REVIEW ARTICLE

Holistic preconception care: Providing real-time guidance via a mobile app to optimise maternal and child health

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ABSTRACT

Introduction: Preconception is a critical period to optimise gamete function and early placental development, essential for successful conception and long-term maternal-child health. However, there is a lack of preconception services and consequently, global fertility rates continue to fall and mothers embark on their pregnancy journey in poor health. There is an urgent need to implement a holistic community-level preconception care programme to optimise risk factors for poor fecundability and improve long-term maternal-child health.

Method: We reviewed current evidence on fecundability lifestyle risk factors, the efficacy of existing preconception interventions and the use of digital platforms for health optimisation, to create a new digital-based preconception intervention model that will be implemented via an app. We present the theory, content and mode of delivery of this holistic model targeting couples planning for pregnancy.

Results: We propose a new model featuring a user-friendly mobile app, which enables couples to self-assess fecundability risks through a personalised risk score that drives a tailored management plan. This tiered management provides anticipatory guidance supported by evidence-based recommendations, and promotes ongoing engagement for behavioural optimisation and specialist referrals as required. Based on the health belief model, this new model delivered with a mobile app seeks to shift couples' perceptions about their susceptibility and severity of subfertility, benefits of making a change and barriers to change.

Conclusion: Our proposed digital-based intervention model via a mobile app stands to enhance preconception care by providing personalised risk assessments, real-time feedback and tiered management to optimise preconception reproductive health of couples. This model forms a reference content framework for future preconception care intervention delivery.

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INTRODUCTION

Global fertility rates have decreased by more than half since 1950, recorded at 2.3 births per woman in 2021.[1] By 2056, this figure is projected to decline further to 2.09, which falls below the replacement fertility rate of 2.1 children per woman.[1] In Singapore, the fertility rate has reached a historic nadir of 1.05 in 2022.[2] The repercussions of such ultra-low fertility are enormous, including a decline in human capital. In developed countries like Singapore, this trend has precipitated an ageing

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CLINICAL IMPACT

What is New

- We propose a new holistic couples-based preconception care programme that optimises lifestyle and sexual health using a mobile health app to be integrated within the framework of the Healthy Early Life Moments in Singapore (HELMS) initiative.
- The programme involves a comprehensive reproductive health self-assessment, which provides a personalised fecundability risk score to guide triaged care and intervention.

Clinical Implications

- Implementation of the programme via a digital platform allows for real-time guidance and timely intervention to improve fecundability in the short-term.
- Intervention during the critical preconception period can better safeguard maternal-child health outcomes in the long-run.

population, characterised by a diminished old-age support ratio and a reduced influx of individuals into the workforce.[3] Consequently, this portends adverse societal and economic outcomes.[4] The fertility rate is affected by a number of factors, encompassing biological, psychological, social and environmental determinants. Various risk factors, including lifestyle and sexual health have been associated with poor fecundability,[5] which refers to a reduced probability of spontaneous conception within a cycle as indicated by an extended time to pregnancy. Herein, we aim to present contemporary evidence on risk factors associated with poor fecundability and draw insights from the 2 largest birth cohorts in Singapore. We also propose an individualised preconception model to be implemented and delivered via a mobile health (mHealth) platform, to improve fertility in couples and promote better maternal-child health outcomes in the long-run.

METHOD

We reviewed the current evidence on lifestyle risk factors impacting fecundability, the efficacy of existing preconception interventions and the use of mHealth platforms for health optimisation, to create a new holistic preconception intervention model. The approach was non-systematic to obtain a broad overview of the field, and synthesise significant developments and emerging trends into a tangible interventional programme that can be used as a reference model.

The primary source of our review was PubMed, which was supplemented with information from government reports and World Health Organization guidelines. Search themes included risk factors of low fecundability, current gaps in preconception fecundability interventions and the efficacy of mHealth apps in health optimisation. Publications were selected based on their relevance to our objectives, and priority was given to articles published in the last 5 years to ensure contemporary relevance. The evidence was then synthesised to provide novel insights, presented in the Results section below.

