacy Life-Style Questionnaire.
PASE: Self-Efficacy for Physical Activity Scale.
BMI: body mass index.
MVPA: moderate to vigorous physical activity.
EPDS: Edinburgh Postnatal Depression Scale.

intervention outcomes. One strength was fidelity in terms of smart ring non-wear time and filled days of the food diaries, which indicated quite consistently that women participating this study were committed to the intervention. Although there was no improvement in self-efficacy or any effect on gestational weight gain, this study was able to assess important factors influencing perinatal weight management.

However, this research also has some limitations. One was the quasi-experimental study design. The participants were not randomized, so there is a risk of selection bias and a higher likelihood that other

Table 3
Factors associated with weight change according to recommendations during perinatal period.

Variable	WEIGHT CHANGE DURING PREGNANCY: Within or less than recommended ^a			POST PARTUM WEIGHT CHANGE: Weight lost		
	Odds ratio	[95 % CI]	<i>p</i>	Odds ratio	[95 % CI]	<i>p</i>
Weight change						
Obese vs. Overweight	2.833	[0.637, 12.6]	0.171	0.829	[0.210, 3.270]	0.786
Age						
30 or more vs. Under 30	7.875	[1.455, 42.609]	0.017	0.127	[0.023, 0.687]	0.017
Education						
College or university vs. Secondary education or below	0.776	[0.189, 3.174]	0.724	0.776	[0.189, 3.174]	0.724
Previous children						
No vs. One or more	0.577	[0.129, 2.584]	0.472	0.577	[0.129, 2.584]	0.472
EPDS						
No depression vs. Possible depression	0.556	[0.099, 3.123]	0.500	0.578	[0.116, 2.889]	0.450
Kcal						
Low vs. high	0.75	[0.15, 3.74]	0.723	0.829	[0.210, 3.270]	0.786
Steps per day (median 8674)						
Low vs. high	2.387	[0.450, 12.228]	0.301	0.781	[0.492, 9.680]	0.299
Rest minutes per day (median 521)						
Low vs. high	1.575	[0.315, 7.882]	0.575	0.739	[0.189, 2.885]	0.659
Inactive minutes per day (median 471)						
Low vs. high	0.576	[0.108, 3.082]	0.513	0.951	[0.233, 3.877]	0.943
MVPA minutes per day (median 29)						
Low vs. high	1.927	[0.371, 10.011]	0.429	2.300	[0.552, 9.570]	0.249
Sleep efficiency minutes per night (median 88)						
Low vs. high	1.032	[0.182, 5.860]	0.972	0.879	[0.203, 3.818]	0.862
Sleep duration minutes per night (median 511)						
Low vs. high	1.064	[0.205, 5.532]	0.940	1.475	[0.370, 5.880]	0.577
Awake minutes per night (median 66)						
Low vs. high	0.715	[0.125, 4.075]	0.701	1.114	[0.262, 4.749]	0.882
Non-wear minutes per day (median 237)						
Low vs. high	0.855	[0.176, 4.146]	0.844	1.042	[0.259, 4.205]	0.954
Food diary (min 5 days filled)						
Yes vs. No	0.41	[0.08, 2.25]	0.298	0.949	[0.196, 4.60]	0.948

^a BMI 25–29.9 kg/m², recommended weight gain during pregnancy: 7–11 kg, BMI ≥30 kg/m², recommended weight gain during pregnancy: 5–9 kg.

WEL: Weight Efficacy Life-Style Questionnaire.

PASE: Self-Efficacy for Physical Activity Scale.

BMI: body mass index.

MVPA: moderate to vigorous physical activity.

EPDS: Edinburgh Postnatal Depression Scale.

variables besides the intervention could have influenced the results. Moreover, we did not have a control group, so we are not able to report, how self-efficacy would have changed during the perinatal period without the intervention. We also had a high refusal rate, with the most common reason being the lack of strength and resources. Factors influencing participation, led us assume that the women, with challenges in their lives, and who would likely have benefited most of the intervention, were also the ones who opted out of the study. This may have biased the study outcomes. In addition, educational meetings every six months may have been inadequate for implementing an intervention in a consistent and effective manner. High turnover within staff may have also influenced the level of knowledge and confidence among public health nurses. We can assume that there was a high variation between individual public health nurses, how they utilized the intervention during perinatal appointments, which may have influenced our results. Finally, the whole data collection period of this study was overshadowed by the pandemic and subsequent organizational changes, which certainly affected the resources of the public health nurses.

Conclusions

This study was the first to assess the possibilities of influencing women’s self-efficacy during pregnancy through a lifestyle intervention. Supporting optimal gestational weight gain is beneficial because it also decreases the postpartum weight retention. This non-randomized pre-post study serves as a starting point for generating hypotheses or exploring potential relationships in the future studies. Based on this quasi-experimental trial, there is a need for a randomized controlled trial to test the efficacy of SLIM intervention, refined with even closer collaboration with perinatal women. By providing efficient, individualized support for weight management during pregnancy at the local level, we have a possibility to influence the well-being of not only the mothers but also their children.

Ethical approval

The study was approved by the Joint Ethics Committee of the Hospital District of Southwest Finland (113/1801/2020) on January 19th, 2021.

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CRediT authorship contribution statement

Johanna Saarikko: Writing – original draft, Visualization, Resources, Methodology, Investigation, Formal analysis, Conceptualization. **Anna Axelin:** Writing – review & editing, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization. **Emilia Huvinen:** Writing – review & editing, Conceptualization. **Amir M. Rahmani:** Writing – review & editing, Software, Funding acquisition, Data curation. **Terhi Kolari:** Writing – review & editing, Formal analysis, Data curation. **Hannakaisa Niela-Vilén:** Writing – review & editing, Supervision, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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