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# OCENA SPOŻYCIA ŻYWNOŚCI I WYBRANYCH PARAMETRÓW ANTROPOMETRYCZNYCH KOBIET W CIĄŻY NA WYSPIE JERSEY ZJEDNOCZONEGO KRÓLESTWA W RELACJI DO STANU URODZENIOWEGO NOWORODKA. BADANIE MIĘDZYETNICZNE.

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# THE RELATIONSHIP BETWEEN DIET AND SELECTED ANTHROPOMETRIC MEASUREMENTS OF PREGNANT WOMEN IN JERSEY, UK AND THE BIRTH STATUS OF THE NEWBORN. CROSSCULTURAL STUDY.

PhD Thesis

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## I. LIST OF ABBREVIATIONS

AAP: American Academy of Paediatrics

ABCD: Anthropometric measurements, Biochemical or laboratory assessments, Clinical assessment and Dietary assessment

AC: Abdominal Circumference

ACE: Angiotensin-converting enzyme

ACOG: American College of Obstetricians and Gynaecologists

ADHD: Attention Deficit Hyperactivity Disorder

aMED score: Mediterranean diet score

ANBM: Andersen and Newman Behavioural Model

ANC: Antenatal Clinic

ARBs: inhibitors and angiotensin receptor blockers

BAME: Black, Asian, and minority ethnic

BF%: Body Fat Percentage

BMI: Body Mass Index

BMI Z-scores: Body Mass Index standard deviation (s.d.) scores

BNF: British Nutrition Foundation

BPD: Biparietal Diameter

BWMPs: Behavioral Weight Management Programs

CBT: Cognitive Behavioural Therapy

CDC: US Centre for Disease Control and Prevention

CHD: Coronary heart disease

CHO: Carbohydrates

CI: Confidence Interval

CMW: Community Midwife

CO: Carbon monoxide

COVID-19: Coronavirus disease

CRH: Corticotrophin-releasing Hormone

CRP: C-Reactive Protein

CSP: Jersey's Common Strategic Policy

CYPES: Children and the Young People, Education and Skills

DASH: Dietary Approaches to Stop Hypertension

DHA: Docosahexaenoic Acid

DHHS: Department of Health and Human Services

DII: Dietary Inflammatory Index

DRI: Dietary Reference Intake

DXA: Dual-energy X-ray Absorptiometry

EFNEP: US Expanded Food and Nutrition Education Program

EFSA: European Food Safety Authority

EFW: Estimated Foetal Weight

EMIS: Egton Management Information System

EPDS: Edinburgh Postnatal Depression Scale

EPIC: Nutrition Norfolk Food Frequency Questionnaire

FFQ1: Food Frequency Questionnaire

FFQ2: Food Frequency Questionnaire

FGA: For Gestational Age

FH: Fundal Height Measurement

FIGO: International Federation of Gynecology and Obstetrics

FL: Femur Length

FMI: Fat Mass Index

FNHC: Family Nursing & Home Care

FOAD: Foetal Origins of Adult Disease

GDM: Gestational diabetes mellitus

GFR: Glomerular filtration rate

GI: Glycaemic Index

GL: Glycaemic Load

GP: General Practitioner

GROW: Gestation Related Optimal Weight software

GWG: Gestational Weight Gain

HC: Head Circumference (HC)

HCS: Health and Community Services

HDL: High-Density Lipoprotein

HDL-C: HDL-Cholesterol

HEI: Healthy Eating Index

HENRY (Health, Exercise, and Nutrition for the Really Young)

HFSS: Food and drinks high in fat, salt or sugar

HHS: Department of Health and Human Services

High-CHO (Carbohydrates with high glycaemic index)

HPS: Hungarian Preconception Service

HSSD: The Health & Social Services Department changed for HCS: Health and Community Services

HVs: Health Visitors

ICCIDD: International Council for the Control of Iodine Deficiency Disorders

ICU: Intensive Care Unit

IFGO: International Federation of Gynaecology and Obstetrics

IFS: UK Infant Feeding Survey UK, 2010

IOM(a): US Institute of Medicine

IOM(b): International Organization for Migration

IQ: Intelligence Quotient

IUGR: Intrauterine Growth Restriction

JGH: Jersey General Hospital

JOLS: Jersey Opinions and Lifestyle Servey

LDL: Low-density lipoprotein cholesterol

Low-CHO (Carbohydrates with low glycaemic index)

