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ORIGINAL ARTICLE

Evaluation of a smartphone nutrition and physical activity application to provide lifestyle advice to pregnant women: The SNAPP randomised trial

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Abstract

Our objective was to evaluate the impact of a smartphone application as an adjunct to face-to-face consultations in facilitating dietary and physical activity change among pregnant women. This multicentre, nested randomised trial involved pregnant women with a body mass index ≥18.5 kg/m^2, with a singleton pregnancy between 10 and 20 weeks' gestation, and participating in 2 pregnancy nutrition-based randomised trials across metropolitan Adelaide, South Australia. All women participating in the SNAPP trial received a comprehensive dietary, physical activity, and behavioural intervention, as part of the GRoW or OPTIMISE randomised trials. Women were subsequently randomised to either the "Lifestyle Advice Only Group," where women received the above intervention, or the "Lifestyle Advice plus Smartphone Application Group," where women were additionally provided access to the smartphone application. The primary outcome was healthy eating index (HEI) assessed by maternal food frequency questionnaire completed at trial entry, and 28 and 36 weeks' gestation. Analyses were performed using intention-to-treat principles, with statistical significance at $p = .05$. One hundred sixty-two women participated: 77 allocated to the Lifestyle Advice plus Smartphone Application Group and 85 to the Lifestyle Advice Only Group. Mean difference in HEI score at 28 weeks of pregnancy was 0.01 (CI [−2.29, 2.62]) and at 36 weeks of pregnancy −1.16 (CI [−4.60, 2.28]). There was no significant additional benefit from the provision of the smartphone application in improving HEI score ($p = .452$). Although all women improved dietary quality across pregnancy, use of the smartphone application was poor. Our findings do not support addition of the smartphone application.

KEYWORDS

diet and physical activity intervention studies, dietary strategies, maternal obesity, nutrition education, pregnancy and nutrition, randomised controlled trial

1 | INTRODUCTION

Approximately 2 million people, or 40% of the world's population, are overweight or obese (World Health Organization [WHO], 2015), representing a significant global health problem. Furthermore, almost 50% of women in developed nations enter pregnancy with a body mass index (BMI) above 25.0 kg/m^2 (Chu, Kim, & Bish, 2009; Scheil, Scott, Catcheside, Sage, & Kennare, 2015). Even for women of normal BMI, pregnancy often represents a significant turning point in their health trajectory, with physiologic changes during pregnancy promoting weight gain (Mannan, Doi, & Mamun, 2013), placing them at risk of subsequent obesity (Gunderson & Abrams, 2000; Schmitt, Nicholson, & Schmitt, 2007). In view of this, the WHO has highlighted the importance

Clinical Trial Registration: GRoW Randomised Trial Registration: Australian and New Zealand Clinical Trials Registry ACTRN12612001277831OPTIMISE Randomised Trial Registration: Australian and New Zealand Clinical Trials Registry ACTRN 12614000583640

of prevention of weight gain, particularly among women of reproductive age (WHO, 2008).

Population-based cohort studies accessing data from more than 240,000 pregnant women have highlighted the effects gestational weight gain during pregnancy on pregnancy and birth outcomes (Cedergren, 2006). Regardless of maternal BMI on entering pregnancy, weight gain above 16 kg was associated with an increased risk of developing pre-eclampsia, of requiring either a caesarean section or instrumental vaginal birth, or giving birth to an infant with weight above 4.0 kg (Cedergren, 2006). Conversely, weight gain of less than 8 kg, again regardless of maternal BMI on entering pregnancy, was associated with a reduction in risk of pre-eclampsia and high infant birthweight, although it appeared to be at the expense of an increase in the chance of birth of an infant small for gestational age (Cedergren, 2006).

These findings led to a number of pregnancy intervention trials to limit gestational weight gain, which have been summarised by Thangaratinam and colleagues in a comprehensive systematic review (Thangaratinam et al., 2012). Provision of an antenatal intervention was associated with a modest reduction in gestational weight gain (n = 6,543, 1.42 kg; 95% CI [0.95–1.89 kg]), although the effect on pregnancy and birth outcomes was less certain (Thangaratinam et al., 2012). Furthermore, provision of a maternal dietary and lifestyle intervention has also been associated with improvements in maternal dietary intake and physical activity patterns (Dodd, Cramp, et al., 2014; Guelinckx, Devlieger, Mullie, & Vansant, 2010; Poston et al., 2015; Poston et al., 2013; Rae et al., 2000; Wolff, Legarth, Vangsgaard, Toubro, & Astrup, 2008), although these studies have largely been conducted in women who are overweight or obese.

Smartphone applications have been used as adjunct tools to standard clinical consultations to promote weight loss in nonpregnant adults, facilitate individual access to resources, and increase engagement and as a strategy to overcome some barriers associated with traditional face-to-face health care interactions (Okorodudu, Bosworth, & Corsino, 2014). Smartphone applications have been used to provide information regarding pregnancy care (Kaewkungwal et al., 2010), and although pregnant women use these tools to seek health-related advice, evaluation of both content and efficacy is limited (Hearn, Miller, & Lester, 2014). Several small pilot studies have investigated smartphone applications as a tool to prevent excessive gestational weight gain or to promote weight loss after birth (Herring, Cruice, Bennett, Davey, & Foster, 2014; Knight-Agarwal et al., 2015; Pollak et al., 2014; Soltani et al., 2015; Willcox et al., 2017), although robust evaluation of their impact on relevant clinical pregnancy and nutritional outcomes is limited by both their small sample size and poor reporting of outcomes indicative of behavioural change, including modification of dietary and physical activity patterns.

Further rigorous methodological evaluation of smartphone applications is required before their widespread introduction as an adjunct tool to support dietary and physical activity change and weight management during pregnancy. Our objective was to conduct a nested randomised trial to evaluate the impact of a smartphone application as an adjunct to standard face-to-face consultations in facilitating dietary and physical activity change among pregnant women with BMI ≥ 18.5 kg/m^2.

Key messages

- Smartphone applications are becoming increasingly popular in the health care setting as a supplementary source of information.
- Smartphone applications have been used to provide pregnancy-related information, and although pregnant women use these tools to seek health-related advice, evaluation of both content and efficacy is limited.
- Although well received by women, providing access to a smartphone application provided no additional benefit over and above face-to-face consultation and printed materials in improving dietary and physical activity patterns.