RESULTS

Risk factors for low fecundability

Multiple factors can negatively affect fecundability.[5] A well-established factor is advanced parental age, which reduces fecundability. The emphasis on education and career progression has led to a trend of delayed maternal age at first pregnancy, impacting fertility dynamics.[6] Another notable phenomenon, particularly prevalent in developed nations, is the rise of metabolic health issues. Shifting dietary choices towards high-calorie fast foods and adopting sedentary lifestyles have exacerbated the global obesity and metabolic disorder epidemic, further worsening fecundability.[7] Additionally, the detrimental effects of smoking and excessive alcohol consumption on fecundability are well-documented.[8] In 2022, tobacco smoking rates remained at 22.3%,[9] and the global average alcohol consumption reached 6.2 litres per person per year among those aged 15 years or older.[10] Sexual dysfunction, influenced by factors including fertility challenges, gynaecological and andrological conditions, and ongoing medications has been associated with prolonged time to pregnancy.[11] Globally, 51% of adults reported insufficient sleep due to intensified work demands, contributing to the landscape of factors affecting fecundability. The escalation in mental health deterioration, both as a contributing factor and a consequence of reduced fecundability, is noteworthy. Global survey indicates that 41% of adults have experienced significant stress, while 42% reported substantial worry.[12] Finally, while the aforementioned factors offer avenues for modification through advocacy and education, current maternal-child health systems across the globe are primarily structured to prevent unintended pregnancies, manage infertility and address medical conditions during pregnancy via routine antenatal care visits.[13]

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Evidence from 2 mother-offspring cohorts in Singapore

Similar findings have been reported from 2 large prospective cohorts in Singapore, namely the Singapore PREconception Study of long-Term maternal and child Outcomes (S-PRESTO) and the Growing Up in Singapore Towards healthy Outcomes (GUSTO) cohorts.[14,15] These cohorts collectively suggest a reciprocal relationship between metabolic syndrome, suboptimal body mass index (BMI), female sexual dysfunction and mental health concerns, culminating in subsequent implications on reproductive function (Fig. 1).[14] Furthermore, these factors are now known to underpin adverse maternal and child health outcomes over the long run.[16]

The preconception period

The preconception phase represents a critical period to optimise gamete function and facilitate early placental development for successful conception.[17] Achieving optimal health during the preconception window is crucial for long-term maternal-child health outcomes.[17] However, it is concerning that a substantial 44% of pregnancies globally are unplanned.[18] Moreover, the prevalence of inadequate nutrition and obesity is alarmingly widespread worldwide.[19] In Singapore, 43% of women are overweight or obese and 18% have metabolic syndrome at preconception.[20] These factors contribute to compromised preconception health, which has far-reaching implications, spanning pregnancy complications to long-term child health, as substantiated by the Developmental Origins of Health and Disease (DOHaD) paradigm.[21]

Overall, there is an urgent need to translate knowledge into action and implement a holistic preconception intervention that optimises lifestyle and sexual health factors to improve fecundability in the short-run, as well as maternal-child health in the long-run.

Gaps in current preconception interventions

Despite a pressing need for a preconception care programme, Singapore's current healthcare lacks such an initiative. Internationally, preconception care programmes can be categorised as: (1) multi-risk factor interventions; (2) technology-assisted

Fig. 1. Preconception exposures and maternal-child health outcomes. Preconception health risks (i.e. suboptimal body mass index (BMI), undesirable metabolic profile, female sexual dysfunction risk and mental health issues) and related unhealthy lifestyle behaviours as observed in Singapore women who are trying to conceive can coexist and influence each other. These have adverse implications on fecundability, obstetric and long-term mother-child health outcomes, specifically risks of metabolic and mental/neurodevelopmental disorders. Boxes in pink represent preconception risk factors. These findings are based on the S-PRESTO and GUSTO studies, with each cohort involving approximately 1000 preconception and pregnant women.[14,15]
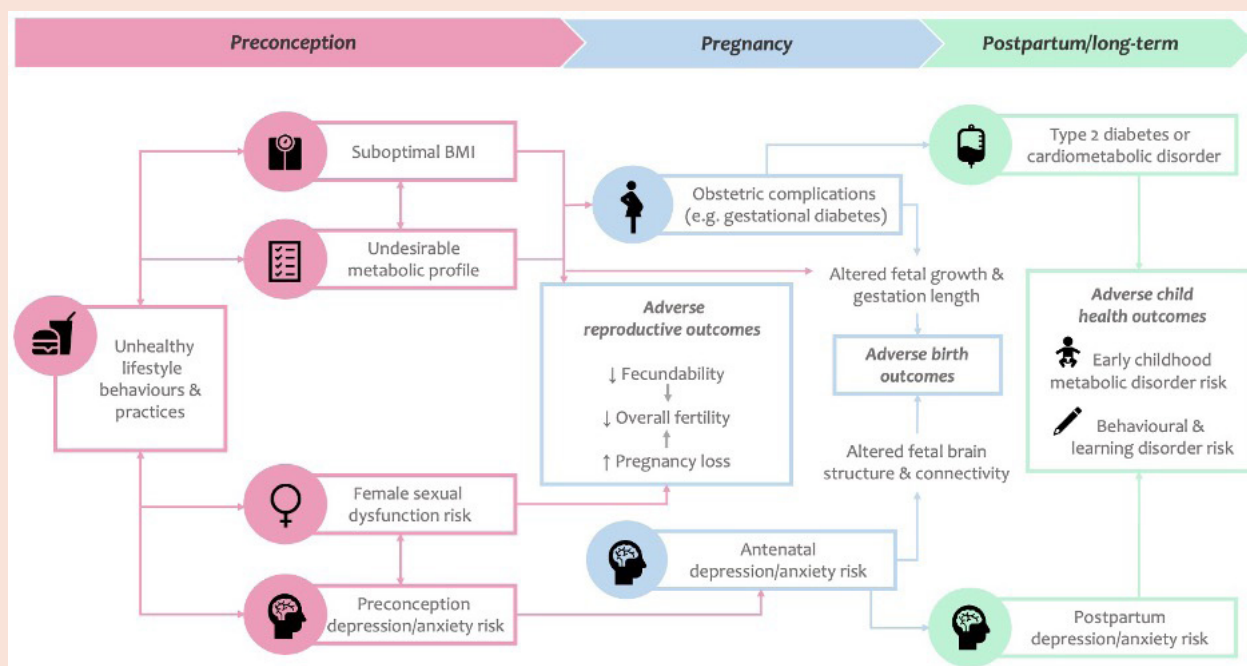
S-PRESTO: Singapore PREconception Study of long-Term maternal and child Outcome; GUSTO: Growing Up in Singapore Towards healthy Outcomes
Superscript numbers: refer to REFERENCES