LPL: Lipoprotein Lipase

MD: Mediterranean diet

MECSH: Maternal Early Childhood Sustained Visiting

MRI: Magnetic Resonance Imaging

MUAC: Mid-upper Arm Circumference

MUFA: Monounsaturated Fatty Acid

NCMP: National Child Measurement Programme

NE: Nutrition Education

NHANES: National Health and Nutrition Examination Survey

NHS: UK National Health Service

NICE: National Institute for Health and Care Excellence

NIPT: Non-Invasive Prenatal Test

NMC: Nursing and Midwifery Council

NRT: Nicotine Replacement Therapy

NTD: Neural Tube Defects

NVP: Nausea and Vomiting in Pregnancy

PHE: Public Health England

PI: Ponderal Index

PUFA: Polyunsaturated Fatty Acid

PUFA:SFA (P:S): monounsaturated fatty acid to saturated fatty acid ratio

RCOG: Royal College of Obstetrics and Gynaecology

RCT: Randomised Control Trial

RPD: Reducing the Preventable Disease

SACN: Scientific Advisory Committee on Nutrition

SBLCBv2: Saving Babies' Lives Care Bundle

SCPHNs: Specialist Community Public Health Nurses

SDG: Sustainable Development Goal

SDIL: Soft Drinks Industry Levy

SDQ: Socioeconomic and Demographic Questionnaire;

SES: Socioeconomic Status

SFA: Saturated Fatty Acid

SGA: Small for Gestation Age;

STIs: Sexually transmitted infections

SWS: UK Southampton Women's Survey

TRAKCARE: Jersey Hospital System

UL: Upper Intake Level

UNICEF: United Nations Children's Fund

UPBEAT: UK Pregnancies Better Eating and Activity Trial

USDA: US Dietary Guidelines for Americans

VBA: Very Brief Advice

VLDL: Very-low-density Lipoprotein

VLDL-C: Very-low-density Lipoprotein-Cholesterol

## II. ABSTRACT

Recent studies have demonstrated that nutrition and general lifestyle choices in pregnancy, a sensitive period of development, induce permanent changes in the physiology of the offspring. Moreover, nutrition and lifestyle choices have an impact on the long-term health of the offspring. Although current evidence-based recommendations for a well-balanced diet and healthy lifestyle are widely available, obesity prevention before, during and after pregnancy remains a challenge for healthcare practitioners and general public health. This observational study, based on a cross-cultural population in Jersey, the Channel Islands (native-born Jersey, British, Polish and Portuguese/Madeiran nationals), was designed to assess diet and the issue of obesity among pregnant women as well as the risk of early childhood obesity. To the best of the author's knowledge, this project is unique because it was conducted on mothers and their offspring from various ethnic backgrounds for the first time in Jersey.

The prospective observational study was offered to 200 women who attended the Antenatal Clinic at Jersey General Hospital (JGH) from January to December 2017. Of the 115 women who agreed to participate in this project, 81 completed all stages of the research. Socioeconomic and demographic data, as well as data on the maternal diet and delivery, birth and feeding methods were compared with selected anthropometric measurements of mothers and their offspring during the child's first year of life. The period of time the mothers had lived on the island was used to split the groups for Native and the UK, women who had lived on the island less than 10 years (Europe < 10y on the island) and women who had lived on the island more than 10 years (Europe ≥ 10y on the island). Advanced statistical software programmes were used to analyse the data, including Statistica 10.0 PL StatSoft. The study, with the RESOLUTIONN no. 9/2015, was approved by the Bioethics Committee at the Faculty of Medical Sciences of the University of Warmia and Mazury in Olsztyn, Poland on the 12th of March 2015. Additionally, this research was reviewed and approved by the Health and Social Services Jersey Ethics Committee on the 11th of May 2016.

