## **Holistic Preconception Care: Providing Real-Time Guidance via a Digital Platform to Optimise Maternal and Child Health**

## **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 programme to optimise risk factors for poor fecundability and improve long-term maternal-child health.

**Method**: This article reviews current evidence on fecundability lifestyle risk factors, the efficacy of existing preconception interventions, and the use of mHealth platforms for health optimization, to create a holistic preconception intervention model. We present the theory, content, and mode of delivery of a novel digital-based preconception intervention model targeting couples planning for pregnancy in the community.

**Results**: This model features a user-friendly digital platform that enables couples to self-assess fecundability risks, producing a personalized risk score that drives a tailored management plan. This tiered management will provide anticipatory guidance supported by evidence-based recommendations and promote ongoing engagement for behavioural optimisation and specialist referrals as required. Based on the health belief model, this 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 stands to enhance preconception care by providing personalized 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 in the community.

**Clinical Impact**

**What’s New**

* This holistic couples-based preconception care programme optimises lifestyle and sexual health factors using a mobile health application.
* The programme involves a comprehensive reproductive health self-assessment, which culminates in a personalized fecundability risk score that guides triaged care and intervention.

**Clinical Implications**

* Implementation of the programme via a digitalised platform allows for real-time guidance and timely intervention to improve fecundability in the short-term.
* By intervening during the critical preconception period, the programme will also promote better maternal-child health outcomes in the long-run.

**Tweetable abstract**

Introducing a comprehensive digitalised preconception couples-based screening and triaged care programme for better fertility and long-term health optimization.

### **INTRODUCTION**

Globally, fertility rates have decreased by more than half since 1950, with the global fertility rate in 2021 recorded at 2.3 births per woman[.](https://www.zotero.org/google-docs/?broken=lETPdH)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, fertility rates have 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 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 concerning risk factors associated with poor fecundability, drawing insights from the two largest birth cohorts in Singapore. Furthermore, we propose an individualized preconception model, to be delivered via a mobile health (mHealth) platform, to improve fertility in couples and promote better maternal-child health outcomes in the long-run.

**METHOD**

This article aims to review the current evidence on fecundability lifestyle risk factors, the efficacy of existing preconception interventions, and the use of mHealth platforms for health optimization, to create a holistic preconception intervention model. The approach is non-systematic, intending to provide a broad overview of the field, synthesizing significant developments and emerging trends into a tangible interventional program that can be used as a reference model.

The primary sources included academic databases like PubMed, 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 applications in health optimization. Publications were selected based on their relevance to the article's objectives, and priority was given to articles published in the last five years to ensure contemporary relevance. The evidence was then synthesized to provide novel insights, presented in the Results.

**RESULTS**

**Risk Factors for Low Fecundability**

Multiple factors exert a negative influence on fecundability.5 Advanced parental age, a well-established factor, is associated with reduced fecundability. The contemporary 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%,9and 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.12Finally, 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

**Evidence from Two Mother-Offspring Cohorts in Singapore**

Similar findings have been reported from two 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).14, 15 These cohorts collectively suggest a reciprocal relationship among metabolic syndrome, suboptimal body mass index (BMI), female sexual dysfunction, and mental health concerns, culminating in subsequent implications for reproductive function **(Figure 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 for optimising gamete function and facilitating 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 preconception women are overweight or obese, and 18% have metabolic syndrome.20{Loy, 2018 #35} These factors contribute to compromised preconception health, which has far-reaching implications, spanning from pregnancy complications to the long-term child health, as substantiated by the Developmental Origins of Health and Disease (DOHaD) paradigm.21

Taken together, 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 programme, Singapore’s current healthcare framework lacks such an initiative. Internationally, preconception care programmes can be categorised as: (i) multi-risk factor interventions, (ii) technology-assisted interventions, (iii) targeted counselling for women with pre-existing medical conditions, (iv) group-based health education, (v) community-driven social marketing initiatives, and (vi) interpregnancy interventions.22 However, these existing strategies bear notable constraints: they often emphasise individualised over population-wide approaches and adopt a short-term, pathology-centric perspective rather than prioritising long-term holistic well-being within preconception care. Recognising the imperative to holistically optimise reproductive health, both partners should be integrated into the approach23, addressing preconception health through a life-course lens to 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 these programmes, impeding their scalability to a broader population level.