interventions; (3) targeted counselling for women with pre-existing medical conditions; (4) group-based health education; (5) community-driven social marketing initiatives; and (6) interpregnancy interventions.[22] However, these existing strategies bear notable constraints in that they often emphasise individualised over population-wide approaches and adopt short-term pathology-centric perspective over long-term holistic well-being within preconception care. To holistically optimise reproductive health, both partners should be integrated into the approach.[23] Preconception health can be viewed through a life-course lens that encompass the cumulative impact of lifestyle behaviours and social determinants on fecundability.[24] Furthermore, a prevailing limitation lies in the conventional face-to-face delivery of existing programmes, which impedes scalability to a broader population level.

Effectiveness of mobile health (mHealth) for community health promotion

The utilisation of mHealth platforms has demonstrated effectiveness in promoting desired lifestyle behaviour changes compared to conventional health programmes. This innovative approach empowers individuals to proactively navigate their preconception journey, offering a sustainable avenue to enhance the overall preconception health of the population. Beyond this, mHealth platforms serve as an effective and convenient medium for diverse healthcare functions, including disease screening, treatment, rehabilitation, behaviour modification and chronic condition management. Specifically, for pregnancy care, mHealth apps have proven efficacious in optimising maternal health, including weight management, gestational diabetes mellitus control and improving maternal mental health.[25] Recent findings from a systematic review and meta-analysis that focused on Asian popula-tions indicate that integrating a personalised mhealth app with multifactorial standard care resulted in more substantial weight loss than what was observed with either intervention independently.[26] mHealth represents a secure and sustainable means to deliver preconception care, facilitate discrete guidance for couples throughout their journey to conceive and enable timely health interventions. This is especially important as fecundability is often shrouded in deep-seated social stigma, which can incite shame, secrecy and delay the time to healthcare. In tandem with preserving privacy, the convenience of mobile apps extends the potential for engagement and outreach. Moreover, the concurrent engagement of various participants through mHealth generates a community effect, motivating couples to work towards their goals.

Emerging data from pilot apps indicate notable user engagement and uptake rates. Specifically, the Smartphone App to Restore Optimal Weight trial in Singapore maintained high user-app engagement with 70.8% and 60.8% of participants using at least 1 feature in the first and fourth month, respectively.[27] Furthermore, a systematic review and meta-analysis on mobile health apps' impact on health behaviours and clinical outcomes indicated that 80% of the studies observed a positive effect, with a marked increase in user satisfaction.[28] Fundamental characteristics that lead to the success of such mobile health apps include personalisation, adaptive and timely feedback, option to engage with a healthcare provider, culturally adapted practices and information, and the ability to track health behaviour.[29] All the aforementioned factors have a role to play in fostering strong adherence and user engagement, leading to the long-term sustainability of such platforms.

A holistic preconception intervention model

There is currently a lack of preconception services available for couples globally and in Singapore. Other than BMI assessment, most of the aforementioned health risks are under-evaluated in couples who are trying to conceive, despite their significant prevalence. Hence, it is imperative to develop a preconception intervention tailored to provide guidance and support for couples who possess the time and opportunity to strategically plan conception. This initiative aligns seamlessly with Singapore's revised healthcare masterplan, characterised by a shift from healthcare provision to health promotion.