2 | METHODS

We conducted a nested randomised trial, in the context of two currently recruiting pregnancy nutrition-based randomised trials, GRoW (Trial Registration Australian and New Zealand Clinical Trials Registry ACTRN12612001277831) and OPTIMISE (Trial Registration Australian and New Zealand Clinical Trials Registry ACTRN 12614000583640). These trials recruited women at 10 to 20 weeks' gestation, from public maternity hospitals across metropolitan Adelaide, South Australia. In brief, the GRoW randomised trial is recruiting pregnant women with BMI ≥ 25 kg/m^2 to evaluate the effects of metformin use during pregnancy, as an adjuvant therapy to a dietary and lifestyle intervention on pregnancy and birth outcomes (Dodd et al., 2016). The OPTIMISE randomised trial is recruiting pregnant women with BMI = 18.5–24.9 kg/m^2 to evaluate the effects of an antenatal dietary and lifestyle intervention on pregnancy and birth outcomes.

2.1 | Inclusion and exclusion criteria

Women who participated in the GRoW trial and women who participated in the intervention arm of the OPTIMISE trials received the comprehensive dietary and lifestyle intervention over the course of pregnancy and were therefore eligible for participation in the nested SNAPP randomised trial. The SNAPP trial was evaluating the use of a smartphone application as an adjunct to standard face-to-face consultations and standard written materials (as utilised previously; Dodd, Turnbull, et al., 2014) to facilitate dietary and physical activity change (Figure S1). Women participating in the OPTIMISE trial had a healthy BMI (≥18.5–24.9 kg/m^2), whereas women participating in the GRoW trial were overweight or obese (BMI ≥ 25.0 kg/m^2).

Women with a multiple pregnancy and a diagnosis of diabetes or who did not own a smartphone were ineligible to participate in the SNAPP randomised trial.

2.2 | Randomisation

At the time of a woman's first antenatal appointment, her height and weight were measured, BMI was calculated, and written informed

consent was provided to participate in the GRoW or OPTIMISE trials. Women from both trials who were randomised to the comprehensive dietary and lifestyle intervention over the course of pregnancy were then provided with additional written information relating to participation in SNAPP. At this point, women were then additionally randomised in the SNAPP nested trial to either the "Lifestyle Advice Only Group" or to the "Lifestyle Advice plus Smartphone Application Group" using the central computer randomisation service. The randomisation schedule was computer generated, with balanced variable blocks, and stratification for BMI category, maternal parity, and centre of recruitment.

2.3 | Treatment schedules

Women who were randomised to the Lifestyle Advice Only Group received a comprehensive lifestyle intervention involving a combination of dietary, physical activity, and behavioural strategies, as have been described and utilised previously (Dodd, 2014; Dodd et al., 2016). Over the course of pregnancy, women attended two face-to-face sessions (within 2 weeks of trial entry and 28 weeks' gestation) with a dietitian and a face-to-face session at 36 weeks' gestation with a research assistant were provided with specific written materials. In addition, each woman received three telephone calls with the research assistant at 22, 24, and 32 weeks' gestation to reinforce both the written information and the information provided in the face-to-face sessions.

The dietary advice provided was consistent with current Australian standards (Australian Guide to Healthy Eating, n.d.), to maintain a balance of carbohydrates, fat, and protein, and to reduce intake of foods high in refined carbohydrates and saturated fats, while increasing intake of fibre and promoting consumption of two servings of fruit, five servings of vegetables, and three servings of dairy each day (Australian Guide to Healthy Eating, n.d.). Exercise advice primarily encouraged women to increase the amount of walking and incidental activity (for example, taking the stairs rather than the elevator; Royal College of Obstetricians and Gynaecologists, 2006). Tailoring of the intervention was informed by stage theories of health decision-making (Bennett & Murphy, 1997). Women were encouraged to set achievable goals for dietary and physical activity change and to self-monitor their progress, to identify potential barriers in the implementation of their dietary and physical activity goals, to use these perceived barriers to solve problems, and to develop individualised strategies to facilitate their successful implementation.

Women who were randomised to the Lifestyle Advice plus Smartphone Application Group received the same comprehensive lifestyle intervention involving a combination of dietary, physical activity, and behavioural strategies as outlined above. In addition, women received access to a specifically developed interactive smartphone application to reinforce the key information presented in both the face-to-face sessions and telephone calls. The application was designed by the researchers and Good Dog Designs (a local web development company) and was web based and accessible on all smartphones and tablets. A web-based application was chosen, as opposed to "native" applications (e.g., *iOS* or Android specific) as it allowed for easier data transfer and was more cost-effective (Hebden, Cook, van der Ploeg, & Allman-Farinelli, 2012). The application was designed to be a simple intuitive application, requiring little instruction. The information provided in the application was based on the Australian dietary guidelines (Australian Guide to Healthy Eating, n.d.) and physical activity guidelines for pregnancy (Royal College of Obstetricians and Gynaecologists, 2006). The application was designed to encourage women to set dietary and physical activity goals and monitor their progress (Okorodudu et al., 2014; Pagoto, Schneider, Jojic, DeBiasse, & Mann, 2014). At their first study appointment, women received a link to the smartphone application and information on how to create a login. They received reminders and encouragement to use the smartphone application at all study appointments and contacts with research staff. Examples of the application interface are presented in Supporting Information.

Following development, the smartphone application was pilot tested with 10 research staff for usability, after which modifications were made to improve ease of use. We then piloted the application on the first 20 women enrolled in the trial who were asked to rate the usability of the application to determine if there were any issues with the operation of the application, after using it for 2 weeks. Feedback indicated the application was easy to use on all mobile devices, and further modification was not required.

2.4 | Study outcomes

The primary outcome of the SNAPP trial was change in healthy eating index (HEI) over the course of pregnancy. Using information derived from the food frequency questionnaire obtained at 28 and 36 weeks' gestation, we used the 2005 HEI as an index of diet quality (Guenther, Reedy, & Krebs-Smith, 2008), consisting of 12 components, with a maximum score of 100. Total fruit (including 100% juice), whole fruits (excluding juice), total vegetables, dark green and orange vegetables, vegetables and legumes (legumes included as a vegetable only after the Meat and Beans standard was met), total grains, and wholegrains categories are each scored out of five. Milk (all products made from cow's milk, goat's milk, and soy beverages but excluding products that are primarily fat such as butter, cream, sour cream, and cream cheese), meat and beans (meat products, eggs, nuts, seeds, soy-based products, and legumes), oils (fats that are liquid at room temperature, from a plant source and not described as "hydrogenated" or "shortening" including oils from plant, fish, nuts and seeds, or margarines), saturated fat, and sodium are each scored out of 10. Calories derived from solid fats (all excess fat from the milk, meat, and beans components beyond that would be consumed if only the lowest fat forms were eaten, solid fats added to foods in preparation or at the table including cream, butter, stick margarine, regular or low-fat cream cheese, lard, meat drippings, cocoa, and chocolate), alcoholic beverages, and added sugars (SoFAAS) are scored out of 20. Scores for saturated fat, sodium, and calories derived from solid fats, alcohol, and added sugars are reverse scored, where a higher score indicates lower consumption. An HEI above 80 is considered good, between 50 and 80 needs improvement, and below 50 poor. The HEI has been validated for use in a pregnant population (Pick, Edwards, Moreau, & Ryan, 2005).