**Effectiveness of Mobile Health for Community Health Promotion**

The utilisation of mobile health (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 for enhancing 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, within the realm of 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 (SRMA) focused on Asian populations indicate that integrating a personalized mobile health application 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 for delivering preconception care, facilitating discrete guidance for couples throughout their journey to conceive, and enabling timely health interventions. This is especially important as fecundability is often shrouded in deep-seated social stigma, which can breed shame, secrecy, and delay the time to healthcare. In tandem with preserving privacy, the convenience of mobile apps extends the potential for community engagement and outreach. Moreover, the concurrent engagement of various participants through mHealth generates a community effect, motivating individual couples to work towards their own goals.

Emerging data from pilot applications indicate notable user engagement and uptake rates. Specifically, the SPAROW trial in Singapore maintained high user-app engagement with 70.8% of participants using at least one feature in the first month and 60.8% in the fourth month.27 Furthermore, a systematic review and meta-analysis (SRMA) 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 personalization, adaptive and timely feedback, option to engage with a healthcare provider, culturally adapted practices and information, and the ability to track health behavior.29 All the aforementioned factors have a role to play in fostering strong adherence and user engagement in users, 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 above-mentioned 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, ultimately fostering transformative, enduring change.

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 a mHealth platform, catering to overweight/obese women. This effort aims to improve metabolic and mental health of women from preconception till 18 months postpartum, potentially enhancing fecundability, pregnancy experiences, as well as maternal-child outcomes.30

Adopting a personalized approach for all preconception couples, we have developed a comprehensive reproductive health evaluation conducted through a mHealth platform. The development of this program draws upon the health belief model, which is based off the framework of perceived susceptibility, perceived severity, health motivation, perceived benefits, perceived barriers and eventual action taken by the target group.31 This intervention model seeks to reshape couples’ perceptions regarding their reproductive health (perceived susceptibility) by firstly 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 three domains, the programme dispenses personalized 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 change, 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 among couples to proactively improve their fecundability.31 Ongoing application engagement (health motivation) solidifies this process, offering resourceful guidance leading to action taken by the couples *(see Section 4. Resource guidance via mHealth application)* **(Figure 2)**.

**1. Self-assessment**

The self-assessment process employs the comprehensive 4S care strategy during preconception: Screening, Size, Supplementation, and Sex **(Figure 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 advancing age on fecundability. Such awareness empowers couples to contemplate initiating their trying to conceive journey sooner, enabling more informed family planning decisions. Apart from age, lifestyle behaviours such as smoking and alcohol consumption exert 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 (a) perceived stress levels, (b) presence of psychiatric disorders, and (c) 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 categorised into low (PSS score 0-13), moderate (PSS score 14-26) and high (PSS score 27-40) levels. 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 three-tier risk stratification system – probable depression (EPDS score ≥14), possible depression (EPDS score 10-13), 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 guidelines.37 This includes a diet low in fats and calories, minimizing the intake of fast food and sugar-sweetened beverages,38 while emphasizing 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 snacks40, chrono-nutrition41, which advocates caloric restriction at night when resting metabolic rate is low, 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 (WHO) advocates a weekly minimum of 150 minutes of moderate intensity, or 75 minutes of vigorous intensity physical activity, that is linked to positive outcomes.43

The synergy of nutritional interventions and augmented physical activity manifests within the validated 6P intervention tool, streamlining eating and activity decisions into six distinct factors: Portion, Proportion, Pleasure, Phase, Physicality, and Psychology **(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 rationalizing 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 significance, fostering adherence.46 Micronutrient supplements such as folic acid 47, iodine 47, zinc, and Vitamin D48 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)*

Lastly, sexual health and functionare important considerations in the preconception stage. Marital relationship quality and the overall reproductive health of the couple dictate sexual health optimisation. Evaluation includes (a) fertility history, (b) gynaecological or andrological history, and (c) sexual function.

Fertility history includes trying to conceive duration, 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 two 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 days49, timed intercourse within a week of ovulation50, and early initiation.

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, adversely impacting fecundability. Andrological history includes identifying past genital trauma. Testicular injury may be due to mechanical trauma or a previous mumps infection53, 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 (FSFI-6);55 while male sexual function can be evaluated using the International Index of Erectile Function (IIEF) tool.56

In sum, the preconception self-assessment module requires approximately 30 minutes for completion, serving 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: the Factor (F) score and an overall fecundability risk score. Guided by the 4S domains, 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 above factors on fecundability and 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 application**

The triage care system and corresponding information guidance are delivered via mHealth, enhancing accessibility to personalised and continuous care via the SIGN approach (Support, Inform, Guide, Nudge).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, namely screening, size, supplementation, and sex, coupled with a personalized 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.57 The HELMS preconception programme is designed to address these pivotal factors and more. Firstly, a user-friendly mobile application offers a unified hub for couples to access educational materials and personalized 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. Secondly, 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.58 Thirdly, 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. Lastly, the program embraces a personalized approach that is accessible to the wider population. It aims to identify individuals who may be unaware of their fecundability risks, provide customized interventions, ultimately promoting healthier families and communities.