Thus, we propose a focused couples-centric preconception self-assessment and management model, integrated within the framework of the Healthy Early Life Moments in Singapore (HELMS) initiative.[30] HELMS is a new model of care that aims to optimise maternal and offspring health outcomes in the general population by optimising preconception metabolic and mental wellness. In a preliminary stage, HELMS piloted a lifestyle intervention delivered via an mHealth platform, catering to overweight/obese women. This effort aims to improve metabolic and mental health of women from preconception until 18 months postpartum, potentially enhancing fecundability, pregnancy experiences as well as maternal-child outcomes.[30]
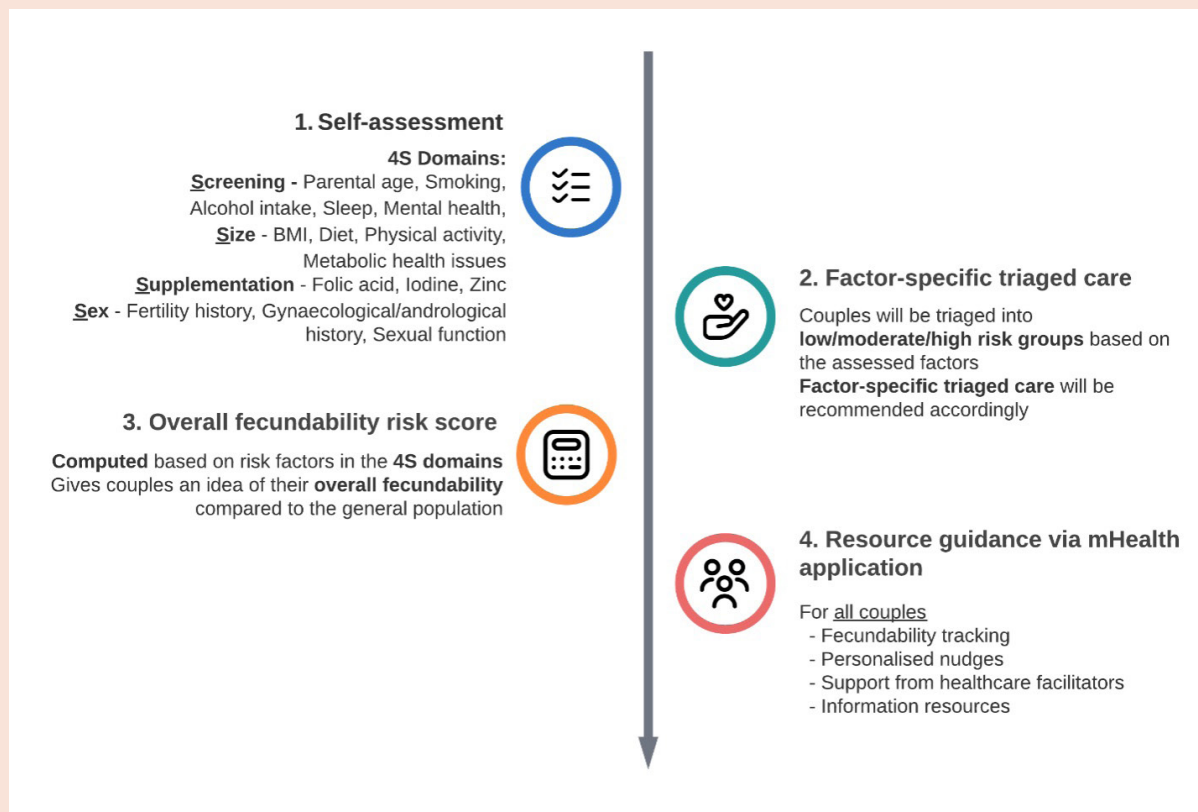
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Adopting a personalised approach for all preconception couples, we have developed a comprehensive reproductive health evaluation programme conducted through an mHealth app. The development of this programme draws upon the health belief model, which is based on the framework of perceived susceptibility, perceived severity, health motivation, perceived benefits, perceived barriers and eventual action taken by the target group.[31] Such an intervention model seeks to reshape couples' perceptions regarding their reproductive health (perceived susceptibility) by first, engaging couples in a self-assessment component where they are screened for lifestyle and sexual health factors through self-administered questionnaires within the mHealth platform or biochemical tests conducted in the primary care setting. The responses from these evaluations are subsequently uploaded onto the mHealth platform (see section 1. Self-assessment). This aims to highlight areas of higher fecundability risk (perceived severity) to the couples. Depending on the identified factors spanning the 4S domains, the programme dispenses personalised guidance

and targeted care, disseminated either through mHealth or via appropriate referrals (see section 2. Factor-specific triaged care). The culmination of this preconception health appraisal is the establishment of a fecundability risk score, which informs the couple's fecundability risk profile (see section 3. Overall fecundability risk score). The benefits of making changes, which would be in this case, increased chances of successful conception, is then emphasised to the couples (perceived benefits). The provision of targeted guidance will hopefully reduce the barriers to change (perceived barriers) for the couples and heighten motivation for them to proactively improve their fecundability.[31] Ongoing app engagement (health motivation) solidifies this process, offering resourceful guidance for action to be taken by the couples (see section 4. Resource guidance via mHealth app) (Fig. 2).

