RBMO

ELSEVIER

ARTICLE

Smartphone-based lifestyle coaching modifies behaviours in women with subfertility or recurrent miscarriage: a randomized controlled trial

BIOGRAPHY

Bonnie Ng is an MRC Clinical Research Fellow at the University of Southampton. Her research focuses on the intrauterine environment and periconceptional care for women with reproductive failures.

Ka Ying Bonnie Ng[1,2,*], Régine Steegers-Theunissen[3], Sten Willemsen[3,4], Susan Wellstead[1,2], Ying Cheong[1,2], Nick Macklon[5,6]

KEY MESSAGE

A personalized online lifestyle coaching platform is effective in improving periconceptional lifestyle behaviours, especially in women with a higher body mass index. It may represent an empowering and cost-effective means of delivering periconceptional advice to women affected by subfertility or recurrent miscarriages.

ABSTRACT

Research question: Is an online lifestyle coaching platform more effective at modifying periconceptional behaviours than standard advice offered by the UK National Health Service (NHS)?

Design: Women with subfertility or recurrent miscarriage were recruited to a two-centre randomized controlled trial. They were randomized to either the online lifestyle coaching platform *Smarter Pregnancy* (intervention) or periconceptional advice provided by NHS websites (control). Participants completed a lifestyle questionnaire at baseline, 6, 12, 18 and 24 weeks, and the results were used to tailor lifestyle coaching in the intervention group. At baseline, 12 and 24 weeks, composite risk scores (CRS) were calculated. A lower CRS corresponds to a healthier lifestyle.

Results: Of the 400 women recruited, 262 women were randomized (131 in each arm). At 12 weeks, a reduction in CRS (includes risk score for intake of folic acid, vegetables and fruits, smoking and alcohol) was observed in the intervention versus control arms. After correcting for baseline, the difference in the CRS between intervention and control was –0.47 (95% CI –0.97 to 0.02) at 12 weeks and –0.32 (95% CI –0.82 to 0.15) at 24 weeks. A statistically significant reduction in lifestyle risk scores was found in women with a body mass index (BMI) of 25 kg/m^2 or above compared with those with a BMI below 25kg/m^2. The odds of being pregnant at 24 weeks was increased in the intervention versus control (OR 2.83, 95% CI 0.35 to 57.76).

Conclusions: The *Smarter Pregnancy* coaching platform is more effective in delivering lifestyle advice and modulating behaviours to support women with a history of subfertility or recurrent miscarriage than standard online NHS advice.

[1] School of Human Development and Health, Faculty of Medicine, University of Southampton, Southampton SO16 6YD, UK
[2] Department of Obstetrics and Gynaecology, Princess Anne Hospital, Room F86, Level F, Coxford Road, Southampton SO16 5YA, UK
[3] Department of Obstetrics and Gynaecology, Erasmus MC, University Medical Centre, Rotterdam, The Netherlands
[4] Department of Epidemiology, Erasmus MC, University Medical Centre, Rotterdam, The Netherlands
[5] Reprohealth, Zealand University Hospital, University of Copenhagen, Denmark
[6] London Women's Clinic, London, UK

KEYWORDS
Ehealth
Lifestyle
Lifestyle coaching
Online
Periconception
Smartphone

*Corresponding author. E-mail address: bonnie.ng@doctors.org.uk (K. Y. B. Ng). https://doi.org/10.1016/j.rbmo.2021.04.003 1472-6483/
Declaration: Over the past 4 years, NM has received grant funding and fees from Merck, Ferring, Gedeon Richter, Anecova, SLP, Abbott and ArtPred.

INTRODUCTION

The optimization of lifestyle, including diet and nutrition, has received increasing attention in the management of periconceptional and pregnancy health, particularly in relation to subfertility, recurrent miscarriage and polycystic ovary syndrome. Various national and international guidelines emphasize the importance of healthy lifestyle when planning a pregnancy (*ESHRE Early Pregnancy Guideline Development Group, 2017*; *National Institute for Health and Care Excellence [NICE], 2017*; *Teede et al., 2018*).

The preconception period is often seen as representing a unique opportunity to reduce risk factors linked to non-communicable diseases in offspring (*Hanson et al., 2018*). The 'periconceptional period' has been defined as the 5–6 month window that includes the important stages of oocyte development, fertilization, conceptus formation and implantation to 10 weeks of gestation, during which lifestyle can greatly affect embryonic development and sustainment of a healthy pregnancy (*Steegers-Theunissen et al., 2013*). The Developmental Origins of Health and Disease paradigm (*Barker, 2004*) is supported by studies showing that the peri-implantation in-utero nutritional environment programmes embryo and fetal development (*Watkins et al., 2018*). It is now clear that the periconceptional period is also a determinant of many (potentially adverse) pregnancy outcomes, including the 'great obstetric syndromes', subfertility, miscarriage, low birth weight and preterm birth (*Steegers-Theunissen et al., 2013*).

Despite strong evidence to support the importance of healthy lifestyle and behaviours during the time around conception, it remains unclear how best to support patients to optimize healthy behaviours. Of the strategies that have been tested so far, widespread implementation has not been advocated owing to either high cost, limited effectiveness or underutilization (*Klerman, 2006*; *Kerber et al., 2007*). In the UK, general practitioners play a role in coordinating preconception care; however, several barriers have been identified, including time constraints, lack of women presenting in the preconception stage, competing preventive priorities within the general practitioner setting, lack of resources and high cost in access to preconception care (*Mazza et al., 2013*). Studies have consistently shown a low level of knowledge in women of reproductive age regarding preconception care and, subsequently, a low level of adherence to nutritional and lifestyle recommendations when planning a pregnancy. Studies such as those revealing a less than 50% uptake of periconceptional folic acid supplements, particularly in socially disadvantaged groups (*Watson et al., 2006*), raise many questions about the efficacy of current methods designed to educate and influence pre-conceptional behaviours.