However, possible challenges must be acknowledged. Foremost, 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 change24 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, 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.59 Lastly, a lack of access to digital devices might prevent certain groups from reaping the benefits of this mHealth program. Nonetheless, this is unlikely to pose a significant challenge, as the mobile penetration rate has reached 95.4% in Singapore in 2023.60 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 educational levels. We also intend to pilot the app in English, with plans to diversify language options progressively. Hence this mHealth program 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 personalized 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 by influencing each life course, it is hoped that each child will receive the best start in life and ultimately achieve a population with healthy life cycles.

**References**

1. United Nations DoEaSA, Population Division. 2022 Revision of World Population Prospects. Available at: <https://population.un.org/wpp/>. Accessed on 2 Dec 2022.

2. Nations U. World Population Prospects - Singapore Fertility Rate 1950-2022. 2022.

3. Division NPaT. Our Sustainable Population Objectives. Available at: <https://www.population.gov.sg/our-population/overview/>.

4. Coale AJ. Demographic Effects of Below-Replacement Fertility and Their Social Implications. Population Council 1986;12:203-16.

5. Loy SL KC, Tiong MMY, Ng CST, Cheung YB, Godfrey KM, Lim SX, Colega MT, Lai JS, Chong YS, Shek LPC, Tan KH, Chan SY, Chong MFF, Yap F, Chan JKY. Modifiable risk factor score and fecundability in a Singapore preconception cohort. Journal of Obstetrics and Gynecology: 2023.

6. Development OfEC-oa. Age of mothers at childbirth and age-specific fertility. Available at: <https://www.oecd.org/els/soc/SF_2_3_Age_mothers_childbirth.pdf>.

7. Saklayen MG. The Global Epidemic of the Metabolic Syndrome. Curr Hypertens Rep 2018;20:12.

8. Wesselink AK, Hatch EE, Rothman KJ, et al. Prospective study of cigarette smoking and fecundability. Hum Reprod 2019;34:558-67.

9. Organization WH. Tobacco. Available at: <https://www.who.int/news-room/fact-sheets/detail/tobacco>. Accessed on Dec 12.

10. Organization WH. Global Information System on Alcohol and Health. Available at: <https://www.who.int/data/gho/data/themes/global-information-system-on-alcohol-and-health>. Accessed on Dec 12.

11. Loy SL, Ku CW, Cheung YB, et al. Fecundability in reproductive aged women at risk of sexual dysfunction and associated risk factors: a prospective preconception cohort study. BMC Pregnancy and Childbirth 2021;21:444.

12. Gallup. Gallup Global Emotions 2022. Available at: <https://www.gallup.com/analytics/349280/gallup-global-emotions-report.aspx>. Accessed on Dec 2.

13. Black RE, Walker N, Laxminarayan R, et al. Reproductive, Maternal, Newborn, and Child Health: Key Messages of This Volume. In: Reproductive, Maternal, Newborn, and Child Health: Disease Control Priorities, Third Edition (Volume 2). Washington (DC): 2016.

14. Loo EXL, Soh SE, Loy SL, et al. Cohort profile: Singapore Preconception Study of Long-Term Maternal and Child Outcomes (S-PRESTO). Eur J Epidemiol 2021;36:129-42.

15. Soh SE, Tint MT, Gluckman PD, et al. Cohort profile: Growing Up in Singapore Towards healthy Outcomes (GUSTO) birth cohort study. Int J Epidemiol 2014;43:1401-9.

16. Developmental Origins of Health and Disease. Cambridge: Cambridge University Press; 2022.

17. Stephenson J, Heslehurst N, Hall J, et al. Before the beginning: nutrition and lifestyle in the preconception period and its importance for future health. Lancet 2018;391:1830-41.

18. Bearak J, Popinchalk A, Alkema L, et al. Global, regional, and subregional trends in unintended pregnancy and its outcomes from 1990 to 2014: estimates from a Bayesian hierarchical model. Lancet Glob Health 2018;6:e380-e89.