1. Self-assessment

The self-assessment process employs the comprehensive screening, size, supplementation and sex (4S) care strategy during preconception

Fig. 2. Framework and procedures of preconception care based on the Healthy Early Life Moments in Singapore (HELMS) programme. The process begins with couples undergoing self-assessment via an mHealth app, employing the 4S domains as the foundation. Subsequently, couples will be triaged and receive pertinent suggestions or necessary referrals according to their distinct factor-specific risks. The culmination of this assessment yields a composite fecundability risk score, enabling couples to benchmark their fecundability against the broader population, thereby gauging their comparative fertility level. Continuous guided intervention creates a supportive environment to steer and navigate couples through their preconception journey.

1. Self-assessment

4S Domains:
Screening - Parental age, Smoking, Alcohol intake, Sleep, Mental health,
Size - BMI, Diet, Physical activity, Metabolic health issues
Supplementation - Folic acid, Iodine, Zinc
Sex - Fertility history, Gynaecological/andrological history, Sexual function

2. Factor-specific triaged care

Couples will be triaged into **low/moderate/high risk groups** based on the assessed factors
Factor-specific triaged care will be recommended accordingly

3. Overall fecundability risk score

Computed based on risk factors in the **4S domains**
Gives couples an idea of their **overall fecundability** compared to the general population

4. Resource guidance via mHealth application

For all couples
- Fecundability tracking
- Personalised nudges
- Support from healthcare facilitators
- Information resources

(Fig. 2). This couples-oriented approach systematically covers critical factors influencing fecundability, identifies areas necessitating improvement and offers tailored interventions to individual patients.[24,30]

Screening (lifestyle factors and mental health)

Screening for the couple's age, lifestyle, sleep and mental health allows early detection and intervention to improve preconception health and fecundability, and prevention of transgenerational effects of poor parental health on their future offspring.

Advanced parental age, a non-modifiable risk factor, is recognised for its influence on subfertility.[5] Although age remains unmodifiable, screening for age equips couples with insights into their fecundability profile. Concurrently, it serves as an educational avenue, apprising couples of the detrimental ramifications of advanced age on fecundability. Such awareness empowers couples to contemplate initiating conception sooner, thus enabling more informed family planning decisions. Apart from age, lifestyle behaviours such as smoking and alcohol consumption have detrimental effects on fecundability, underscoring the need for holistic screening encompassing type, amount, and duration of these practices.[8] Additionally, sleep plays a significant role in fecundability. Screening tools such as the Pittsburgh Sleep Quality Index (PSQI) facilitates identification of individuals at elevated risk, indicated by a PSQI score ≥5.[32] Lastly, mental health is correlated with fecundability. Mental wellness can be influenced by perceived stress levels, presence of psychiatric disorders and sleep health. Perceived stress can be assessed using the Perceived Stress Scale (PSS),[33] a 10-question screening tool with a total score of 40. Scores are categorised as low (PSS score 0–13), moderate (PSS score 14–26) and high (PSS score 27–40) levels of stress. Psychiatric disorders, such as major depressive disorder, negatively impact fecundability. The severity of depressive symptoms was inversely associated with fecundability, regardless of the use of psychotropic medications, highlighting the need to diagnose and treat underlying psychiatric disorders as part of a holistic preconception programme.[34] The Edinburgh Postnatal Depression Scale (EPDS) is a 10-item tool that can be used with a 3-tier risk stratification system: probable depression (EPDS score ≥14), possible depression (EPDS score 10–13) and unlikely depression (EPDS score ≤9).[35,36]

Size (weight optimisation with diet, physical activity and metabolic risk factor management)

Body size optimisation involves weight monitoring coupled with personalised adjustments in dietary choices and physical activity regimens based on self-determined goals, and management of metabolic risk factors. Positive weight management outcomes are closely tied to adopting eating habits that incorporate a diverse range of foods in controlled portions, as recommended by My Healthy Plate, a visual guide to plan healthy meals by Singapore's Health Promotion Board.[37] This includes a diet low in fats and calories, minimising the intake of fast food and sugar-sweetened beverages,[38] while emphasising ample consumption of fresh fruits,

vegetables, nuts and healthy oils for a balanced nutritional profile.[39] Beyond these guidelines, there should also be a stronger emphasis on reducing calorie-dense snacks,[40] chrono-nutrition that advocates caloric restriction at night when resting metabolic rate is low[41] and considering motivation to drive long-term sustainable behavioural change.[40]

Physical activity is a pivotal driver of metabolic health, conferring a number of health benefits including enhanced metabolic and mental well-being, and perceived quality of life.[42] The World Health Organization advocates a weekly minimum of 150 minutes of moderate intensity or 75 minutes of vigorous intensity physical activity, which is linked to positive outcomes.[43]

The synergy of nutritional interventions and augmented physical activity manifests within the validated intervention tool, which streamlines eating and activity decisions into 6 distinct factors: portion, proportion, pleasure, phase, physicality and psychology (i.e. the 6P tool) (Table 1).[40] This forms an intuitive mental model that couples can utilise to screen, understand, monitor and modify their eating and activity habits. This is largely guided by the Theory of Planned Behaviour, which emphasises the role of attitude, subjective norms and perceived behavioural control on human behavior.[44] By rationalising the components that make up healthy eating patterns, the 6P tool seeks to enable behavioural modification such that couples are empowered to set their own 6P goals and take control of and improve their current eating habits.