Secondary outcomes included maternal dietary intake of macronutrients and number of servings of each food group, assessed by completion of the Harvard Semi-quantitative Food Frequency

questionnaire (The Willett Questionnaire) at 28 and 36 weeks' gestation. The Willett Questionnaire was developed in 1985 in the United States to measure the daily intake of nutrients from 126 food items, with an indication of standard portion size, divided into seven food groups (Willett, Reynolds, Cottrell-Hoehner, Sampson, & Browne, 1987), and has been validated for use during pregnancy (Fawzi, Rifas-Shiman, Rich-Edwards, Willett, & Gillman, 2004) and in an Australian setting (Ibiebele et al., 2009; Rumbold et al., 2006).

Maternal physical activity was assessed by completion of the Short Questionnaire to Assess Health-enhancing physical activity (SQUASH; Wendel-Vos, Schuit, Saris, & Kromhout, 2003), at 28 and 36 weeks' gestation. The 11-item questionnaire evaluates the time spent in different categories of physical activity, including commuting, leisure, household and incidental, and work-related activities. Each activity was assigned an estimate of intensity in metabolic equivalent task units (METs; Ainsworth et al., 2011). As the SQUASH reports physical activity during an average week, MET minutes per week was calculated as duration (in minutes) × frequency (days per week) × MET intensity.

Evaluation of the smartphone application was completed by women randomised to the Lifestyle Advice plus Smartphone Application Group via self-completed questionnaire at 36 weeks' gestation. Specific questions included whether the application was easy to understand, whether women considered it useful, and whether the information assisted in making healthier food choices and more time to exercise. For each of the 12 questions, there were five alternate answers on a Likert scale (*strongly agree*, *agree*, *undecided*, *disagree*, or *strongly disagree*).

2.5 | Sample size

On the basis of our previous work in a similar population of pregnant women, we estimated a mean (SD) HEI score of 72.1 (±7.1) following the provision of a similar face-to-face lifestyle intervention (Dodd, Cramp, et al., 2014). To detect a difference in mean HEI score between treatment groups of 3.5 points (power 80%; $\alpha = .05$), and allowing for 85% return rate of valid questionnaires, we required a sample size of 162 women. Previous trials have found significant associations between diet quality and health complications with differences in HEI score as small as 2 points (Mangou et al., 2012); we have chosen 3.5 points as more clinically meaningful difference and more likely to influence practice.

2.6 | Statistical analyses

Analyses were performed on an intention-to-treat basis, according to the treatment group allocated at randomisation (Lifestyle Advice Only or Lifestyle Advice plus Smartphone Application). Analysis was on raw data only without imputation for missing data. Women were included in the analysis if they returned one or more valid questionnaires. Dietary questionnaires were considered invalid if over 25% of responses were missing or if total energy intake was unrealistic (<4,500 or >20,000 kJ; Meltzer, Brantsaeter, Ydersbond, Alexander, & Haugen, 2008). Physical activity questionnaires were considered invalid if the total hours of activity reported exceeded the number of hours in a week (Dodd, Cramp, et al., 2014; Dodd, Turnbull, et al., 2014).

To examine the effect of the smartphone application over time, analyses used linear regression models with a generalised estimating equation to account for repeated measures, and a time by treatment interaction term. Results are presented as mean (and standard deviation), with estimates of effect reported as differences in means with 95% confidence intervals, and derived separately at each time point. Models included adjustment for centre, parity, and BMI category.

Responses to the questionnaire assessing women's opinions on the smartphone application were assessed descriptively, using frequencies and percentages. All analyses were performed using SAS v9.3 (Cary, NC, USA).

2.7 | Ethics approval

Ethics approval was granted by the Women's and Children's Local Health Network Human Research and Ethics Committee at the Women's and Children's Hospital, the Central Northern Adelaide Health Service Ethics of Human Research Committee (Lyell McEwin Hospital), and the Flinders Clinical Research Ethics Committee (Flinders Medical Centre). All women provided written informed consent to participate.

3 | RESULTS

A total of 162 women participated in the SNAPP nested randomised trial, with 77 women allocated to the Lifestyle Advice plus Smartphone Application Group and 85 women to the Lifestyle Advice Only Group. At least one valid dietary and physical activity questionnaire was received from 76 women in the Lifestyle Advice plus Smartphone Application Group and 85 women in the Lifestyle Advice Only Group (Figure 1). At the time of trial entry, maternal characteristics were

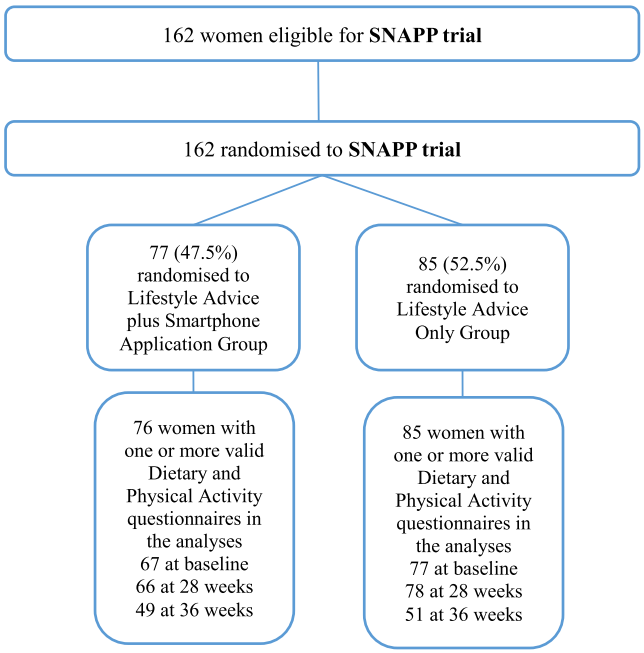

FIGURE 1 Flow of participants through the SNAPP trial

similar between the two treatment groups (Table 1). Approximately 43% of women were of normal BMI, 19% were overweight, and 38% were obese. Approximately 9% of women were smokers, and 44% were in their first ongoing pregnancy. Almost 50% of women were from the two highest quintiles of social disadvantage, and 73% identified themselves as of Caucasian background.

3.1 | Healthy eating index

At trial entry, the HEI score and its components were similar between the two treatment groups. The addition of the smartphone application was not associated with any statistically significant differences in HEI score, compared with the provision of lifestyle advice alone, at any time point across pregnancy (Table 2). All women participating in the trial demonstrated improvements in their consumption of milk and wholegrains, and a reduction in their consumption of sodium over the course of pregnancy, although there were no statistically significant differences between the two treatment groups.

