Smartphone based lifestyle coaching modifies behaviours in women with subfertility or recurrent miscarriage: An RCT

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**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 RCT where they were randomised 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; 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 with a healthier lifestyle.

**Results**

Of the 400 women recruited, 262 women were randomised (131 in each arm). At 12 weeks, there was a reduction in CRS (includes risk score for intake of folic acid, vegetables and fruits, smoking and alcohol) in the intervention vs control arms. After correcting for baseline, the difference in the CRS between intervention and control were -0.47 (95% CI -0.97, 0.02) at 12 weeks and -0.32 (95% CI -0.82, 0.15) at 24 weeks. There was a statistically significant reduction in lifestyle risk scores in women with a BMI ≥25kg/m2 compared to those with a BMI <25kg/m2. The odds of being pregnant at 24 weeks was increased in the intervention vs control (OR 2.83, 95% CI 0.35, 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.

**Key words**

Periconception, lifestyle, lifestyle coaching, online, ehealth, smartphone

**Introduction**

The optimisation 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 ovarian syndrome. Various national and international guidelines emphasise 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 which includes the important stages of oocyte development, fertilisation, conceptus formation and implantation to 10 weeks of gestation, during which lifestyle can greatly impact on embryonic development and sustainment of a healthy pregnancy (Steegers-Theunissen et al., 2013). The Developmental Origins of Health and Disease (DOHaD) 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 optimise healthy behaviours. Of the strategies that have been tested so far, widespread implementation has not been advocated due to either high cost, limited effectiveness or underutilisation (Kerber et al., 2007; Klerman, 2006). In the UK, General Practitioners (GPs) play a role in the coordination of preconception care; however, several barriers have been identified including time constraints, lack of women presenting in the preconception stage, competing preventive priorities within the GP 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 (m-health) platforms (the practice of medicine and public health supported by mobile devices) have increased (Overdijkink et al., 2018). They are considered to represent an easily accessible and low-cost method of self-management for health care (Donker et al., 2013; Fanning et al., 2012; 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 this 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**

This prospective randomised controlled trial (the iPLAN trial ‘Impact of a Personalised Lifestyle coaching phone ApplicatioN in modifying periconceptional behaviours) aims to address the question of whether the online based lifestyle coaching application is 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 to 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 women receiving investigation/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, for example 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 randomised by the application.

**Study design**

This study was a two-centre randomised control trial of using an online smartphone application in providing lifestyle coaching and modifying lifestyle parameters in women attending the outpatient department in Princess Anne Hospital, Southampton and Salisbury District Hospital. Randomisation 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)), register and activate their account by entering their unique validation code. Women were automatically randomised 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 personalised credentials created at registration.

The ‘Smarter Pregnancy’ online lifestyle coaching platform was launched in 2012 and provides personalised 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 the 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 (Bandura, 2004; Fogg, 2009; Prochaska and Velicer, 1997). 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 (Oostingh et al., 2020; van Dijk et al., 2017b).

In the intervention arm, women had access to a personalised 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 3 per week) with feedback on progress, recommendations, tips, facts and recipes were sent to the intervention arm participants 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 were presented on a personal online page to display individual progress (comparing to previous results) and stimulate compliance. The smartphone application allowed participants to update their pregnancy status by asking this question every 6 weeks; if the subject became pregnant during the study, lifestyle advice was adapted for the pregnancy. Those randomised to the control arm had access to standard periconceptional advice provided by NHS. They were referred to a website which 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 identified 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 optimising lifestyle behaviours in the periconceptional period, through a validated lifestyle questionnaire (see Appendix 1) at 12 and 24 weeks after randomisation. Patient compliance with the programme was assessed at 12 and 24 weeks after randomisation and the proportion of women achieving natural conception during the study period was recorded. Each subject was asked to participate in the study for 24 weeks after randomisation.

**Primary and secondary endpoints**

The primary endpoint of the study was the composite dietary and lifestyle risk score at 12 weeks after randomisation. Secondary endpoints included (i) percentage of patients remainingcompliant with system at 12 and 24 weeks after randomisation, (ii) proportion achieving spontaneous conception during study period and (iii) composite dietary and lifestyle risk score at 24 weeks after randomisation. The level of compliance was defined as the percentage of participants who completed the questionnaires at specific timepoints in this study.