Metabolic screening includes biomarker assessments, specifically glucose and lipid profiles. Results are automatically integrated into individual profiles, enabling timely recognition and intervention for metabolic syndrome,[45] a precursor to potential health issues.

Supplementation (micronutrients)

Multi-micronutrient supplementation is recommended for couples during preconception. The intervention incorporates an educational platform emphasising supplementation requirements and

Table 1. Components of the portion, proportion, pleasure, phase, physicality and psychology (6P) tool (adapted from Ku et al. 2021).[40]

	6P	Description
P1	Portion	Amount of food intake
P2	Proportion	Caloric-density of food intake
P3	Pleasure	Frequency of snacks and sugar-sweetened beverages and meal regularity
P4	Phase	Time of day of food intake
P5	Physicality	Physical activity and sedentary behaviour
P6	Psychology	Readiness for change

significance to foster adherence.[46] Micronutrient supplements such as folic acid,[47] iodine,[47] zinc, and vitamin D[48] have been associated with improved fecundability and/or multiple obstetric and postnatal outcomes. Individuals log daily supplement intake on the app, with tracking facilitated through the digital tracker function, thus promoting sustained adherence.

Sex (sexual health and function)

Last, sexual health and function are important considerations in the preconception stage. Marital relationship quality and the overall reproductive health of the couple dictate sexual health optimisation. Evaluation includes (1) fertility history, (2) gynaecological or andrological history, and (3) sexual function.

Fertility history includes the period of trying to conceive , intercourse frequency and history of recurrent pregnancy loss and/or miscarriages. Couples attempting to conceive for over a year despite regular unprotected intercourse, or encountering 2 or more consecutive clinical pregnancy losses, will receive triaged care and directed to a specialist fertility assessment. Concurrently, all couples are encouraged to engage in optimal behavioural practices for conception, including regular unprotected sex every 2–3 days,[49] timed intercourse within a week of ovulation,[50] and early initiation of conception.

Gynaecological history involves screening for history of sexually transmitted diseases (STDs), pelvic or abdominal surgeries, as well as gynaecological medical conditions. STDs such as *Chlamydia trachomatis* and *Neisseria gonorrhoeae* contribute to tubal factor infertility.[51] Gynaecological conditions potentially impeding fecundability encompass ovarian dysfunction (e.g. polycystic ovarian syndrome), uterine structural abnormalities (e.g. bicornuate uterus) or pathology (e.g. fibroids), cervical abnormalities, fallopian tube dysfunction and endometriosis.[52] Past pelvic or abdominal surgery may result in pelvic adhesions, which

adversely impacts fecundability. Andrological history includes identifying past genital trauma. Testicular injury may be due to mechanical trauma or a previous mumps infection,[53] both of which have been shown to increase the risk of subfertility. Medications potentially affecting fecundability are examined, considering direct toxic effects or indirectly through the alteration of the reproductive hormonal axis.[54]

Sexual health investigation involves screening for sexual dysfunction. Female sexual dysfunction can be assessed via the 6-Item Female Sexual Function Index;[55] while male sexual function can be evaluated using the International Index of Erectile Functiontool.[56]

In sum, the preconception self-assessment module requires approximately 30 minutes for completion and serves as an approximate baseline profile of the couple's health status.

2. Factor-specific triaged care

A dual-tier scoring system is implemented, stemming from the reproductive health assessment, i.e. the factor (F) score and an overall fecundability risk score. Guided by the 4S screening and intervention strategy, each individual's risk profile is quantified through the F score, stratifying across distinct risk levels aligned with established clinical guidelines. This represents a triage process to navigate subsequent management decisions (Table 2). Low-risk individuals are encouraged to engage with the mHealth app to track their fecundability journey. Moderate-risk individuals are offered follow-up care in the primary care setting where they will be guided to make lifestyle modifications and optimise health. High-risk individuals are referred to tertiary care, such as fertility specialists for comprehensive fertility consultations and evaluations, or relevant specialists for more intensive intervention.