3.2 | Macronutrient and food group intake

At trial entry, macronutrient and food group intake were similar between the two treatment groups. The addition of the smartphone application was not associated with any statistically significant differences in macronutrient or food group intake, compared with the provision of lifestyle advice alone, at any time point across pregnancy (Table S1). Women participating in the trial demonstrated increased consumption of the number of servings of dairy per day and decreased consumption of noncore food groups over the course of pregnancy, although there were no statistically significant differences between the two treatment groups.

3.3 | Physical activity

Overall, baseline physical activity patterns were similar between the two treatment groups. Although women in the Lifestyle Advice plus Smartphone Application Group reported higher leisure activity at trial entry, this did not persist over the course of pregnancy (Table 3). There were no statistically significant differences between the treatment groups with regard the nature of the physical activity engaged in, and all women reduced their total activity and work-related activity over the course of pregnancy.

3.4 | Evaluation of the smartphone application

A total of 24 women (31.2%) reported using the smartphone application during their pregnancy (Table 4). Of those women who did not use the smartphone application, reasons included that they forgot (28.3%), they did not feel that they needed the additional information (9.4%), or that they were too busy (7.6%). Only two women (3.7%) indicated that they did not use the application due to problems in accessing or navigation. Although the overall response rate was poor, of those women who responded, approximately 50% liked the smartphone application and found the information provided useful, particularly in relation to portion size, food groups and recipe suggestions, as well as the opportunity to set dietary and exercise goals. Women indicated that use of the smartphone application assisted them to make healthier food choices and time to exercise.

TABLE 1 Baseline characteristics at trial entry

Characteristic	Lifestyle Advice plus Smartphone Application Group *n* = 77	Lifestyle Advice Only Group *n* = 85	Overall *n* = 162
Maternal age: Mean (SD)	30.87 (5.07)	31.01 (6.16)	30.94 (5.65)
Gestational age: Mean (SD)	16.78 (2.07)	16.51 (2.07)	16.63 (2.07)
BMI category: *N* (%)			
BMI = 18.0 to 24.9 kg/m^2	33 (42.86)	36 (42.35)	69 (42.59)
BMI = 25.0 to 29.9 kg/m^2	17 (22.08)	14 (16.47)	31 (19.14)
BMI = 30.0 to 34.9 kg/m^2	16 (20.78)	16 (18.82)	32 (19.75)
BMI = 35.0 to 39.9 kg/m^2	6 (7.79)	10 (11.76)	16 (9.88)
BMI ≥ 40.0 kg/m^2	5 (6.49)	9 (10.59)	14 (8.64)
Caucasian ethnicity: *N* (%)	56 (72.73)	62 (72.94)	118 (72.84)
Smoker: *N* (%)	7 (9.09)	8 (9.41)	15 (9.26)
Nulliparous: *N* (%)	33 (42.86)	39 (45.88)	72 (44.44)
SEIFA IRSD quintile[a]: *N* (%)			
Quintile 1 (most disadvantaged)	20 (25.97)	20 (23.53)	40 (24.69)
Quintile 2	17 (22.08)	21 (24.71)	38 (23.46)
Quintile 3	13 (16.88)	16 (18.82)	29 (17.90)
Quintile 4	17 (22.08)	16 (18.82)	33 (20.37)
Quintile 5 (least disadvantaged)	10 (12.99)	12 (14.12)	22 (13.58)

Note. Data are presented as mean ± SD for continuous data, and *n* and percentage for categorical data. BMI = body mass index; IRSD = Index of Relative Socio-Economic Disadvantage; SEIFA = Socio-economic Indexes for Areas.

[a]Index of socio-economic disadvantage as measured by SEIFA.

TABLE 2 Maternal dietary healthy eating index

Outcome	Lifestyle Advice plus Smartphone Application Group	Lifestyle Advice Only Group	Estimated effect of smartphone application (95% CI)	*p* value
HEI				0.452[a]
Trial entry	66.94 (9.44)	67.82 (8.86)	−1.77 [−4.57, 1.03]	0.214
28 weeks	68.73 (8.29)	68.01 (8.86)	0.01 [−2.59, 2.62]	0.992
36 weeks	67.69 (9.24)	68.51 (10.21)	−1.16 [−4.60, 2.28]	0.509
Total fruit score				0.616[a]
Trial entry	4.65 (0.83)	4.50 (1.15)	0.10 [−0.22, 0.41]	0.548
28 weeks	4.68 (0.79)	4.56 (0.96)	0.03 [−0.24, 0.30]	0.846
36 weeks	4.59 (1.03)	4.62 (0.96)	−0.08 [−0.45, 0.28]	0.645
Whole fruit score				0.040[a]
Trial entry	4.88 (0.59)	4.65 (0.91)	0.21 [−0.03, 0.46]	0.089
28 weeks	4.87 (0.68)	4.87 (0.65)	−0.05 [−0.28, 0.17]	0.635
36 weeks	4.71 (0.98)	4.80 (0.79)	−0.12 [−0.45, 0.20]	0.457
Total vegetable score				0.962[a]
Trial entry	4.84 (0.51)	4.78 (0.59)	0.05 [−0.12, 0.22]	0.595
28 weeks	4.91 (0.37)	4.86 (0.49)	0.03 [−0.11, 0.17]	0.673
36 weeks	4.85 (0.49)	4.77 (0.68)	0.05 [−0.16, 0.26]	0.645
Dark green/orange veg score				0.524[a]
Trial entry	4.57 (0.99)	4.34 (1.14)	0.14 [−0.19, 0.47]	0.409
28 weeks	4.69 (0.82)	4.49 (1.09)	0.12 [−0.17, 0.42]	0.414
36 weeks	4.56 (0.98)	4.51 (1.11)	−0.06 [−0.43, 0.31]	0.760
Total grains score				0.299[a]
Trial entry	2.96 (1.09)	3.12 (1.15)	−0.24 [−0.59, 0.12]	0.190
28 weeks	3.16 (1.09)	3.13 (1.18)	0.03 [−0.32, 0.39]	0.847
36 weeks	3.03 (0.99)	3.15 (0.97)	−0.17 [−0.53, 0.20]	0.372
Wholegrains score				0.454[a]
Trial entry	1.39 (1.24)	1.24 (1.22)	0.07 [−0.30, 0.44]	0.706
28 weeks	1.51 (1.28)	1.54 (1.35)	−0.03 [−0.43, 0.37]	0.878
36 weeks	1.44 (1.21)	1.67 (1.36)	−0.23 [−0.67, 0.21]	0.300
Total milk score				0.168[a]
Trial entry	6.57 (2.92)	6.30 (2.99)	0.34 [−0.59, 1.27]	0.474
28 weeks	7.51 (2.43)	7.66 (2.42)	−0.22 [−1.00, 0.55]	0.569
36 weeks	7.52 (2.49)	8.26 (2.02)	−0.58 [−1.43, 0.27]	0.182
Meat and beans score				0.493[a]
Trial entry	9.82 (0.80)	9.81 (0.73)	−0.02 [−0.28, 0.23]	0.874
28 weeks	9.93 (0.45)	9.77 (0.67)	0.11 [−0.09, 0.31]	0.279
36 weeks	9.74 (0.85)	9.73 (0.93)	−0.04 [−0.37, 0.29]	0.819
Total oils score				0.325[a]
Trial entry	3.67 (3.03)	4.04 (3.32)	−0.47 [−1.46, 0.51]	0.346
28 weeks	3.44 (3.01)	3.60 (3.13)	0.05 [−0.94, 1.04]	0.919
36 weeks	3.53 (2.97)	3.49 (3.48)	0.24 [−0.86, 1.35]	0.668
Total saturated fat score				0.804[a]
Trial entry	3.97 (3.28)	4.56 (2.95)	−0.83 [−1.82, 0.17]	0.104
28 weeks	3.65 (3.01)	3.94 (3.11)	−0.48 [−1.45, 0.49]	0.335
36 weeks	3.37 (2.72)	3.83 (3.24)	−0.54 [−1.61, 0.54]	0.326
Total sodium score				0.146[a]
Trial entry	8.01 (1.41)	8.36 (1.40)	−0.41 [−0.82, 0.01]	0.054
28 weeks	8.51 (1.09)	8.40 (1.40)	−0.03 [−0.43, 0.38]	0.891
36 weeks	8.59 (1.13)	8.48 (1.17)	0.02 [−0.37, 0.42]	0.902
Total SoFAAS score				0.321[a]
Trial entry	11.61 (5.55)	12.11 (5.83)	−0.73 [−2.51, 1.05]	0.419