Recently, the number of mobile health platforms (the practice of medicine and public health supported by mobile devices) has increased (*Overdijkink et al., 2018*). They are considered to represent an easily accessible and low-cost method of self-management for health care (*Fanning et al., 2012*; *Donker et al., 2013*; *Free et al., 2013*; *Okorodudu et al., 2015*). Within reproductive medicine, the use of an online, smartphone-accessed lifestyle coaching application (*Smarter Pregnancy* [www.smarterpregnancy.co.uk]), has been reported to improve periconceptional behaviours in the general population and women and men who are undergoing IVF (*Van Dijk et al., 2016*), especially within obese women (*van Dijk et al., 2017a*) and in the cohort with lower socioeconomic status (*Gootjes et al., 2019*). The aim of the present study was to assess the effectiveness of the online lifestyle coaching platform *Smarter Pregnancy* in modifying periconceptional behaviours in women referred to a subfertility or recurrent miscarriage clinic.

MATERIALS AND METHODS

Study objective

The aim of this prospective randomized controlled trial (the iPLAN trial 'Impact of a Personalised Lifestyle coaching phone ApplicatioN in modifying periconceptional behaviours) was to address whether the online-based lifestyle coaching application was a more effective means of delivering periconceptional advice than standard NHS information given to women affected by subfertility or recurrent miscarriage.

Hypothesis

It is hypothesized that a smartphone-delivered online lifestyle coaching application can be a more effective means of delivering periconceptional pregnancy advice compared with conventional measures of periconceptional counselling through standard information provided by NHS websites and patient information leaflets.

Study population and recruitment

All women who attended the gynaecological outpatient department in Princess Anne Hospital, Southampton, and Salisbury District Hospital, who met the inclusion and exclusion criteria, were invited to participate in the iPLAN study. Women participating in the iPLAN trial were undergoing investigation or treatment for subfertility or recurrent miscarriage, aged between 18 and 45 years and actively trying to conceive. They were only included if they were fluent in the use and understanding of English and had a smartphone capable of running the online application.

Exclusion criteria included women who were on a specific diet for medical reasons, women with insulin-dependent diabetes and those undergoing any other means of lifestyle coaching, e.g. personal trainer or group lifestyle coaching.

Eligible patients were informed about the iPLAN study during their first outpatient appointment and consultation with the medical team. In addition, patients had the option to self-refer by contacting the research team, the details of which were on recruitment posters displayed in the outpatient departments of the participating hospitals. Eligible patients who wished to participate were required to provide written informed consent. After this, the participant was given a unique activation code for the online lifestyle coaching application. Once registered, the participants were randomized by the application.

Study design

This study was a two-centre randomized controlled trial of using an online smartphone application in providing lifestyle coaching and modifying lifestyle parameters in women attending the outpatient department of Princess Anne Hospital, Southampton, and Salisbury District Hospital. Randomization into the trial occurred per centre. Participants seen in the outpatient clinic who were having investigations or receiving treatment for subfertility or recurrent miscarriage were referred to the research nurse. The research nurse explained the study in further detail and ensured that the inclusion and exclusion criteria were met before taking informed written consent.

Women were asked to visit the *Smarter Pregnancy* website (Smarter Pregnancy [www.smarterpregnancy.co.uk]), and register and activate their account by entering their unique validation code. Women were automatically randomized by the *Smarter Pregnancy* computer programme to either intervention arm or control arm. They were then asked to input their personal details and to complete the baseline lifestyle questionnaire of the programme, which assessed parameters, including smoking habits, alcohol consumption, diet, exercise and weight. Both intervention and control group logged in to *Smarter Pregnancy* using their personalized credentials created at registration.

The *Smarter Pregnancy* online lifestyle coaching platform was launched in 2012 and provides personalized lifestyle coaching based on individual nutrition and lifestyle profiles during the periconceptional period. In developing the programme, elements of Prochaska and Velicer's transtheoretical model, with a focus on readiness for change, Bandura's social cognitive theory for self-efficacy and Fogg's behaviour model to include triggers to motivate and increase the ability to change, were applied (*Prochaska and Velicer, 1997*; *Bandura, 2004*; *Fogg, 2009*). The validity of the *Smarter Pregnancy* programme has been confirmed by previous studies and serum biomarkers, such as serum folate levels reflect the reported change in lifestyle behaviours in users (*van Dijk et al., 2017b*; *Oostingh et al., 2020*).

In the intervention arm, women had access to a personalized smartphone lifestyle coaching programme. Through baseline and follow-up lifestyle questionnaires (at 6, 12, 18 and 24 weeks) sent out via email, tailored lifestyle advice was generated based on the participant's responses in the baseline and follow-up questionnaires; emails (maximum of three per week) with feedback on progress, recommendations, tips, facts and recipes were sent to participants in the intervention arm to encourage them to change unhealthy habits and maintain healthy habits. Coaching was directed at addressing inadequate intake of vegetables and fruit, absence of folic acid supplementation, and unfavourable alcohol and smoking habits, as identified by the baseline and follow-up questionnaires. The information from the questionnaires was presented on a personal online page to display individual progress (a comparison with previous results) and to stimulate compliance. The smartphone application allowed participants to update their pregnancy status by asking this question every 6 weeks. Those randomized to the control arm had access to standard periconceptional advice provided by the NHS. They were referred to a website that offers standard lifestyle advice for women planning a pregnancy, including advice on folic acid supplementation, stopping smoking, cutting out the alcohol and keeping a healthy weight (*NHS, 2020*). At baseline, 6, 12, 18 and 24 weeks, all participants were asked to complete the same online lifestyle questionnaire on baseline characteristics and nutritional and lifestyle behaviours. Those in the control arm did not receive any feedback on inadequate behaviours identified from the questionnaires.

The results were analysed to determine whether a smartphone lifestyle coaching application is more effective than standard NHS advice in optimizing lifestyle behaviours in the periconceptional period, through a validated lifestyle questionnaire (Supplementary Table 1) at 12 and 24 weeks after randomization. Patient compliance with the programme was assessed at 12 and 24 weeks after randomization, and the proportion of women achieving natural conception during the study period was recorded. Everyone was asked to participate in the study for 24 weeks after randomization.