3. Overall fecundability risk score

The composite score of all factors, termed the fecundability risk score, estimates the potential impact of the overall factors on fecundability and

Table 2. A multi-level scoring system will be used to be used to triage a user using the 4S screening and intervention strategy as framework (screening, size, supplementation and sex). Each individual will receive a factor-specific score (F score) based on a relevant screening tool and receive triaged care accordingly. The amalgamation of all factor-specific scores and the fecundability risk score will serve as visual/numeric guides for couples to track and compare their progress.

Preconception model	Factor	Screening tool	Factor (F) scoring system
Screening	Parental age	Preconception screening form	• Score of 0: Maternal age <35 years • Score of 1: Maternal age ≥35 years
	Lifestyle: Smoking	Preconception screening form + continuous app engagement	• Score of 0: Non-smoker • Score of 1: Smoker
	Lifestyle: Alcohol intake	Preconception screening form + continuous app engagement	Yes/no, type of alcohol, quantity & frequency
	Lifestyle: Sleep health	Pittsburgh Sleep Quality Index (PSQI) [32]	• Score of 0: PSQI score <5 • Score of 1: PSQI score ≥5
	Mental health: (a) Stress	Perceived Stress Scale (PSS) [33]	10-question screening tool of perceived stress levels with a total score of 40: • Score of 0: Low (PSS score 0–13) • Score of 1: Moderate (PSS score 14–26) • Score of 2: High (PSS score 27–40)
	Mental health: (b) Psychiatric disorders, e.g. major depressive disorder	Edinburgh Postnatal Depression Scale (EPDS)[35]	A 10-item tool that can be used with a 3-tier risk stratification system: • Score of 0: Unlikely depression (EPDS score ≤9). • Score of 1: Possible depression (EPDS score 10–13) • Score of 2: Probable depression (EPDS score ≥14)
Size	Body mass index (BMI)	Singapore Health Promotion Board BMI Guidelines	• Score of 0: Low risk (BMI <22.9) • Score of 1: Moderate risk (BMI 23–27.5) • Score of 2: High risk (BMI >27.5)
	Diet	6P tool: Portion, proportion, pleasure, phase, physicality and psychology[40]	• Score of 0: >50% • Score of 1: <50%
	Physical activity	World Health Organization (WHO) Physical Activity Vital Sign[43]	• Score of 0: Green/highly active (≥150 minutes of moderate or ≥75 minutes of vigorous activity/week) • Score of 1: Amber/minimally active (<150 minutes of moderate or <75 minutes of vigorous activity/week)
	Metabolic health issues	WHO Metabolic Syndrome (MetS) Diagnostic Criteria[57] In-person metabolic screen of glycaemic and lipid profiles	• Score of 0: No metabolic syndrome • Score of 1: Presence of metabolic syndrome
Supplementation	Folic acid, iodine and zinc	Preconception screening form + continuous app engagement	• Score of 0: Adequate supplementation (individualised dose) • Score of 1: Inadequate supplementation (individualised dose)

Table 2. A multi-level scoring system will be used to be used to triage a user using the 4S screening and intervention strategy as framework (screening, size, supplementation and sex). Each individual will receive a factor-specific score (F score) based on a relevant screening tool and receive triaged care accordingly. The amalgamation of all factor-specific scores and the fecundability risk score will serve as visual/ numeric guides for couples to track and compare their progress. (Cont'd)

Preconception model	Factor	Screening tool	Factor (F) scoring system
Sex	Fertility history	Preconception screening form + continuous app engagement	• Score of 0: Individuals who do not fulfil the infertility criteria • Score of 1: Individuals who have been trying to conceive for >1 year despite regular unprotected sexual intercourse, or with two or more consecutive clinical pregnancy losses will be considered high risk.
	Gynaecological & andrological history	Preconception screening form + Continuous app engagement	• Score of 0: No concerning gynaecological or andrological history • Score of 1: Any concerning gynaecological or andrological history
	Sexual function	6-Item Female Sexual Function Index (FSFI-6)[55]	• Score of 0: FSFI-6 score of >26 • Score of 1: FSFI-6 score of ≤26
		International Index of Erectile Function (IIEF)[56]	• Score of 0: IIEF score of ≥12 • Score of 1: IIEF score of 8–11 • Score of 2: IIEF score of 5–7
Total composite score (taking into account all previous sections)			
Fecundability risk score	Low risk: 0- 33% Moderate risk: 34–66% High risk: 67–100%		

Superscript numbers: refer to REFERENCES

serves as a visual/numeric guide for couples to track and compare their progress. The 4S self-assessments are used to compute the fecundability risk score. Using data from the S-PRESTO study, fecundability was found to be reduced in women with higher-risk score levels.[5] However, this risk score system only considered maternal factors and neglected paternal factors. Herein, we suggest a more comprehensive fecundability risk score that considers combined maternal and paternal factors relevant to fecundability.