19. Hill B, Skouteris H, Teede HJ, et al. Health in Preconception, Pregnancy and Postpartum Global Alliance: International Network Preconception Research Priorities for the Prevention of Maternal Obesity and Related Pregnancy and Long-Term Complications. Journal of Clinical Medicine 2019;8:2119.

20. Loy SL, Chan DWK, Ku CW, et al. Metabolic health status and fecundability in a Singapore preconception cohort study. Am J Obstet Gynecol 2022;226:714 e1-14 e16.

21. Low FM, Gluckman PD, Godfrey KM. Early-life development and epigenetic mechanisms. In: Nutrigenomics and Proteomics in Health and Disease. 2017:42-63.

22. Hemsing N, Greaves L, Poole N. Preconception health care interventions: A scoping review. Sex Reprod Healthc 2017;14:24-32.

23. Warner JN, Frey KA. The well-man visit: addressing a man's health to optimize pregnancy outcomes. J Am Board Fam Med 2013;26:196-202.

24. Yap F, Loy SL, Ku CW, et al. A Golden Thread approach to transforming Maternal and Child Health in Singapore. BMC Pregnancy and Childbirth 2022;22.

25. Hussain T, Smith P, Yee LM. Mobile Phone-Based Behavioral Interventions in Pregnancy to Promote Maternal and Fetal Health in High-Income Countries: Systematic Review. JMIR Mhealth Uhealth 2020;8:e15111.

26. Ang SM, Chen J, Liew JH, et al. Efficacy of Interventions That Incorporate Mobile Apps in Facilitating Weight Loss and Health Behavior Change in the Asian Population: Systematic Review and Meta-analysis. J Med Internet Res 2021;23:e28185.

27. Lim K, Chan SY, Lim SL, et al. A Smartphone App to Restore Optimal Weight (SPAROW) in Women With Recent Gestational Diabetes Mellitus: Randomized Controlled Trial. JMIR Mhealth Uhealth 2021;9:e22147.

28. Han M, Lee E. Effectiveness of Mobile Health Application Use to Improve Health Behavior Changes: A Systematic Review of Randomized Controlled Trials. Healthc Inform Res 2018;24:207-26.

29. Lentferink AJ, Oldenhuis HK, de Groot M, et al. Key Components in eHealth Interventions Combining Self-Tracking and Persuasive eCoaching to Promote a Healthier Lifestyle: A Scoping Review. J Med Internet Res 2017;19:e277.

30. Chan JKY, Ku CW, Loy SL, et al. Effects of an integrated mobile health lifestyle intervention among overweight and obese women planning for pregnancy in Singapore: protocol for the single-arm healthy early life moments in Singapore (HELMS) study. BMJ Open 2022;12:e061556.

31. Becker MH, Maiman LA, Kirscht JP, et al. The Health Belief Model and Prediction of Dietary Compliance: A Field Experiment. Journal of Health and Social Behavior 1977;18:348-66.

32. Buysse DJ, Reynolds CF, 3rd, Monk TH, et al. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. Psychiatry Res 1989;28:193-213.

33. Cohen S, Kamarck T, Mermelstein R. A global measure of perceived stress. J Health Soc Behav 1983;24:385-96.

34. Nillni YI, Wesselink AK, Gradus JL, et al. Depression, anxiety, and psychotropic medication use and fecundability. Am J Obstet Gynecol 2016;215:453 e1-8.

35. Levis B, Negeri Z, Sun Y, et al. Accuracy of the Edinburgh Postnatal Depression Scale (EPDS) for screening to detect major depression among pregnant and postpartum women: systematic review and meta-analysis of individual participant data. BMJ 2020;371:m4022.

36. Kee MZL, Ponmudi S, Phua DY, et al. Preconception origins of perinatal maternal mental health. Arch Womens Ment Health 2021;24:605-18.

37. HealthHub. My Healthy Plate. Available at: <https://www.healthhub.sg/live-healthy/plan-your-meals-with-my-healthy-plate>. Accessed on 6 Nov 2023.

38. Grieger JA. Preconception diet, fertility, and later health in pregnancy. Curr Opin Obstet Gynecol 2020;32:227-32.

39. Skoracka K, Ratajczak AE, Rychter AM, et al. Female Fertility and the Nutritional Approach: The Most Essential Aspects. Adv Nutr 2021;12:2372-86.