**Randomisation**

After completing baseline questionnaires, subjects were randomised to the intervention or control arm by computer generation of a series of validation codes unique for each participant. The randomisation 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 randomisation; personalised lifestyle advice was provided to the intervention group based on responses. The lifestyle questionnaire included assessment of folate and vitamin D intake, pregnancy status, BMI, diet (including fruit, vegetables, meat and/or meat substitutes, liver and/or liver products, 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 Appendix 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 based on 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; Oostingh et al., 2019; Twigt et al., 2012). The composite risk score (CRS) was defined as the sum of all individual risk scores for each lifestyle behaviour. A lower CRS corresponds with a healthier lifestyle. Fruit and vegetable intake were subdivided into a risk score from ‘0’ (adequate daily intake, ≥2 pieces of fruit per day and ≥200 grams of vegetable per day) to ‘3’ (inadequate daily intake, <1.5 pieces of fruit per day, <150 grams of 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 cigarettes per day), and alcohol intake was subdivided into a risk score from ‘0’ (no alcohol intake) to ‘3’ (≥ alcoholic beverages per day).

**Sample size calculation and power considerations**

In order 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 randomisation rate of 50% and a drop-out rate of 15-20%, 220 patients were randomised to each arm (440 patients recruited in total).

**Data analysis**

Prior to analysis, the data were subject to range checks, identification of extreme values (Mean +/- 3\*Std Dev) 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); a chi-squared test was used to determine the difference between control and intervention groups. For continuous variables, we present the median and the first and third quartiles of the distribution; 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 randomisation, 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, 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 performed 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 performed for overweight and obese women (BMI ≥25kg/m2).

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

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

**IRB approval**

This study was designed in compliance with the guidelines for good clinical practice (GCP and the Declaration of Helsinki 1964 as revised and recognised by governing laws and EU directives. Full ethical approval (16/YH/0129) was granted (on 23rd 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 prior to randomisation into the study as per GCP guidelines. The study is registered with ISRCTN (trial registration number 89523555, date of registration 22nd February 2018).

**Results**

A total of 440 women were recruited and 262 women were randomised into the study (Figure 1 shows the patient flow through the RCT). Only 60% of the women originally recruited were randomised due to a high proportion of participants failing to log-on to the programme despite having provided written consent to participate. Table 1 shows the baseline characteristics of those randomised to the intervention or control group. There were no significant differences 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 randomisation (Figure 2). A negative value for the difference in risk scores demonstrates a larger improvement in lifestyle in the intervention group compared to 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, 0.02) at 12 weeks and -0.32 (95% CI -0.82, 0.15) at 24 weeks. Regarding fruit intake risk score, the difference between intervention and control arms correcting for baseline was -0.14 (95% CI -0.60, 0.07) at 12 weeks and -0.21 (95% CI -0.50, 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, 0.03) at 12 weeks and 0.00 (95% CI -0.30, 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, 0.21) at 12 weeks and -0.16 (95% CI -0.42, 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, 0.10) at 12 weeks and 0.08 (95% CI -0.02, 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, 0.09) at 12 weeks and -0.02 (95% CI -0.15, 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 ≥25kg/m2 compared to those with a BMI <25 kg/m2 (Figure 3). After correcting for baseline scores, intervention group showed a smoking risk score at 24 weeks of -0.05 (95% CI -0.18, 0.00) in women with BMI ≥25kg/m2 and 0.004 (95% CI 0.00, 0.03) in women with BMI <25 kg/m2. The alcohol risk score in the intervention group was -0.21 (-0.43, -0.03) in women with BMI ≥25kg/m2 and 0.14 (-0.04, 0.36) in women with BMI <25 kg/m2. 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 randomisation was 87.4% (n=229/262, 95% CI 82.8-91.1%) and at 24 weeks after randomisation was 72.1% (n=189/262, 95% CI 66.3-77.5%). Level of compliance was defined by the percentage of participants who completed the questionnaires at specific timepoints in this study. There was no difference 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 randomisation for the intervention group vs control group is 2.83 (95% CI 0.35, 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 randomisation.

**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 randomisation into the study, and the improvement in the smoking and alcohol intake risk was particularly pronounced within the subgroup of women with a BMI≥25 kg/m2 (overweight or obese populations). There was also a statistically significant increased OR for pregnancy within the period of study for the intervention group, in comparison to the control group.