4. Resource guidance via mHealth app

The triage care system and corresponding information guidance are delivered via mHealth, enhancing accessibility to personalised and continuous care via the support, inform, guide and nudge (SIGN) approach.[24] Users stand to benefit from timely digitalised health support and interventions resulting from continuous health status monitoring. At the same time, users gain insights into pertinent preconception topics, such as diet, exercise, mental wellness and sleep hygiene through digestible educational bites. Individuals are empowered to attain lifestyle modification goals through habit trackers; while real-time,

tailored-made performance feedback generated by the mHealth algorithm enables users to dynamically monitor their health and behaviour. Nudges, aligned with individual lifestyle goals, guide users toward favourable trajectories. This framework is applicable to both couples who are trying to conceive and couples who are considering conception soon. For couples currently not attempting conception, this preconception programme functions as an extended preparatory phase, fostering familiarity with preconception facets and facilitating health optimisation well ahead of conception intention.

DISCUSSION

Taken together, a modifiable risk factor-based self-assessment approach, with the 4S screening and intervention strategy, along with a personalised fecundability risk score for both the individual and the couple, can be utilised to triage preconception couples, and provide anticipatory guidance and support in their preconception journey. A substantial demand for improved preconception care underscores the significance of timely, relevant information and an encompassing delivery framework with sustained engagement.[58] The

HELMS programme was designed to address these pivotal factors and more. First, a user-friendly mobile app offers a unified hub for couples to access educational materials and personalised nudges, enhancing the accessibility of essential information during their preconception journey. The concurrent engagement of numerous participants on the app generates a community effect, fostering motivation among couples to pursue their individual objectives. Second, the private nature of self-assessment enhances objectivity and the uptake of the derived fecundability risk score. The secure environment mitigates apprehensions about judgment or stigma, encouraging greater participation and informed awareness of their fecundability risk profiles. [59] Third, the triaged care model ensures targeted interventions, increasing the effectiveness of this programme. Couples have the option of following the recommendations provided by mHealth or seeking relevant medical advice at their own discretion. This patient-centric approach empowers couples to actively shape their preconception journey. Last, the programme embraces a personalised approach that is accessible to the wider population. It aims to identify individuals who may be unaware of their fecundability risks and provide customised interventions, thus ultimately promoting healthier families and communities.

However, possible challenges must be acknowledged. Foremostly, the successful adoption of the HELMS preconception programme hinges on couples' proactive engagement in self-assessment and subsequent action. Barriers such as time constraints and perceived relevance could hinder adherence. To overcome these obstacles, the mobile app provides convenience and privacy, reinforced by ongoing nudges and healthcare support with primary care collaboration being essential for community education and empowerment. Beyond personal barriers, there are societal determinants as part of the socioecological model of behavioural change[24] beyond the individual's control. To this end, the app allows for participants to choose actionable goals to achieve. Furthermore, an increased healthcare system burden is plausible. The programme encourages comprehensive screening to identify potential fecundability risk factors, possibly leading previously generally well couples to seek medical advice. The triaged approach, however, directs couples to appropriate healthcare partners and promotes self-modification to lifestyle before specialist consultation, thus balancing system demands. Besides, healthcare professionals might not be equipped with the skills or may be reluctant to consider the DOHaD approach when caring for their patients. Adequate

training will ensure that primary care physicians and specialists alike are more familiar with preconception care and are better equipped to manage preconception concerns. [60] Last, a lack of access to digital devices might prevent certain groups from reaping the benefits of this mHealth app. Nonetheless, this is unlikely to pose a significant challenge, as the mobile penetration rate has reached 95.4% in Singapore in 2023.[61] Furthermore, the app's design does not differentiate based on users' educational backgrounds, presenting a risk of unequal information accessibility. To address this, the design incorporates a user-friendly interface with visual cues and straightforward language to ensure clarity and ease of use for all. We also intend to pilot the app in English, with plans to diversify language options progressively. Hence, this mHealth app and preconception programme will be accessible to most of the population. Despite potential challenges, optimising health upstream through preconception care holds the promise of substantial long-term cost savings by mitigating chronic disease development and its associated costs.

CONCLUSION

Given the global decline in fertility rates and the rising burden of non-communicable diseases, a holistic preconception programme becomes imperative to address modifiable risk factors and improve couples' preconception health. This preconception programme adopts a modifiable risk factor-based self-assessment approach, along with the 4S screening and intervention strategy encompassing screening, size, supplementation and sex. Bolstering this framework is the introduction of a personalised fecundability risk score for both individuals and couples, which serves to triage and provide them with insightful foresight and support throughout their preconception journey. Successful implementation of this programme requires strong collaboration at individual, interpersonal, community, institutional and national levels. By providing couples with a strong foundation in their preconception journey and influencing each life course, it is hoped that each child will receive the best start in life as well as ultimately achieving a population with healthy life cycles.

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