(Continues)

TABLE 2 (Continued)

Outcome	Lifestyle Advice plus Smartphone Application Group	Lifestyle Advice Only Group	Estimated effect of smartphone application (95% CI)	*p* value
28 weeks	11.88 (5.14)	11.18 (5.90)	0.54 [1.15, 2.23]	0.533
36 weeks	11.75 (5.82)	11.20 (5.29)	0.38 [−1.63, 2.40]	0.709

Note. Results are presented as mean and standard deviation; estimates of effect are differences in means, with 95% confidence intervals. Models included adjustment for centre, parity and body mass index category. HEI = Healthy Eating Index; SoFAAS = calories from saturated fats, alcohol and added sugar.

[a]*p* values are for test of time by treatment interaction.

TABLE 3 Maternal physical activity

Outcome	Lifestyle Advice plus Smartphone Application Group	Lifestyle Advice Only Group	Estimated effect of smartphone application (95% CI)	*p* value
Commuting				0.158[a]
Trial entry	98.55 (178.67)	89.37 (260.64)	5.48 [−63.99, 74.96]	0.877
28 weeks	76.83 (152.67)	110.37 (342.39)	−40.77 [−126.04, 44.51]	0.349
36 weeks	66.83 (125.86)	133.23 (361.53)	−81.96 [−180.92, 17.00]	0.105
Leisure				0.154[a]
Trial entry	1480.26 (1590.64)	917.51 (1090.16)	517.49 [91.56, 943.41]	0.017
28 weeks	1030.29 (947.31)	879.02 (1071.42)	96.34 [−224.20, 416.87]	0.556
36 weeks	940.98 (880.56)	760.40 (1021.09)	155.33 [−207.33, 518.00]	0.401
Housework				0.578[a]
Trial entry	3709.11 (3955.37)	3505.87 (3857.23)	13.21 [−1083.19, 1109.60]	0.981
28 weeks	2890.46 (3080.78)	3242.52 (3643.54)	−528.09 [−1482.95, 426.76]	0.278
36 weeks	2849.60 (2901.83)	3147.62 (3317.30)	−233.11 [−1231.08, 764.86]	0.647
Work				0.681[a]
Trial entry	4723.75 (3041.92)	4343.88 (3348.65)	733.67 [−144.81, 1612.16]	0.102
28 weeks	4484.89 (3306.10)	3757.48 (3379.39)	783.01 [−136.90, 1702.92]	0.095
36 weeks	3609.34 (3405.45)	2252.91 (2764.43)	1191.17 [65.70, 2316.65]	0.038
Total METs				0.382[a]
Trial entry	10011.68 (4303.88)	8856.64 (4108.97)	1233.91 [−111.66, 2579.49]	0.072
28 weeks	8517.06 (4088.03)	7989.38 (4305.85)	336.04 [−956.72, 1628.79]	0.610
36 weeks	7452.67 (4230.63)	6294.16 (3978.80)	1018.02 [−503.98, 2540.02]	0.190

Note. Results are presented as mean and standard deviation measured in MET minutes per week; estimates of effect are differences in means, with 95% confidence intervals. Models included adjustment for centre, parity, and body mass index category. MET = metabolic equivalent task.

[a]*p* values are for test of time by treatment interaction.

TABLE 4 Evaluation of the smartphone application

Question	Strongly agree	Agree	Undecided	Disagree	Strongly disagree	No response
Liked smartphone application	3 (12.50)	9 (37.50)	1 (4.17)	0 (0.00)	0 (0.00)	11 (45.83)
Overall easy to follow and understand	5 (20.83)	8 (33.33)	1 (4.17)	0 (0.00)	0 (0.00)	10 (41.67)
Information on food groups easy to follow	4 (16.67)	9 (37.50)	1 (4.17)	0 (0.00)	0 (0.00)	10 (41.67)
Information on safe exercise easy to follow	4 (16.67)	10 (41.67)	0 (0.00)	0 (0.00)	0 (0.00)	10 (41.67)
Information on portions easy to follow	4 (16.67)	9 (37.50)	1 (4.17)	0 (0.00)	0 (0.00)	10 (41.67)
Practical suggestions in app were useful	5 (20.83)	8 (33.33)	1 (4.17)	0 (0.00)	0 (0.00)	10 (41.67)
Recipe suggestions were useful	5 (20.83)	7 (29.17)	2 (8.33)	0 (0.00)	0 (0.00)	10 (41.67)
Overall found app useful	4 (16.67)	7 (29.17)	3 (12.50)	0 (0.00)	0 (0.00)	10 (41.67)
Helped me make healthier food choices	2 (8.33)	6 (25.00)	5 (20.83)	1 (4.17)	0 (0.00)	10 (41.67)
Helped me make time to exercise	2 (8.33)	6 (25.00)	5 (20.83)	1 (4.17)	0 (0.00)	10 (41.67)
Setting dietary goals helped	3 (12.50)	10 (41.67)	1 (4.17)	0 (0.00)	0 (0.00)	10 (41.67)
Setting exercise goals helped	3 (12.50)	10 (41.67)	1 (4.17)	0 (0.00)	0 (0.00)	10 (41.67)

4 | DISCUSSION

The findings of our nested randomised trial indicate that the addition of a smartphone application as an adjunct to a comprehensive lifestyle intervention comprising face-to-face and telephone contact with dietitians and research assistants, in addition to provision of written information, was not associated with significant improvements in maternal dietary intake or physical activity patterns. Although the smartphone application was favourably evaluated, overall uptake and utilisation during pregnancy was poor.