Primary and secondary end points

The primary end point of the study was the composite dietary and lifestyle risk score at 12 weeks after randomization. Secondary end points included the following: percentage of patients remaining compliant with the system at 12 and 24 weeks after randomization; proportion achieving spontaneous conception during the study period; and composite dietary and lifestyle risk score at 24 weeks after randomization. The level of compliance was defined as the percentage of participants who completed the questionnaires at specific time points in this study.

Randomization

After completing baseline questionnaires, participants were randomized to the intervention or control arm by computer generation of a series of validation codes unique for each participant. The randomization process was concealed, and the research team were blinded to the resulting allocation.

Data collection

All women giving informed consent were asked to complete an electronic registration and baseline questionnaire using their computer, laptop, tablet or smartphone. Participants were requested to complete a validated lifestyle questionnaire (via email) at baseline, at 6, 12, 18 and 24 weeks after randomization; personalized lifestyle advice was provided to the intervention group based on responses. The lifestyle questionnaire included assessment of folate and vitamin D intake, pregnancy status, body mass index (BMI), diet (including fruit, vegetables, meat, meat substitutes, or both, liver, liver products, or both, fish, shellfish and fish products, savoury snacks, sweet snacks, bread and rice, and ready-made meals and fast food), smoking status, alcohol intake and exercise. The full questionnaire can be found in the Supplementary Table 1. From the questionnaire responses at baseline, 12 and 24 weeks, composite risk scores (CRS), defined as the sum of all individual risk scores for each lifestyle behaviour, were calculated and used in the analyses.

Statistical analysis

Risk scores

All recorded lifestyle behaviours were translated into risk scores, developed on the basis of the Rotterdam Reproduction Risk Score (R3-score) and the Preconception Dietary Risk Score (PDR) (*Huijgen et al., 2014*). Previous research demonstrates that smoking, alcohol consumption, folic acid intake, fruit and vegetable intake have strong associations with reproductive outcomes (*Homan et al., 2007*; *Twigt et al., 2012*; *Oostingh et al., 2019*). The CRS was defined as the sum of all individual risk scores for each lifestyle behaviour. A lower CRS corresponds to a healthier lifestyle. Fruit and vegetable intake were subdivided into a risk score from '0' (adequate daily intake, two or more pieces of fruit per day and 200 g or more of vegetables per day) to '3' (inadequate daily intake, less than 1.5 pieces of fruit per day, less than 150 g vegetable per day). Folic acid intake was scored '0' (adequate, taking the recommended 400 µg folic acid during the periconceptional period) or '3' (inadequate). Smoking was subdivided into a risk score from '0' (no smoking) to '6' (15 or more cigarettes per day), and alcohol intake was subdivided into a risk score from '0' (no alcohol intake) to '3' (three or more alcoholic beverages per day).

Sample size calculation and power considerations

To show a difference in the proportion of participants achieving a high composite lifestyle risk score from 30% in the control arm to 50% in the study arm after 24 weeks of the intervention, with 80% power at a test size (alpha) of 0.05, 93 patients were required in each arm. With an estimated randomization rate of 50% and a drop-out rate of 15–20%, 220 patients were randomized to each arm (440 patients recruited in total).

Data analysis

Before analysis, the data were subject to range checks, identification of extreme values (mean +/– 3*SD), and consistency checks were used to identify possible data entry errors. Any data entry considered to be erroneous was excluded from the analysis.

Baseline data for categorical variables is presented as the number of individuals by outcome category (together with the percentage of total); chi-squared test was used to determine the difference between control and intervention groups. For continuous variables, the median and the first and third quartiles of the distribution are presented; a t-test was used to determine the difference between control and intervention groups. $P < 0.05$ was considered statistically significant.

At 12 and 24 weeks after randomization, the expected CRS by group (intervention and control) is presented together with a difference and 95% confidence intervals computed with the bootstrap (*Efron and Tibshirani, 1993*) to account for the possible non-normal distribution of the errors. The same was done with the individual risk scores for each lifestyle behaviour (fruit and vegetable intake, folic acid intake, and smoking and alcohol intake).

The primary outcome of the trial was the difference in the composite risk score at 12 weeks between the intervention group and the control group adjusted for the CRS at baseline. This difference was calculated using linear regression analysis. A 95% confidence interval was calculated using the bootstrap. Similar analyses were carried out for the composite risk score at 24 weeks and for the individual contributions of vegetables, fruit, folic acid, smoking and alcohol to the composite score. Subgroup analysis was conducted for overweight and obese women (BMI ≥25 kg/m^2).

Missing data were described by presenting the number of patients for which outcomes could not be computed at each time point and for each arm. This number was also expressed as a fraction of all individuals that were randomized to each arm.

The data were analysed according to the intention to treat principle, meaning that each participant was analysed as belonging to the group to which they were randomized, regardless of actual behaviour. The complete cases were analysed in the main analysis only.

Institutional Review Board approval

The present study was designed in compliance with the guidelines for good clinical practice (GCP) and the Declaration of Helsinki 1964 as revised and recognized by governing laws and European Union directives. Full ethical approval (16/YH/0129) was granted on 23 May 2016 from Yorkshire and The Humber Research Ethics Committee via the Integrated Research Application System (IRAS). Written informed consent was obtained from all participants before randomization into the study as per GCP guidelines. The study is registered with ISRCTN (trial registration number 89523555, date of registration 22 February 2018).

RESULTS

A total of 440 women were recruited and 262 women were randomized into the study. The patient flow through the randomized controlled trial is presented in FIGURE 1. Only 60% of the women originally recruited were randomized owing to a high proportion of participants failing to log on to the programme despite having provided written consent to participate. The baseline characteristics of those randomized to the intervention or control group are presented in TABLE 1. No significant differences were found in baseline vegetable or fruit intake, number taking folate supplementation, cigarette smoking or alcohol intake at the 5% significance level.