Although, no significant differences were observed regarding the weights and BMIs among the research group, this study indicated that overall there was a high prevalence of overweight and obese women who attended the maternity unit of JGH in 2017 (44%). No statistically significant differences in gestational weight gain (GWG) were observed

among the three groups of women, although the migrant women Europe ≥ 10y on the island had a higher average weight gain compared to the other groups of women. An analysis of the offspring at birth did not reveal significant differences regarding the anthropometric measurements, except for the weight for gestational age (FGA) z-score, for which the natives showed significantly higher scores compared with the other groups. The highest average birth weight FGA, length FGA centiles and percentage growth percentiles were also observed among the natives. The children born of native women showed the highest weight and length gain while the children born of participants in the immigrants ≥ 10yrs group showed the lowest weight and length gain. Regarding the maternal diet, the general intake of animal proteins during pregnancy for all women did not change from the pre-pregnancy period, the intake of fats and oils increased during pregnancy, and the intake of milk and dairy products decreased during pregnancy for all three groups of women. Although the intake of vegetables decreased for all the groups, the intake of fruit increased for the Native and Europe < 10y on the island groups. The women in the Europe ≥ 10y on the island group were the only participants who registered the alcohol intake during pregnancy. In terms of the Mediterranean diet scores, the participants in the immigrants ≥ 10yrs group shifted to a worse diet during pregnancy, while the women in the immigrants < 10yrs group adopted a healthier diet after becoming pregnant. However, the aMED scores among the three groups were not statistically significant. The largest proportion of women who used formula feeds in the first 48 hours and at the 6-month follow-up were the native and UK women.

No significant correlations were observed between either the women's diet and their selected anthropometric measurements or any of the mother or child pregnancy outcomes. The period of stay in Jersey influenced some of the pregnancy outcomes for both mother and child, therefore a more individualised and ethnic-specific pregnancy and postpartum care may help to improve dietary habits and encourage weight management. Similar future studies among a larger cohort are needed to confirm the findings of this research.

**Keywords:** pregnancy, nutrition, anthropometric measurements, child health, weight, ethnicity, public health

**ABSTRAKT**

Dostępne dane literaturowe wskazują na istotny wpływ stylu życia matki w okresie ciąży na adaptację dziecka do życia pozamacicznego oraz jego długoterminowy dobrostan. Pomimo wdrażania rekomendacji żywieniowych opartych o dowody naukowe (evidence-based), zapobieganie otyłości przed, w trakcie i po ciąży pozostaje nadal wyzwaniem dla opieki nad ciężarną. Niniejsze badanie obserwacyjne, przeprowadzono wśród międzynarodowej populacji zamieszkującej na wyspie Jersey (ludności rdzennej oraz napływowej z Wielkiej Brytanii, Polski oraz Portugalii i Madery). Celem badań była ocena sposobu żywienia, częstości występowania otyłości wśród kobiet w wieku rozrodczym, w ciąży wśród kobiet zamieszkujących Wyspę Jersey oraz ocena ryzyka występowania otyłości u ich potomstwa we wczesnym okresie dzieciństwa.

Do badania zrekrutowano 200 kobiet z Oddziału Położniczego Szpitala Generalnego na Wyspie Jersey (JGH) w terminie od stycznia do grudnia 2017 r. Na udział w projekcie zgodziło sie 115 pacjentek, a łącznie 81 kobiet ukończyło wszystkie etapy badania.

W badanej grupie zebrano dane socjoekonomiczne i demograficzne, a także dane dotyczące diety matki, rodzaju i terminu porodu oraz sposobu karmienia w pierwszym roku życia dziecka. Analizę wyników przeprowadzono wśród 3 grup etnicznych: rodowite mieszkanki Jersey oraz Wielkiej Brytanii (Native); kobiety mieszkujące na wyspie krócej niż 10 lat (Europa < 10 lat na wyspie); kobiety mieszkujące na wyspie ponad 10 lat (Europa ≥ 10 lat na wyspie).

Badanie wykazało, wysoką częstość występowania nadwagi i otyłości wśród wszystkich kobiet w ciąży w 2017 (44%), natomiast nie zaobserwowano istotnych różnic dotyczących masy ciała i BMI pomiędzy grupami etnicznymi w badanej grupie. Także nie stwierdzono istotnych różnic w ciążowym przyroście masy ciała pomiędzy trzema grupami kobiet, chociaż kobiety z grupy Europa ≥ 10 lat na wyspie, miały wyższy przyrost masy ciała w porównaniu z pozostałymi grupami kobiet. Analiza parametrów urodzeniowych potomstwa także nie wykazała istotnych różnic w zakresie pomiarów antropometrycznych, z wyjątkiem wskaźnika z-score masy ciała dla wieku ciążowego (FGA), dla którego dzieci rodowitych mieszkanek uzyskaly istotnie wyższe wyniki w porównaniu z pozostałymi grupami. Najwyższą średnią wartość masy urodzeniowej FGA, centyl długości FGA oraz percentyl procentowego wzrostu zaobserwowano również wśród rodowitych mieszkanek Jersey oraz Wielkiej Brytanii. Dzieci urodzone