Our nested randomised trial utilised robust methodology and, to our knowledge, is the first to evaluate the use of a smartphone application as an adjunct tool to a comprehensive lifestyle intervention during pregnancy, and the first to evaluate the impact on maternal dietary intake and physical activity. Limitations include our reliance on self-completed questionnaires, which may have introduced an element of recall bias, although this would be expected to be operating in a similar direction and magnitude across treatment groups. Although more detailed 24-hr dietary recall methods and use of an accelerometer may have provided more accurate assessments of dietary intake and physical activity, it was not considered feasible in this research context. A further limitation is the low response rate of women in the evaluation of the smartphone application, with potential introduction of non-responder bias, where women who responded may have viewed the application in a more positive manner, than those women who did not complete the evaluation questionnaire.

Willcox and colleagues report the feasibility of a comprehensive mHealth intervention during pregnancy, although not directly comparable with our trial, compared with provision of healthy diet and exercise brochures involving a total of 91 women. A combination of programme-generated information and maternal self-report supported the feasibility of the intervention, which was also found to be associated with improvements in gestational weight gain. Although women reported a smaller reduction in physical activity during pregnancy following access to the intervention, there were no reported differences in maternal dietary intake (Willcox et al., 2017). The PEARS randomised trial is evaluating the impact of an mHealth lifestyle package as compared with usual care among pregnant women who are overweight or obese on gestational diabetes (Kennelly et al., 2016). The findings of this trial will further add to the available literature evaluating the role of mHealth interventions during pregnancy.

There has been considerable interest in the use of smartphone applications for the delivery of dietary and lifestyle interventions to facilitate weight loss in nonpregnant individuals, with a number of systematic reviews conducted (DiFilippo, Huang, Andrade, & Chapman-Novakofski, 2015; Hutchesson et al., 2015; Stephens & Allen, 2013). Some studies assessing smartphone applications have been associated with improved knowledge about nutrition (DiFilippo et al., 2015), including an effect on weight loss and increased physical activity (Stephens & Allen, 2013). A more comprehensive systematic review and meta-analysis by Hutchesson et al. (2015) evaluated a broader range of electronic health care interventions, including internet, computer, mobile, and smartphone technologies to promote weight loss. The addition of any one of these modalities to standard face-to-face counselling was not associated with any additional clinical benefit in terms of weight loss (Hutchesson et al., 2015). Although such interventions have been evaluated favourably (Stephens & Allen, 2013), current evidence would suggest little additional benefit over standard counselling sessions.

We report a low uptake and use of the smartphone application, being used by only 31.2% of eligible women, despite the provision of reminders at all study appointments and contacts with research staff, a finding consistent with other reports in the limited pregnancy literature (Hearn et al., 2014; van Zutphen, Milder, & Bemelmans, 2008). Following focus group consultation, the Western Australian Government developed a healthy lifestyle website and smartphone application for pregnancy, which was subsequently promoted through antenatal clinics, hospitals, and general practitioners (Hearn et al., 2014). Uptake of the smartphone application was very low with only 7% of pregnant women accessing this information (Hearn et al., 2014). In a Dutch study, similar low rates (17%) of use have been reported for an online lifestyle intervention in pregnancy, even following the advice and recommendation of their midwife (van Zutphen et al., 2008). Importantly, the women who accessed this online intervention were more highly educated and had a healthier lifestyle, when compared with the general pregnant population (van Zutphen et al., 2008), highlighting the difficulty in engaging women who may derive most benefit such an intervention. Furthermore, in both of these studies, the information provided in the smartphone application was provided as a stand-alone intervention (Hearn et al., 2014; van Zutphen et al., 2008).

Further research is required to determine the optimal method of engaging pregnant women in healthy lifestyle interventions, particularly those delivered by mobile and smartphone technologies. The mean gestational age of recruitment to the SNAPP trial was 16 weeks. This may be too late, with evidence that women are accessing information about pregnancy on smartphone applications and the internet prior to attendance for their first antenatal appointment (Kraschnewski et al., 2014; Rodger et al., 2013). Women report accessing and comparing information across multiple websites and applications, and of tiring of applications quickly (Rodger et al., 2013). Similar themes have been identified in a study in young adults (Dennison, Morrison, & Conway, 2013). Although participants indicated an interest in improving health, they were not committed to using any one particular application, often downloading and comparing several related applications (Dennison et al., 2013).

Our smartphone application included a combination of information provision, goal setting, feedback, and self-monitoring. More recent studies are investigating the use of momentary or context sensing, and gaming to increase uptake of interventions (Dicianno, Parmanto, & Fairman, 2015). Momentary sensing involves the collection of data in real time from the smartphone and may include information such as movement, location, and mood (Dennison et al., 2013; Dicianno et al., 2015). This information can then be used to provide responses that are appropriate to the context without needing the user to input any information, for example, providing feedback and encouragement when activity is sensed and goals are met (Dennison et al., 2013). Gaming

involves the use of popular strategies to maintain interest and engagement with the application and may include virtual points or rewards, and individual or team challenges with other users (Dicianno et al., 2015). Incorporation of momentary sensing or gaming strategies may potentially increase usage and uptake of future smartphone applications among pregnant women.

5 | CONCLUSION

To our knowledge, the SNAPP randomised trial is the first to evaluate effect of the addition of a smartphone application to support an antenatal lifestyle intervention among pregnant women, with an assessment of dietary and physical activity outcomes. Our findings do not support the use of a smartphone application over and above a comprehensive intervention comprising face-to-face and telephone contacts with research staff. Future research should further explore ways of improving engagement with and uptake of healthy lifestyle messages during pregnancy and may include the further use of evolving technologies.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

CONTRIBUTIONS

JMD, JL, CC prepared the initial draft of the manuscript; JMD had full access to all of the study data and takes responsibility for the integrity of the data, and the accuracy of the data analysis. JMD, JL were responsible for conducting the statistical analyses. JMD, JL, ARD were responsible for revision of the manuscript. All authors, CC, J MD, RMG, LJM, ARD, JL, were involved in the study concept and design of the trial, supervision of conduct of the trial, the acquisition of data, the analysis and interpretation of data, and critical revision of the manuscript for important intellectual content and provided approval of the final submitted version.