Participants who received the coaching programme demonstrated a reduction in the composite lifestyle risk scores (showing an improvement in lifestyle) at both 12 and 24 weeks after randomization (FIGURE 2). A negative value for the difference in risk scores demonstrates a larger improvement in lifestyle in the intervention group compared with the control group having corrected for baseline risk profiles. The difference in the composite risk scores between intervention and control arms correcting for baseline were –0.47 (95% CI –0.97 to 0.02) at 12 weeks and –0.32 (95% CI –0.82 to 0.15) at 24 weeks. In assessing the fruit intake risk score, the difference between intervention and control arms correcting for baseline was –0.14 (95% CI –0.60 to 0.07) at 12 weeks and –0.21 (95% CI –0.50 to 0.66) at 24 weeks. The difference in the vegetable intake risk score between intervention and control arms correcting for baseline was –0.21 (95% CI –0.48 to 0.03) at 12 weeks and 0.00 (95% CI –0.30 to 0.27) at 24 weeks. Folic acid supplementation risk score differed between intervention and control arms correcting for baseline; the difference was –0.04 (95% CI –0.29 to 0.21) at 12 weeks and –0.16 (95% CI –0.42 to 0.09) at 24 weeks. The difference in the smoking risk score between intervention and control arms correcting for baseline was 0.02 (95% CI –0.01 to 0.10) at 12 weeks and 0.08 (95% CI –0.02 to 0.28) at 24 weeks. The alcohol intake risk score comparing intervention and control arms after correcting for baseline showed zero difference (95% CI –0.14 to 0.09) at 12 weeks and –0.02 (95% CI –0.15 to 0.10) at 24 weeks.

Subgroup analysis revealed a statistically significant reduction in smoking and alcohol intake risk scores within the subgroup of women with a BMI 25 kg/m^2 or higher compared with those with a BMI below 25 kg/m^2 (FIGURE 3). After correcting for baseline scores, the intervention group showed a smoking risk score at 24 weeks of –0.05 (95% CI –0.18 to 0.00) in women with BMI 25 kg/m^2 or

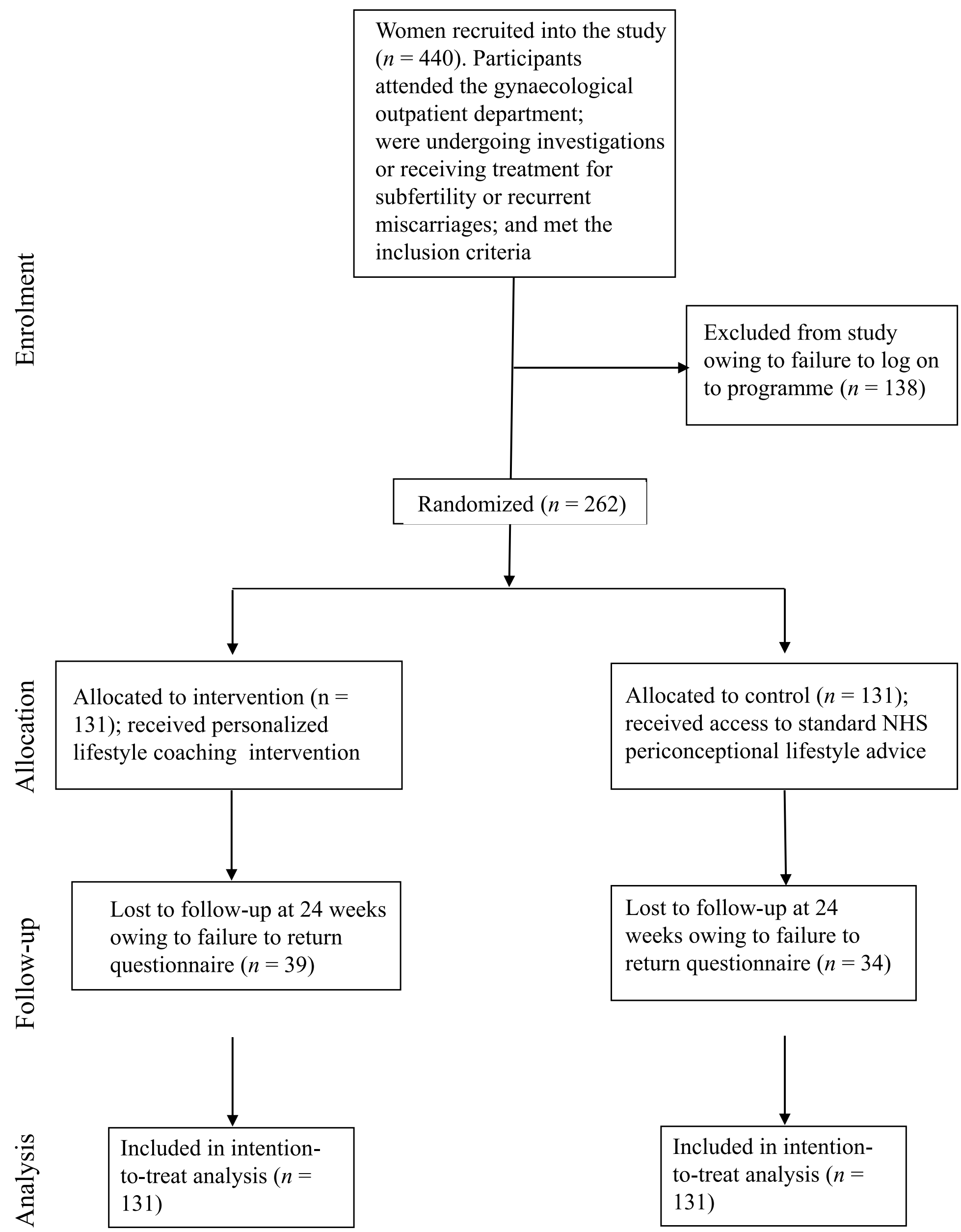

FIGURE 1 Progression of participants through the trial.

higher and 0.004 (95% CI 0.00 to 0.03) in women with BMI lower than 25 kg/m^2. The alcohol risk score in the intervention group was –0.21 (–0.43 to –0.03) in women with BMI 25kg/m^2 or higher and 0.14 (–0.04 to 0.36) in women with BMI lower than 25 kg/m^2. Subgroup analyses by BMI in other lifestyle risk scores did not reach statistical significance (data not shown).