przez kobiety z grupy Native wykazały najwyższy przyrost masy ciała i długości, podczas gdy dzieci urodzone przez uczestniczki z grupy imigrantek ≥ 10 lat na wyspie wykazały najniższy przyrost masy ciała i długości. Analizując spożycie produktów spożywczych przed zajściem w ciąże w relacji do spożycia w czasie ciąży odnotowano, że spożycie produktów pochodzenia zwierzęcego nie zmieniło się, spożycie tłuszczów i olejów wzrosło w czasie ciąży, a spożycie mleka i produktów mleczarskich zmniejszyło się w czasie ciąży we wszystkich trzech grupach kobiet. Pomimo, że spożycie warzyw zmniejszyło się we wszystkich grupach, spożycie owoców wzrosło w grupie Native i Europa < 10 lat na wyspie. Kobiety z grupy Europa ≥ 10 lat na wyspie były jedynymi uczestniczkami, które wykazały spożycie alkoholu w czasie ciąży. Odnosząc się do zaleceń żywieniowych diety śródziemnomorskiej stwierdzono, że uczestniczki z grupy imigrantek ≥ 10 lat nie przestrzegały zaleceń tej diety w czasie ciąży, podczas, gdy kobiety z grupy imigrantek < 10 lat bardziej przestrzegały tych rekomendacji po rozpoczęciu ciąży. Niemniej wskaźnik aMED w tych trzech grupach nie uzyskał mocy statystycznej. W pracy odnotowano najwyższy odsetek kobiet karmiących dzieci mlekiem zastepczym w pierwszych 48 godzinch, a także 6 miesięcy później, w grupie rodowitych mieszkanek Jersey.

W niniejszym badaniu nie zaobserwowano istotnych współzależności między spożyciem żywności oraz wybranymi parametrami antropometrycznymi kobiet w ciąży a stanem urodzeniowym noworodków. Badanie ujawniło kilka statystycznie istotnych różnic w stosunku do długość pobytu na wyspie Jersey, co może wskazywać na potrzebę bardziej zindywidualizowanej i etnicznie specyficznej opieki w czasie ciąży oraz po porodzie, w celu poprawy nawyków żywieniowych i kontroli masy ciała. Konieczne są dalsze badania angażujące większą próbę kobiet w celu dokładniejszego wyjaśnienia zaobserwowanych związków.

**Słowa kluczowe**: ciąża, odżywianie, pomiary antropometryczne, zdrowie dziecka, masa ciała, pochodzenie etniczne, zdrowie publiczne

## III. INTRODUCTION

Research efforts inferring to the significance of maternal health in the early growth and development of children has gained significant momentum in recent years. The changes in nutrition and lifestyle that comes with modernisation and economic development have been vital in promoting some of the studies (Tang et al., 2017). Nutritional and lifestyle factors in the pre-pregnancy and the pregnancy periods have been implicated in shaping childbirth and child health from different perspectives (Berglund & Lindmark, 2016). According to Barker and Clark (1997), prenatal nutrition and general lifestyle choices in this specific and sensitive period of early-life development are sensitive environmental heath factors important for the long-term health of both mother and child. Among intrauterine environmental factors, nutrition plays the most critical role in influencing placental and foetal growth. There is increasing evidence that impaired growth and development during fetal life and infancy is a major cause of conditions such as cerebro-vascular accident (stroke), non-insulin dependent diabetes, hypertension and coronary heart disease in adult life (Barker, 2007). This realisation calls for achieving optimal nutritional care for women of childbearing age in practice on a community level and whether we can reach the most vulnerable subgroups from the community as early as possible to conduct meaningful studies, successful interventions as well as health promotion with long-lasting effect.

The Global Nutrition Report (Haddad et al., 2015) suggests that the human diet and nutritional status have undergone a sequence of major shifts among characteristic states defined as broad patterns of food use and corresponding nutrition-related disease. The urban feeding pattern is associated with an increased consumption of processed food with a higher proportion of fat and sugar when compared with traditional, rural diets containing high-fibre-complex carbohydrate foods (Marinos et al., 2013). Consequently, the urban diet is linked with the pathogenesis of nontransmissible diseases. Dietary pattern studies appear to show positive outcomes around improving healthier diet furthermore, according to Grieger and Clifton (2015) intervention studies assessing whole foods rather than specific nutrients may provide valuable information on optimal nutrition during pregnancy, and how certain dietary patterns improve maternal and perinatal outcomes. This all suggests that there is an urgent need for healthy lifestyle education but planned and delivered with a more individualised approach for the targeted community.