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REFERENCES

Ainsworth, B. E., Haskell, W. L., Herrmann, S. D., Meckes, N., Bassett, D. R. J., Tudor-Locke, C., … Leon, A. S. (2011). 2011 Compendium of Physical Activities: a second update of codes and MET values. *Medicine and Science in Sports and Exercise*, *43*(8), 1575–1581.

Australian Guide to Healthy Eating. from http://www.health.gov.au/internet/main/publishing.nsf/content/health-pubhlth-publicat-document-fdcons-cnt.htm

Bennett, P., & Murphy, S. (1997). *Psychology and health promotion*. Buckingham: Open University Press.

Cedergren, M. I. (2006). Effects of gestational weight gain and body mass index on obstetric outcomes in Sweden. *International Journal of Gynecology & Obstetrics*, *93*, 269–274.

Chu, S. Y., Kim, S. Y., & Bish, C. L. (2009). Prepregnancy obesity prevalence in the United States, 2004–2005. *Maternal Child Health J*, *13*(5), 614–620.

Dennison, L., Morrison, L., & Conway, G. (2013). Opportunities and challenges for smartphone applications in supporting health behavior change: Qualitative study. *Journal of Medical Internet Research*, *15*(4), e86.

Dicianno, B. E., Parmanto, B., & Fairman, A. D. (2015). Perspectives on the evolution of mobile (mHealth) technologies and application to rehabilitation. *Physical Therapy*, *95*(3), 397–405.

DiFilippo, K. N., Huang, W. H., Andrade, J. E., & Chapman-Novakofski, K. M. (2015). The use of mobile apps to improve nutrition outcomes: A systematic literature review. *Journal of Telemedicine and Telecare*, *21*(5), 243–253.

Dodd, J. M. (2014). Optimising gestational weight gain and improving maternal and infant health outcomes through antenatal dietary, lifestyle and exercise advice: The OPTIMISE randomised trial. ACTRN12614000583640 (https://www.anzctr.org.au/Trial/Registration/TrialReview.aspx?id=366222&isReview=true).

Dodd, J. M., Cramp, C. S., Sui, Z., Yelland, L. N., Deussen, A. R., Grivell, R. M., … LIMIT Randomised Trial group. (2014). Effects of antenatal lifestyle advice for women who are overweight or obese on maternal diet and physical activity: The LIMIT randomised trial. *BMC Medicine*, *12*, 161. http://www.biomedcentral.com/1741-7015/12/161

Dodd, J. M., Grivell, R. M., Deussen, A. R., Dekker, G., Louise, J., & Hague, W. (2016). Metformin and dietary advice to improve insulin sensitivity and promote gestational restriction of weight among pregnant women who are overweight or obese: The GRoW Randomised Trial. *BMC Pregnancy and Childbirth*, *16*(1), 359.

Dodd, J. M., Turnbull, D., McPhee, A. J., Deussen, A. R., Grivell, R. M., Yelland, L. N., … Robinson, J. S. (2014). Antenatal lifestyle advice for women who are overweight or obese: LIMIT randomised trial. *BMJ*, *348*, g1285.

Fawzi, W. W., Rifas-Shiman, S. L., Rich-Edwards, J. W., Willett, W. C., & Gillman, M. W. (2004). Calibration of a semi-quantitative food frequency questionnaire in early pregnancy. *Annals of Epidemiology*, *14*, 754–762.

Guelinckx, I., Devlieger, R., Mullie, P., & Vansant, G. (2010). Effect of a lifestyle intervention on dietary habits, physical activity, and gestational

weight gain in obese pregnant women: A randomized controlled trial. *The American Journal of Clinical Nutrition*, *91*, 373–380.

Guenther, P. M., Reedy, J., & Krebs-Smith, S. M. (2008). Development of the Healthy Eating Index—2005. *Journal of the American Dietetic Association*, *108*, 1896–1901.

Gunderson, E. P., & Abrams, B. (2000). Epidemiology of gestational weight gain and body weight changes after pregnancy. *Epidemiologic Reviews*, *22*(2), 261–274.

Hearn, L., Miller, M., & Lester, L. (2014). Reaching perinatal women online: The Healthy You, Healthy Baby website and app. *Journal of Obesity*, *2014*, 573928. https://doi.org/10.1155/2014/573928

Hebden, L., Cook, A., van der Ploeg, H. P., & Allman-Farinelli, M. (2012). Development of smartphone applications for nutrition and physical activity behavior change. *JMIR Res Protoc*, *1*(2), e9.

Herring, S. J., Cruice, J. F., Bennett, G. G., Davey, A., & Foster, G. D. (2014). Using technology to promote postpartum weight loss in urban, low-income mothers: A pilot randomized controlled trial. *Journal of Nutrition Education and Behavior*, *46*(6), 610–615.

Hutchesson, M. J., Rollo, M. E., Krukowski, R., Ells, L., Harvey, J., Morgan, P. J., … Collins, C. E. (2015). eHealth interventions for the prevention and treatment of overweight and obesity in adults: A systematic review with meta-analysis. *Obesity Reviews*, *16*(5), 376–392.

Ibiebele, T. I., Parekh, S., Mallitt, K. A., Hughes, M. C., O'Rourke, P. K., & Webb, P. M. (2009). Reproducibility of food and nutrient intake estimates using a semi-quantitative FFQ in Australian adults. *Public Health Nutrition*, *12*(12), 2359–2365.

Kaewkungwal, J., Singhasivanon, P., Khamsiriwatchara, A., Sawang, S., Meankaew, P., & Wechsart, A. (2010). Application of smart phone in "Better Border Healthcare Program": A module for mother and child care. *BMC Medical Informatics and Decision Making*, *Nov 3*, *10*, *69*.

Kennelly, M. A., Ainscough, K., Lindsay, K., Gibney, E., Mc Carthy, M., & McAuliffe, F. M. (2016). Pregnancy, exercise and nutrition research study with smart phone app support (Pears): Study protocol of a randomized controlled trial. *Contemporary Clinical Trials*, *46*, 92–99.

Knight-Agarwal, C., Davis, D. L., Williams, L., Davey, R., Cox, R., & Clarke, A. (2015). Development and pilot testing of the Eating4two mobile phone app to monitor gestational weight gain. *JMIR Mhealth Uhealth*, *3*(2), e44.

Kraschnewski, J. L., Chuang, C. H., Poole, E. S., Peyton, T., Blubaugh, I., Pauli, J., … Reddy, M. (2014). Paging "Dr. Google": Does technology fill the gap created by the prenatal care visit structure? Qualitative focus group study with pregnant women. *Journal of Medical Internet Research*, *16*(6), e147.