The total compliance rates at week 12 after randomization was 87.4% (*n* = 229/262, 95% CI 82.8 to 91.1%) and at 24 weeks after randomization was 72.1% (*n* = 189/262, 95% CI 66.3 to 77.5%). Level of compliance was defined by the percentage of participants who completed the questionnaires at specific time points in this study. No difference was found in the compliance rates between intervention (*n* = 92/131 [70.2%]) and control (*n* = 97/131 [74.0%]) arms at 24 weeks (*P* = 0.58).

The odds ratio for pregnancy at 24 weeks after randomization for the intervention group versus control group is 2.83 (95% CI 0.35 to 57.76). In the control group, 1.22% (1/82) and in the intervention group 3.41% (3/88) were pregnant by 24 weeks after randomization.

DISCUSSION

Main findings

This study demonstrates that the *Smarter Pregnancy* online lifestyle coaching platform is more effective than referral to standard NHS advice at improving certain periconceptional behaviours in women affected by subfertility or recurrent miscarriage. Compared with the control group, use of the platform improved overall lifestyle risk scores at 12 weeks and 24 weeks after randomization into the study, and the improvement in the smoking and alcohol intake risk was particularly pronounced within the

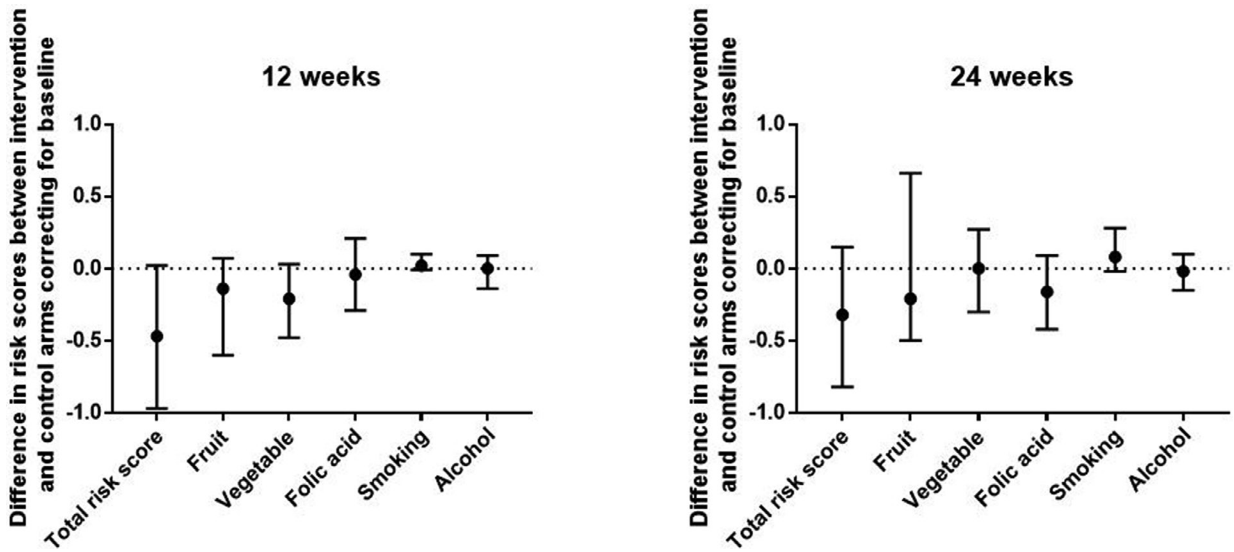

FIGURE 2 Difference in composite risk scores for total lifestyle, fruit intake, vegetable intake, folic acid supplement intake, smoking and alcohol intake at (A) 12 weeks and (B) 24 weeks between intervention and control arms correcting for baseline. '0' represents no difference between groups. Risk score less than 0 favours intervention. The error bars represent 95% confidence intervals.

subgroup of women with a BMI 25 kg/m^2 or higher (overweight or obese populations). A statistically significant increased odds ratio was observed for pregnancy within the period of study for the intervention group, compared with the control group.

Weight and BMI are closely related to reproductive function, amenorrhoea, anovulation, subfertility and recurrent miscarriage, all occurring at higher body weights, with or without controlling for height (Bolumar et al., 1997; Killick, 2004; Hassan and van der Steeg et al., 2008; Cavalcante et al., 2019). As Barker (2004) described, the period *in utero* is one of the most critical, shaping future abilities and health trajectories; the peri-implantation in-utero nutritional environment programmes embryo and early fetal development (Watkins et al., 2018). Therefore, poor nutrition and lifestyle are key contributors to non-communicable diseases, including subfertility; mechanisms for this include increasing susceptibility to the metabolic syndrome (Warner and Ozanne, 2010; Grieger et al., 2019; He et al., 2019).

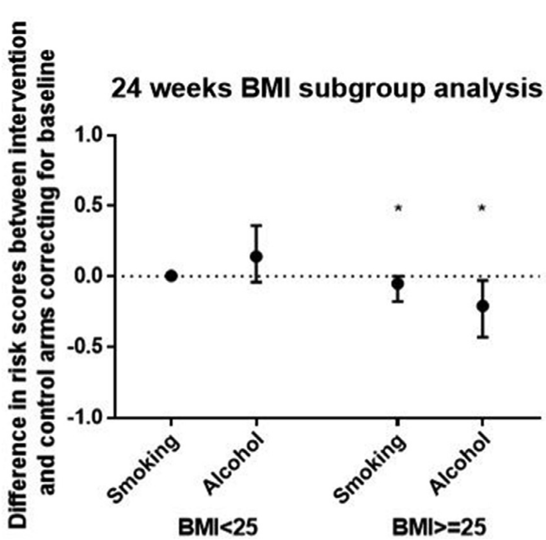

FIGURE 3 Subgroup analyses by body mass index (BMI). Graph shows difference in risk scores at 24 weeks correcting for baseline between intervention and control arms in two groups (BMI <25 or BMI ≥25). The error bars represent 95% confidence levels. *denotes significance at the 5% level.