BMI and weight are closely related to reproductive function, and amenorrhoea, anovulation, subfertility and recurrent miscarriage, all occurring at higher body weights, with or without controlling for height (Bolumar et al., 1997; Cavalcante et al., 2019; Hassan and Killick, 2004; van der Steeg et al., 2008). As Barker described, the period *in utero* is one of the most critical, shaping future abilities and health trajectories (Barker, 2004); 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 (Grieger et al., 2019; He et al., 2019; Warner and Ozanne, 2010).

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 for those who are obese, have described negative experiences of the professional care they have received during preconception counselling, during their pregnancy and childbirth (Furber and McGowan, 2011; Nyman et al., 2010; Puhl and Heuer, 2009). The stigmatisation and perceived patronisation 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; Olander et al., 2013).

Studies assessing personalised and individualised 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 to improve nutritional behaviours, especially increasing vegetable intake in the periconceptional period (van Dijk et al., 2020). We have shown the use of this personalised online lifestyle coaching programme to be particularly effective in improving behaviours associated with cigarette smoking and alcohol intake in the cohort with a BMI ≥25kg/m2. The use of this self-management tool may provide effective motivation in the overweight and obese populations and may potentially avoid any negative experiences associated with interacting with a health professional, who may be perceived as patronising, judgemental or non-supportive. Digital interventions may be particularly useful in supporting disadvantaged populations because users experience less stigmatisation than conventional strategies (Dennison et al., 2014).

NHS England has published guidance 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, to make decisions about their care, giving them choice and control. This should be achieved though 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 has the potential to reach and therefore impact a large population. This study has demonstrated 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 to conventional advice offered and delivered through NHS websites. However, in this study, no differences in the compliance to the programme in those randomised to the intervention were evident compared to those randomised to the control groups. The total compliance rates at week 12 after randomisation was 87.4% and at 24 weeks was 72.1% in our 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).

This study had 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 (Oostingh et al., 2020; Van Dijk et al., 2016; van Dijk et al., 2017a). Although this study identified improvement in lifestyle risk scores at 24 weeks after randomisation, 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 randomisation and not clinical pregnancy rate. Due to the nature of the study, it was also not possible to blind women who were randomised. The women’s diet and lifestyle were self-reported through questionnaires, and although the questionnaires have been validated (Oostingh et al., 2020; van Dijk et al., 2020), it was not possible to eliminate reporting biases in our sample. The randomisation rate of 60% of the recruited women was due to participants failing to register for the programme within one week of recruitment, after which the activation code given to them was invalid. No qualitative assessment of women’s views and perceptions of the lifestyle coaching programme was made in the present study.

This personalised 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. However, further research is required to ascertain in more detail women’s attitudes to using the programme and what impact changing behaviours might have on clinical outcomes.

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**Declaration of interest statement**

“Smarter Pregnancy” is a commercial product and licenses to use the software under trial were purchased. In the last four years,NM has received grant funding and fees from Merck, Ferring, Gedeon Richter, Anecova, SLP, Abbott and ArtPred.

**Data availability**

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.

**References**

Bandura, A. (2004). Health promotion by social cognitive means. Health Educ Behav *31*, 143-164.

Barker, D.J. (2004). The developmental origins of adult disease. J Am Coll Nutr *23*, 588S-595S.

Bolman, C., and de Vries, H. (1998). Psycho-social determinants and motivational phases in smoking behavior of cardiac inpatients. Prev Med *27*, 738-747.

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

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

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

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

Efron, B., and Tibshirani, R. (1993). Introduction to Bootstrap. (Boca Raton, Florida: Chapman & Hall/CRC).

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

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

Fogg BJ (2009). A behaviour model for persuasive design. In Proeedings of the 4th international conference on persuasive technology (California USA).

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

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

Gootjes, D.V., van Dijk, M.R., Koster, M.P., Willemsen, S.P., Steegers, E.A., and Steegers-Theunissen, R.P. (2019). 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 *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., et al. (2019). Metabolic syndrome and time to pregnancy: a retrospective study of nulliparous women. BJOG *126*, 852-862.

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

Hassan, M.A., and Killick, S.R. (2004). Negative lifestyle is associated with a significant reduction in fecundity. Fertil Steril *81*, 384-392.