Mangou, A., Grammatikopoulou, M. G., Mirkopoulou, D., Sailer, N., Kotzamanidis, C., & Tsigga, M. (2012). Associations between diet quality, health status and diabetic complications in patients with type 2 diabetes and comorbid obesity. *Endocrinología y Nutrición*, *59*(2), 109–116.

Mannan, M., Doi, S. A., & Mamun, A. A. (2013). Association between weight gain during pregnancy and postpartum weight retention and obesity: A bias-adjusted meta-analysis. *Nutrition Reviews*, *71*(6), 343–352.

Meltzer, H. M., Brantsaeter, A. L., Ydersbond, T. A., Alexander, J., & Haugen, M. (2008). Methodological challenges when monitoring the diet of pregnant women in a large study: Experiences from the Norwegian Mother and Child Cohort Study (MoBa). *Maternal & Child Nutrition*, *4*(1), 14–27.

Okorodudu, D. E., Bosworth, H. B., & Corsino, L. (2014). Innovative interventions to promote behavioral change in overweight or obese individuals: A review of the literature. *Ann Med*, *Jul*, *10*, 1–7. *[Epub ahead of print]*

Pagoto, S. L., Schneider, K. L., Jojic, M., DeBiasse, M. A., & Mann, D. M. (2014). Weight loss using evidence-based strategies in mobile apps. Authors' response. *Am J Prev Med*, *47*(1), e2.

Pick, M. E., Edwards, M., Moreau, D., & Ryan, E. A. (2005). Assessment of diet quality in pregnant women using the Healthy Eating Index. *Journal of the American Dietetic Association*, *105*, 240–246.

Pollak, K. I., Alexander, S. C., Bennett, G., Lyna, P., Coffman, C. J., Bilheimer, A., … Østbye, T. (2014). Weight-related SMS texts promoting appropriate pregnancy weight gain: A pilot study. *Patient Education and Counseling*, *97*(2), 256–260.

Poston, L., Bell, R., Croker, H., Flynn, A. C., Godfrey, K. M., Goff, L., … Briley, A. L., on behalf of The UPBEAT Trial Consortium. (2015). Effect of a behavioural intervention in obese pregnant women (the UPBEAT study): A multicentre, randomised controlled trial. *Lancet Diabetes and Endocrinology*. *July 10*(http://dx.doi.org/10.1016/S2213-8587(15)00227-2)

Poston, L., Briley, A. L., Barr, S., Bell, R., Croker, H., Coxon, K., … Sandall, J. (2013). Developing a complex intervention for diet and activity behaviour change in obese pregnant women (the UPBEAT trial); assessment of behavioural change and process evaluation in a pilot randomised controlled trial. *BMC Pregnancy and Childbirth*, *13*(1), 148.

Rae, A., Bond, D., Evans, S. F., North, F., Roberman, B., & Walters, B. (2000). A randomised controlled trial of dietary energy restriction in the management of obese women with gestational diabetes. *ANZJOG*, *40*(4), 416–422.

Rodger, D., Skuse, A., Wilmore, M., Humphreys, S., Dalton, J., Flabouris, M., & Clifton, V. L. (2013). Pregnant women's use of information and communications technologies to access pregnancy-related health information in South Australia. *Australian Journal of Primary Health*, *19*(4), 308–312.

Royal College of Obstetricians and Gynaecologists. (2006). *Recreational exercise and pregnancy: Information for you*. London: RCOG Press.

Rumbold, A. R., Crowther, C. A., Haslam, R. R., Dekker, G. A., Robinson, J. S., … for the ACTS Study Group. (2006). Vitamins C and E and the risks of preeclampsia and perinatal complications. *The New England Journal of Medicine*, *354*(17), 1796–1806.

Scheil, W., Scott, J., Catcheside, B., Sage, L., & Kennare, R. (2015). Pregnancy outcome in South Australia 2013.

Schmitt, N. M., Nicholson, W. K., & Schmitt, J. (2007). The association of pregnancy and the development of obesity—Results of a systematic review and meta-analysis on the natural history of postpartum weight retention. *International Journal of Obesity*, *31*(11), 1642–1651.

Soltani, H., Duxbury, A. M., Arden, M. A., Dearden, A., Furness, P. J., & Garland, C. (2015). Maternal obesity management using mobile technology: A feasibility study to evaluate a text messaging based complex intervention during pregnancy. *Journal of Obesity*, *2015*, 814830. https://doi.org/10.1155/2015/814830

Stephens, J., & Allen, J. (2013). Mobile phone interventions to increase physical activity and reduce weight: A systematic review. *Journal of Cardiovascular Nursing*, *28*(4), 320–329.

Thangaratinam, S., Rogozinska, E., Jolly, K., Glinkowski, S., Roseboom, T., Tomlinson, J. W., … Khan, K. S. (2012). Effects of interventions in pregnancy on maternal weight and obstetric outcomes: Meta-analysis of randomised evidence. *BMJ*, May 16, *344*, e2088.

Wendel-Vos, G. C., Schuit, A. J., Saris, W. H., & Kromhout, D. (2003). Reproducibility and relative validity of the short questionnaire to assess health-enhancing physical activity. *Journal of Clinical Epidemiology*, *56*, 1163–1169.

Willcox, J. C., Wilkinson, S. A., Lappas, M., Ball, K., Crawford, D., McCarthy, E. A., … Campbell, K. J. (2017). A mobile health intervention promoting healthy gestational weight gain for women entering pregnancy at a high body mass index: The txt4two pilot randomised controlled trial. *BJOG* https://10.1111/1471-0528.14552.

Willett, W. C., Reynolds, R. D., Cottrell-Hoehner, S., Sampson, L., & Browne, M. L. (1987). Validation of a semi-quantitative food frequency questionnaire: Comparison with a 1-year diet record. *Journal of the American Dietetic Association*, *87*(1), 43–47.

Wolff, S., Legarth, J., Vangsgaard, K., Toubro, S., & Astrup, A. (2008). A randomized trial of the effects of dietary counseling on gestational weight

gain and glucose metabolism in obese pregnant women. *International Journal of Obesity*, *32*, 495–501.

World Health Organization. (2008). *2008–2013 action plan for the global strategy for the prevention and control of noncommunicable diseases: Prevent and control cardiovascular diseases, cancers, chronic respiratory diseases and diabetes*. Geneva: WHO.

World Health Organization. (2015). WHO Fact Sheet Obesity and Overweight. from http://www.who.int/mediacentre/factsheets/fs355/en/

van Zutphen, M., Milder, I. E., & Bemelmans, W. J. (2008). Usage of an online healthy lifestyle program by pregnant women attending midwifery practices in Amsterdam. *Preventive Medicine*, *46*(6), 552–557.

SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

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