Although there is ample evidence for the importance of maintaining a healthy diet, BMI and of other lifestyle risk factors, including smoking and alcohol intake, effective methods of delivering periconceptional advice within a subgroup of women with a history of subfertility or recurrent miscarriage is less well defined. Women who are planning a pregnancy, especially those who are obese, have described negative experiences of the professional care they have received during preconception counselling, during their pregnancy and childbirth (Puhl and Heuer, 2009; Nyman et al., 2010; Furber and McGowan, 2011). The stigmatization and perceived patronization can be barriers for engaging in lifestyle support (Puhl and Heuer, 2009). Furthermore, deeply rooted lifestyle patterns can be highly resistant to change (Olander et al., 2011; 2013).

Studies assessing personalized and individualized care through electronic health are only just emerging. The mhealth *Smarter Pregnancy* programme (Dutch version available at www.slimmerzwanger.nl) has been shown to be an effective tool in improving nutritional behaviours, especially increasing vegetable intake in the periconceptional period (van Dijk et al., 2020). We have shown the use of this personalized online lifestyle coaching programme to be particularly effective in improving behaviours associated with cigarette smoking and alcohol intake in the

TABLE 1 BASELINE VEGETABLE AND FRUIT INTAKE AND THE PROPORTION OF WOMEN WHO WERE TAKING FOLIC ACID SUPPLEMENTS, WERE NON-SMOKERS AND WHO CONSUMED NO ALCOHOL IN THE INTERVENTION AND CONTROL GROUPS

	Control		Intervention		*P*-value
Baseline	**Mean**	**SD**	**Mean**	**SD**	
Vegetable intake, g/day	126	92	136	83	0.174
Fruit intake, pieces/day	2.0	1.8	2.4	1.8	0.061

	Control		Intervention		*P*-value
Baseline	***n***	**%**	***n***	**%**	
Taking folic acid supplements	97/131	74.0	91/131	69.5	0.493
Non-smokers[a]	118/122	96.7	111/121	91.7	0.164
No alcohol[a]	66/122	54.1	50/120	41.7	0.708

The differences between the groups were non-significant.

[a] In the smoking and alcohol variables, not all study participants reported this at baseline, hence *n* is not 131.

present cohort with a BMI 25 kg/m^2 or higher. The use of this self-management tool may provide effective motivation in overweight and obese populations, and may potentially avoid any negative experiences associated with interacting with a health professional who may be perceived as patronizing, judgemental or non-supportive. Digital interventions may be particularly useful in supporting disadvantaged populations because users experience less stigmatization than conventional strategies (Dennison et al., 2014).

Guidance has been published by NHS England on 'involving people in their own health and care', which means supporting patients to become involved as much as they would like to, or be able to, so that they can make decisions about their care, giving them choice and control. This should be achieved through routinely providing individuals with information, care and support to determine and achieve the outcomes that matter to them (NHS England, 2017). Within the guidance, it supports the use of self-management approaches that re-enforces patients as experts in their own health and provides support to develop understanding and confidence, improved patient experience and adherence to treatment and medication (The King's Fund, 2015). Digital interventions, such as *Smarter Pregnancy*, have the advantage that they are portable, easily accessible, cheap and have the potential to reach and therefore affect a large population. The present study has shown that support can be specifically tailored to meet the concerns of women before conception and, through this tool, patients may feel more empowered to make changes compared with conventional advice offered and delivered through NHS websites. In the present study however, no differences in the compliance of the programme in those randomized to the intervention were evident compared with those randomized to control groups. The total compliance rates at week 12 after randomization was 87.4% and, at 24 weeks, was 72.1% in the present study. Our compliance rate is comparable to those of other studies; one study reported a 64.9% compliance rate at 24 weeks when the *Smarter Pregnancy* platform was offered to couples planning a pregnancy (Van Dijk et al., 2016), and a more recent study reported a compliance rate of 81.2% in the general population (van Dijk et al., 2020).

The present study has several limitations. Assessment of the efficacy of the smartphone lifestyle coaching programme was restricted to women planning a pregnancy, i.e. efficacy was not assessed in the women's partners. The effect of the intervention when partners have been included has been explored previously in a Dutch cohort (Van Dijk et al., 2016; 2017a; Oostingh et al., 2020). Although the present study identified improvement in lifestyle risk scores at 24 weeks after randomization, it was not determined whether these behaviours are sustained beyond 24 weeks. Although a statistically significant difference in the pregnancy rates (at the 5% significance level) between intervention and control groups was identified at 24 weeks, the study was only powered to detect a change in periconceptional risk scores at 12 weeks after randomization and not clinical pregnancy rate. Because of the nature of the study, it was also not possible to blind women who were randomized. The women's diet and lifestyle were self-reported through questionnaires and, although the questionnaires were validated (Oostingh et al., 2020; van Dijk et al., 2020), it was not possible to eliminate reporting biases in our sample. The randomization rate of 60% of the recruited women was a result of participants failing to register for the programme within 1 week of recruitment, after which the activation code given to them became invalid. No qualitative assessment of women's views and perceptions of the lifestyle coaching programme was made in the present study.

In conclusion, this personalized online lifestyle coaching platform has the potential to be a useful adjunct to standard resources in improving behaviours, especially within the cohort of women with a higher BMI. As health service providers seek further efficiencies, more widespread application of effective self-management tools, such as the online lifestyle coaching programme investigated in this study, should be considered. The evidence presented suggests that women should be given the opportunity to register for online lifestyle coaching either when they attend specialist subfertility or recurrent miscarriage clinics or at an earlier opportunity within primary care before referral to specialist care. This approach may represent an empowering and cost-effective means of delivering periconceptional advice to women affected by subfertility or recurrent miscarriage. Further research, however, is required to ascertain in more detail the attitudes of women using the programme and what effect changing behaviours might have on clinical outcomes.