Moreover, effective public health interventions, appropriately tailored according to ethnicity and other socio-demographic parameters are necessary at each of these stages to safeguard the maternal and child health especially with the current global obesity epidemic (Poston, et al., 2016). There is also broader understanding needed around the health care use and self-perceptions of health among less acculturated groups of populations (Lara et al., 2005).

With this background, the author conducted the study in a multicultural community of Jersey in the Channel Islands. Due to the complexity of the development of pregnancy, the longevity of children's growth as well as the remoteness of the island, it was logical to adopt a local study covering three years in order to efficiently investigate women's and young children's health in Jersey and the factors influencing their health outcomes. The environmental and social factors impact on health causing long-term effects into adult life. Therefore, the ultimate goal of this research had been to develop hypotheses, which can then be evaluated and tested for health and social interventions to improve childhood and adult health. The primary objective in this observational study was to evaluate diet and lifestyle among pregnant women living in Jersey. Because this research was designed for a cross-cultural population the author also would like to find out whether the process by which immigrants come to adopt new culture called the acculturation and factors like the period of living in multicultural community may be associated with health pregnancy outcomes for women and their offspring.

Through this work, the author would like to raise local awareness around the value of essential nutrition and lifestyle knowledge in the context of a short and longer-term health outcomes for both mother and offspring. This work also aimed to utilise the research results to optimise nutritional health promotion in different critical points of pregnancy development to prevent the risk of obesity development among a cross-cultural community on the local level. Additionally, the author expects to investigate whether information collected locally, could be used to develop the pre-pregnancy and an early life health promotion by building a more individualised approach to improve health status and minimise the risk of obesity development in women of childbearing age, expectant mothers and their young children. Moreover, this research project aimed to identify gaps in literature that need further research with regards to the health of women and children in Jersey.

The island of Jersey is located near the coast of Normandy in France. It is a British Crown dependency. The region is a diverse, multicultural environment with different ethnicities from various origins inhabiting the island (States of Jersey Statistics Unit, 2012). As Jersey witnesses the constant movement of migrants to and from the island (States of Jersey Statistics Unit, 2012), the question of how continuous residence in Jersey impacts maternal and the child's health is a valid issue of concern. It also forms a potentially new direction of research for community development projects and opportunities for further work in partnership with the public and private health care sector on putting in place policies and interventions to tackle the diet, lifestyle and weight management matters as a crucial part of the primary and secondary care model. The island of Jersey as a research area is described in Chapter II: Research Design and Methods by providing a brief outline of the island's geographical location, demographics, health figures related to this study as well as the public health context for pregnancy and early years care, health initiatives and government settings.

In terms of health outcomes for women and children in Jersey, the Medical Officer of Health in the 2008 Annual Report noted a high percentage of pregnant women with excess weight at the beginning of their pregnancy: 32% of pregnant women were overweight and 10% were obese (States of Jersey, 2008). This has been the case for quite some time, as the Obesity, Diet and Physical Activity report showed that about 50% of adults living in Jersey are overweight or obese, including 17% with a BMI of 30 or more (Statistics Jersey, 2019d). The Jersey Child Measurement Programme 2018/2019, with figures for 97% of all eligible children, showed that 21% of children in Reception (4–5 year olds) and 30% in Year 6 (10-11 year olds) are overweight or obese (Statistics Jersey, 2019a). Furthermore, the same paper, looking from a longer-term perspective, showed that a high percentage (70%) of children with excess weight in Year 6 had been defined as obese or severely obese six years previously (Statistics Jersey, 2019a). The rate of children aged 9-12 months who are breastfed on the island is about 23% (Statistics Jersey, 2020b).

Although current evidence-based recommendations for well-balanced diet and for a healthy lifestyle are widely available, obesity prevention before, during and after pregnancy is still a challenge for healthcare practitioners and for general Public Health activity around the word as well as in smaller jurisdictions like Jersey, in the Channel Islands. The high number of overweight and obese children and women of childbearing

age is a worldwide issue. For Jersey, the figures given above support this project's objectives of identifying the correlation between pregnant women's dietary patterns, selected anthropometric measurements and birth outcome for both mother and child. Furthermore, current data raises questions on the efficiency of weight measurement parameters that this study intended to investigate during pregnancy and in the child's early life.