40. Ku CW, Loo RSX, Lim CJE, et al. Development and Validation of a Lifestyle Behavior Tool in Overweight and Obese Women through Qualitative and Quantitative Approaches. Nutrients 2021;13.

41. Almoosawi S, Vingeliene S, Karagounis LG, et al. Chrono-nutrition: a review of current evidence from observational studies on global trends in time-of-day of energy intake and its association with obesity. Proceedings of the Nutrition Society 2016;75:487-500.

42. Strohle A. Physical activity, exercise, depression and anxiety disorders. J Neural Transm (Vienna) 2009;116:777-84.

43. Greenwood JL, Joy EA, Stanford JB. The Physical Activity Vital Sign: a primary care tool to guide counseling for obesity. J Phys Act Health 2010;7:571-6.

44. Armitage CJ, Conner M. Efficacy of the Theory of Planned Behaviour: A meta-analytic review. British Journal of Social Psychology 2001;40:471-99.

45. Alberti KG, Zimmet PZ. Definition, diagnosis and classification of diabetes mellitus and its complications. Part 1: diagnosis and classification of diabetes mellitus provisional report of a WHO consultation. Diabet Med 1998;15:539-53.

46. Toivonen KI, Lacroix E, Flynn M, et al. Folic acid supplementation during the preconception period: A systematic review and meta-analysis. Prev Med 2018;114:1-17.

47. Ku CW, Ku CO, Tay LPC, et al. Dietary Supplement Intake and Fecundability in a Singapore Preconception Cohort Study. Nutrients 2022;14.

48. Tamblyn JA, Pilarski NSP, Markland AD, et al. Vitamin D and miscarriage: a systematic review and meta-analysis. Fertil Steril 2022;118:111-22.

49. Konishi S, Saotome TT, Shimizu K, et al. Coital Frequency and the Probability of Pregnancy in Couples Trying to Conceive Their First Child: A Prospective Cohort Study in Japan. Int J Environ Res Public Health 2020;17.

50. Wilcox AJ, Weinberg CR, Baird DD. Timing of sexual intercourse in relation to ovulation. Effects on the probability of conception, survival of the pregnancy, and sex of the baby. N Engl J Med 1995;333:1517-21.

51. Tsevat DG, Wiesenfeld HC, Parks C, et al. Sexually transmitted diseases and infertility. Am J Obstet Gynecol 2017;216:1-9.

52. Walker MH, Tobler KJ. Female Infertility. In: StatPearls. Treasure Island (FL): 2022.

53. Pillai RN, McEleny K. Management of male infertility. Obstetrics, Gynaecology & Reproductive Medicine 2021;31:192-98.

54. Buchanan JF, Davis LJ. Drug-induced infertility. Drug Intell Clin Pharm 1984;18:122-32.

55. Isidori AM, Pozza C, Esposito K, et al. Development and validation of a 6-item version of the female sexual function index (FSFI) as a diagnostic tool for female sexual dysfunction. J Sex Med 2010;7:1139-46.

56. Rosen RC, Cappelleri JC, Gendrano N, 3rd. The International Index of Erectile Function (IIEF): a state-of-the-science review. Int J Impot Res 2002;14:226-44.

57. Ku CW, Leow SH, Ong LS, et al. Developing a lifestyle intervention program for overweight or obese preconception, pregnant and postpartum women using qualitative methods. Scientific Reports 2022;12:2511.

58. Channon S, Coulman E, Cannings-John R, et al. Acceptability and feasibility of a planned preconception weight loss intervention in women with long-acting reversible contraception: the Plan-it mixed-methods study. Health Technol Assess 2023;27:1-224.

59. Ku CW, Kwek LK, Loo RSX, et al. Developmental origins of health and disease: knowledge, attitude and practice of obstetrics & gynecology residents, pediatric residents, and medical students. Women & Health 2023;1-11.

60. Department SR. Smartphone penetration rate as share of the population in Singapore from 2019 to 2028. Singapore: Statista; 2023.

**Figure & Table Captions**

**Figure 1.** Preconception exposures and maternal-offspring health outcomes. Preconception health risks (i.e. suboptimal 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 co-exist 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

**Figure 2.** Framework and procedures of the HELMS preconception programme. The process begins with couples undergoing self-assessment via a mHealth application, 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.

**Table 1.** Components of the 6P Tool (Adapted from Ku et al., 2021)

**Table 2**. A multi-levelscoring system will be used to be used to triage a user using the 4S 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, the fecundability risk score, will serve as a visual/numeric guide for couples to track and compare their progress.