ACKNOWLEDGEMENTS

The authors thank all the women who have participated in this randomized controlled trial. This study was funded by NIHR Southampton Biomedical Research Centre (Nutrition) and the Department of Obstetrics and Gynaecology at the Erasmus MC University Medical Center in Rotterdam, The Netherlands. *Smarter Pregnancy* is a commercial product and licenses to use the software under trial were purchased. The data underlying this article cannot be shared publicly due to the privacy of individuals that participated in the study. The data will be shared on reasonable request to the corresponding author.

SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.rbmo.2021.04.003.

REFERENCES

Bandura, A. **Health promotion by social cognitive means.** Health Educ. Behav. 2004; 31: 143–164

Barker, D.J. **The developmental origins of adult disease.** J. Am. Coll. Nutr. 2004; 23: 588S–595S

Bolumar, F., Olsen, J., Boldsen, J. **[Smoking reduces the biological capacity of conception. Results from a European multicenter study. The European Study Group on Infertility and Subfecundity].** Ugeskr Laeger 1997; 159: 4526–4532

Cavalcante, M.B., Sarno, M., Peixoto, A.B., Araujo Junior, E., Barini, R. **Obesity and recurrent miscarriage: A systematic review and meta-analysis.** J. Obstet. Gynaecol. Res. 2019; 45: 30–38

Dennison, L., Morrison, L., Lloyd, S., Phillips, D., Stuart, B., Williams, S., Bradbury, K., Roderick, P., Murray, E., Michie, S. **Does brief telephone support improve engagement with a web-based weight management intervention? Randomized controlled trial.** J. Med. Internet Res. 2014; 16: e95

Donker, T., Petrie, K., Proudfoot, J., Clarke, J., Birch, M.R., Christensen, H. **Smartphones for smarter delivery of mental health programs: a systematic review.** J. Med. Internet Res. 2013; 15: e247

Efron, B., Tibshirani, R. 1993 **Introduction to Bootstrap.** Chapman & Hall/CRCBoca Raton, Florida

ESHRE Early Pregnancy Guideline Development Group. **Recurrent Pregnancy Loss.** Guideline of the European Society of Human Reproduction and Embryology 2017

Fanning, J., Mullen, S.P., McAuley, E. **Increasing physical activity with mobile devices: a meta-analysis.** J. Med. Internet Res. 2012; 14: e161

Fogg, B.J. **A behaviour model for persuasive design.** Proeedings of the 4th international conference on persuasive technology 2009 (California USA)

Free, C., Phillips, G., Galli, L., Watson, L., Felix, L., Edwards, P., Patel, V., Haines, A. **The effectiveness of mobile-health technology-based health behaviour change or disease management interventions for health care consumers: a systematic review.** PLoS Med. 2013; 10e1001362

Furber, C.M., McGowan, L. **A qualitative study of the experiences of women who are obese and pregnant in the UK.** Midwifery 2011; 27: 437–444

Gootjes, D.V., van Dijk, M.R., Koster, M.P., Willemsen, S.P., Steegers, E.A., Steegers-Theunissen, R.P. **Neighborhood Deprivation and the Effectiveness of Mobile Health Coaching to Improve Periconceptional Nutrition and Lifestyle in Women: Survey in a Large Urban Municipality in the Netherlands.** JMIR Mhealth Uhealth 2019; 7: e11664

Grieger, J.A., Grzeskowiak, L.E., Smithers, L.G., Bianco-Miotto, T., Leemaqz, S.Y., Andraweera, P., Poston, L., McCowan, L.M., Kenny, L.C., Myers, J. **Metabolic syndrome and time to pregnancy: a retrospective study of nulliparous women.** BJOG 2019; 126: 852–862

Hanson, M., Bhutta, Z.A., Dain, K., Fuchtner, C., Hod, M. **Intergenerational burden and risks of NCDs: need to promote maternal and child health.** Lancet 2018; 392: 2422–2423

Hassan, M.A., Killick, S.R. **Negative lifestyle is associated with a significant reduction in fecundity.** Fertil. Steril. 2004; 81: 384–392

He, Y., Lu, Y., Zhu, Q., Wang, Y., Lindheim, S.R., Qi, J., Li, X., Ding, Y., Shi, Y., Wei, D. **Influence of metabolic syndrome on female fertility and in vitro fertilization outcomes in PCOS women.** Am. J. Obstet. Gynecol. 2019; 221

Homan, G.F., Davies, M., Norman, R **The impact of lifestyle factors on reproductive performance in the general population and those undergoing infertility treatment: a review.** Hum. Reprod. Update 2007; 13: 209–223

Huijgen, N.A., van de Kamp, M.E., Twigt, J.M., de Vries, J.H.M., Eilers, P.H.C., Steegers, E.A.P., Laven, J.S.E., Steegers-theunissen, R.P.M. **The Preconception Dietary Risk score; a simple tool to assess an inadequate habitual diet for clinical practice.** e-SPEN journal 2014; 9: e13–e19

Kerber, K.J., de Graft-Johnson, J.E., Bhutta, Z.A., Okong, P., Starrs, A., Lawn, J.E. **Continuum of care for maternal, newborn, and child health: from slogan to service delivery.** Lancet 2007; 370: 1358–1369

Klerman, L.V. **Family planning services: an essential component of preconception care.** Matern Child Health J. 2006; 10: S157–S160

Mazza, D., Chapman, A., Michie, S. **Barriers to the implementation of preconception care guidelines as perceived by general practitioners: a qualitative study.** BMC Health Serv. Res. 2013; 13: 36

National Institute for Health and Care Excellence (NICE) (2017). Clinical Guideline [CG156] Fertility problems: assessment and treatment

NHS (2020). Planning your pregnancy. https://www.nhs.uk/pregnancy/trying-for-a-baby/planning-your-pregnancy/.