He, Y., Lu, Y., Zhu, Q., Wang, Y., Lindheim, S.R., Qi, J., Li, X., Ding, Y., Shi, Y., Wei, D., et al. (2019). Influence of metabolic syndrome on female fertility and in vitro fertilization outcomes in PCOS women. Am J Obstet Gynecol *221*, 138 e131-138 e112.

Homan, G.F., Davies, M., and Norman, R. (2007). The impact of lifestyle factors on reproductive performance in the general population and those undergoing infertility treatment: a review. Hum Reprod Update *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., and Steegers-theunissen, R.P.M. (2014). The Preconception Dietary Risk score; a simple tool to assess an inadequate habitual diet for clinical practice. e-SPEN journal *9*, e13-e19.

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

Klerman, L.V. (2006). Family planning services: an essential component of preconception care. Matern Child Health J *10*, S157-160.

Mazza, D., Chapman, A., and Michie, S. (2013). Barriers to the implementation of preconception care guidelines as perceived by general practitioners: a qualitative study. BMC Health Serv Res *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., and Flensner, G.E. (2010). Obese women's experiences of encounters with midwives and physicians during pregnancy and childbirth. Midwifery *26*, 424-429.

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

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

Olander, E.K., Fletcher, H., Williams, S., Atkinson, L., Turner, A., and French, D.P. (2013). 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 *10*, 29.

Oostingh, E.C., Hall, J., Koster, M.P.H., Grace, B., Jauniaux, E., and Steegers-Theunissen, R.P.M. (2019). The impact of maternal lifestyle factors on periconception outcomes: a systematic review of observational studies. Reprod Biomed Online *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., et al. (2020). 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.

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

Prochaska, J.O., and Velicer, W.F. (1997). The transtheoretical model of health behavior change. Am J Health Promot *12*, 38-48.

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

Smarter Pregnancy ([www.smarterpregnancy.co.uk](file:///C%3A%5CUsers%5Ckyn1y14%5CDesktop%5CiPLAN%20paper%5CiPLAN%20resubmission%20to%20RBMO%5CFinal%20Resubmission%5Cwww.smarterpregnancy.co.uk)) Smarter pregnancy online lifestyle coaching platform.

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

Stephenson, J., Heslehurst, N., Hall, J., Schoenaker, D., Hutchinson, J., Cade, J.E., Poston, L., Barrett, G., Crozier, S.R., Barker, M., et al. (2018). Before the beginning: nutrition and lifestyle in the preconception period and its importance for future health. Lancet *391*, 1830-1841.

Teede, H.J., Misso, M.L., Costello, M.F., Dokras, A., Laven, J., Moran, L., Piltonen, T., Norman, R.J., and International, P.N. (2018). Recommendations from the international evidence-based guideline for the assessment and management of polycystic ovary syndrome. Hum Reprod *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., and Steegers-Theunissen, R.P. (2012). The preconception diet is associated with the chance of ongoing pregnancy in women undergoing IVF/ICSI treatment. Hum Reprod *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., and Mol, B.W. (2008). Obesity affects spontaneous pregnancy chances in subfertile, ovulatory women. Hum Reprod *23*, 324-328.

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

van Dijk, M.R., Koster, M.P.H., Oostingh, E.C., Willemsen, S.P., Steegers, E.A.P., and Steegers-Theunissen, R.P.M. (2020). 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 *22*.

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

van Dijk, M.R., Oostingh, E.C., Koster, M.P., Willemsen, S.P., Laven, J.S., and Steegers-Theunissen, R.P. (2017b). 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 *17*, 46.

Warner, M.J., and Ozanne, S.E. (2010). Mechanisms involved in the developmental programming of adulthood disease. Biochem J *427*, 333-347.

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

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

**Figure and table legends**

**Figure 1-** Flowchart showing progress of participants through the trial.

**Figure 2-** Difference in composite risk scores for total lifestyle, fruit intake, vegetable intake, folic acid supplement intake, smoking and alcohol intake at 12 weeks (a) and 24 weeks (b) between intervention and control arms correcting for baseline. ‘0’ represents no difference between groups. Risk score <0 favours intervention. The error bars represent 95% confidence intervals.

**Figure 3-** Subgroup analyses by BMI. Graph shows difference in risk scores at 24 weeks correcting for baseline between intervention and control arms in 2 groups (BMI<25 or BMI ≥25). The error bars represent 95% confidence levels. \* denotes significance at the 5% level.