NHS England (2017). Involving people in their own health and care: statutory guidance for clinical commissioning groups and NHS England.

Nyman, V.M., Prebensen, A.K., Flensner, G.E. **Obese women's experiences of encounters with midwives and physicians during pregnancy and childbirth.** Midwifery 2010; 26: 424–429

Okorodudu, D.E., Bosworth, H.B., Corsino, L. **Innovative interventions to promote behavioral change in overweight or obese individuals: A review of the literature.** Ann. Med. 2015; 47: 179–185

Olander, E.K., Atkinson, L., Edmunds, J.K., French, D.P. **The views of pre- and post-natal women and health professionals regarding gestational weight gain: An exploratory study.** Sex Reprod. Healthc 2011; 2: 43–48

Olander, E.K., Fletcher, H., Williams, S., Atkinson, L., Turner, A., French, D.P. **What are the most effective techniques in changing obese individuals' physical activity self-efficacy and behaviour: a systematic review and meta-analysis.** Int. J. Behav. Nutr. Phys. Act. 2013; 10: 29

Oostingh, E.C., Hall, J., Koster, M.P.H., Grace, B., Jauniaux, E., Steegers-Theunissen, R.P.M **The impact of maternal lifestyle factors on periconception outcomes: a systematic review of observational studies.** Reprod. Biomed. Online 2019; 38: 77–94

Oostingh, E.C., Koster, M.P.H., van Dijk, M.R., Willemsen, S.P., Broekmans, F.J.M., Hoek, A., Goddijn, M., Klijn, N.F., van Santbrink, E.J.P., Steegers, E.A.P. **First effective mHealth**

nutrition and lifestyle coaching program for subfertile couples undergoing in vitro fertilization treatment: a single-blinded multicenter randomized controlled trial. Fertil. Steril. 2020

Overdijkink, S.B., Velu, A.V., Rosman, A.N., van Beukering, M.D., Kok, M., Steegers-Theunissen, R.P. **The Usability and Effectiveness of Mobile Health Technology-Based Lifestyle and Medical Intervention Apps Supporting Health Care During Pregnancy: Systematic Review.** JMIR Mhealth Uhealth 2018; 6: e109

Prochaska, J.O., Velicer, W.F. **The transtheoretical model of health behavior change.** Am. J. Health Promot 1997; 12: 38–48

Puhl, R.M., Heuer, C.A. **The stigma of obesity: a review and update.** Obesity (Silver Spring) 2009; 17: 941–964

Steegers-Theunissen, R.P., Twigt, J., Pestinger, V., Sinclair, K.D. **The periconceptional period, reproduction and long-term health of offspring: the importance of one-carbon metabolism.** Hum. Reprod. Update 2013; 19: 640–655

Teede, H.J., Misso, M.L., Costello, M.F., Dokras, A., Laven, J., Moran, L., Piltonen, T., Norman, R.J., International, P.N. **Recommendations from the international evidence-based guideline for the assessment and management of polycystic ovary syndrome.** Hum. Reprod. 2018; 33: 1602–1618

The King's Fund (2015). Ten priorities for commissioners: transforming our health care system summary.

Twigt, J.M., Bolhuis, M.E., Steegers, E.A., Hammiche, F., van Inzen, W.G., Laven, J.S., Steegers-Theunissen, R.P. **The preconception diet is associated with the chance of ongoing pregnancy in women undergoing IVF/ICSI treatment.** Hum. Reprod. 2012; 27: 2526–2531

van der Steeg, J.W., Steures, P., Eijkemans, M.J., Habbema, J.D., Hompes, P.G., Burggraaff, J.M., Oosterhuis, G.J., Bossuyt, P.M., van der Veen, F., Mol, B.W. **Obesity affects spontaneous pregnancy chances in subfertile, ovulatory women.** Hum. Reprod. 2008; 23: 324–328

Van Dijk, M.R., Huijgen, N.A., Willemsen, S.P., Laven, J.S., Steegers, E.A., Steegers-Theunissen, R.P. **Impact of an mHealth Platform for Pregnancy on Nutrition and Lifestyle of the Reproductive Population: A Survey.** JMIR Mhealth Uhealth 2016; 4: e53

van Dijk, M.R., Koster, M.P.H., Oostingh, E.C., Willemsen, S.P., Steegers, E.A.P., Steegers-Theunissen, R.P.M **A Mobile App Lifestyle Intervention to Improve Healthy Nutrition in Women Before and During Early Pregnancy: Single-Center Randomized Controlled Trial.** Journal of Medical Internet Research 2020; 22

van Dijk, M.R., Koster, M.P.H., Willemsen, S.P., Huijgen, N.A., Laven, J.S.E., Steegers-Theunissen, R.P.M **Healthy preconception nutrition and lifestyle using personalized mobile health coaching is associated with enhanced pregnancy chance.** Reprod. Biomed. Online 2017; 35: 453–460

van Dijk, M.R., Oostingh, E.C., Koster, M.P., Willemsen, S.P., Laven, J.S., Steegers-Theunissen, R.P. **The use of the mHealth program Smarter Pregnancy in preconception care: rationale, study design and data collection of a randomized controlled trial.** BMC Pregnancy Childbirth 2017; 17: 46

Warner, M.J., Ozanne, S.E. **Mechanisms involved in the developmental programming of adulthood disease.** Biochem. J. 2010; 427: 333–347

Watkins, A.J., Dias, I., Tsuro, H., Allen, D., Emes, R.D., Moreton, J., Wilson, R., Ingram, R.J.M., Sinclair, K.D **Paternal diet programs offspring health through sperm- and seminal plasma-specific pathways in mice.** Proc. Natl. Acad. Sci. U. S. A. 2018; 115: 10064–10069

Watson, L.F., Brown, S.J., Davey, M.A. **Use of periconceptional folic acid supplements in Victoria and New South Wales, Australia.** Australian and New Zealand journal of public health 2006; 30: 42–49

Received 17 November 2020; received in revised form 18 March 2021; accepted 6 April 2021.