Jersey in the Channel Islands is open for public health prevention perspective and recently developed framework to focus on campaigns and education aimed at changing individual behaviour (Government of Jersey, 2020a). This framework is aligned with the Jersey Care Model and Jersey's Performance Framework (Gov.je, 2020a). There is a growing understanding that behaviour change is not easy to achieve and needs a multidirectional spectrum of engagement from all critical parties (Government of Jersey, 2019b). This is as a result of multiple factors as shown in the Dahlgren and Whitehead model in 1991 including not only level of education, attitudes, motivation and cultural norms and expectations, but even more by social disadvantage confounders (socioeconomic position, employment status, language barrier and housing facilities) (Dahlgren & Whitehead, 1991). The variation in pregnancy and weight-related outcomes for both mother and a child should be investigated on local level with carful interpretation of all social characteristics. The mindful planning and implementation of the weight management programmes which would screen the risk group and guide the prevention of lifestyle disease burden could be an essential part of public health strategies. This should not only be based on current scientific evidence but also on locally available health and ethnic-specific data collected by the government and other already involved parties like the charitable and private health sectors which know their community.

# IV. LITERATURE REVIEW

This review discusses evidence-based research on the relationship between various nutritional and lifestyle factors and maternal and child health. Governmental and health agency reports, published literature, textbook sources and clinical practice guidelines were reviewed and summarised to support the background for this thesis.

## 4.1. A woman's health perspective

### 4.1.1. Pre-conception: A mother's health perspective

Maternal health in the immediate preconception period is a focus of national agencies, such as the World Health Organization (WHO) *Preconception care: Maximising the gains for maternal and child health. Policy brief* (WHO, 2013), the US Centers for Disease Control and Prevention (CDC) (Floyd et al., 2013), the international health agencies such as the International Federation of Gynaecology and Obstetrics (IFGO) (Hanson et al., 2015) and the UK Department of Health (Davies, 2015). Pre-pregnancy nutrition and lifestyle patterns have been shown to have significant implications regarding the mother's pregnancy outcomes. Adolescent females and women of reproductive age should receive optimal counselling concerning nutrition and lifestyle, cessation of substance use and engagement in physical activity (among other health promotion factors) to facilitate the adoption of healthy habits early in life.

#### 4.1.1.1. Nutrition changes when planning a pregnancy

In February 2012, the WHO developed a global consensus regarding the optimum preconception care to improve the outcomes of maternal and child health. The consensus report, addressed primarily to primary health caregivers emphasised healthy eating habits in preparation for pregnancy. Moreover, as a follow-up to the consensus report, the WHO (2013) developed a preconception care package, and optimised nutrition was one of 13 critical areas addressed. Among the evidence-based interventions mentioned in the package, nutrient-dense food, folic acid and iron supplementation, salt iodisation screening, and the optimisation of nutritional care for diet-associated illnesses such as diabetes and anaemia were included.

**Major food groups and macronutrients**

An appropriate mix of food is recommended in the pre-pregnancy period. *The Dietary Guidelines for Americans 2015–2020* provides comprehensive dietary guidelines for the recommended food groups to be included in a healthy diet (HHS & USDA, 2015). The five major food groups to be included in the diet are vegetables, fruits, grains, dairy and protein. Vegetables should consist of five vegetable groups: dark green vegetables, legumes, starchy vegetables, red vegetable and orange vegetables, and should total approximately 2.5 cup-equivalents/day. Approximately 2.5 cup-equivalents/day of fruits, 3 cup-equivalents/day of dairy, 6 oz-equivalents/day of grains and 5.5 oz-equivalents/day of protein is recommended (HHS & USDA, 2015). Plant oils rather than animal oils are also recommended. Similar recommendations are included in the NHS Eatwell Guide (NHS, 2019a).

**Micronutrients and Policies on Folic Acid, Iron and Iodine**

While micronutrients do not directly provide the much-needed energy required during pregnancy, they are critical for the relatively high catabolic and anabolic processes during gestation. In a review conducted by Schaefer and Nock (2019), the potential benefits of micronutrients in fertility and pregnancy outcomes were substantiated. For example, vitamins A, C, E and the micronutrients zinc, folate and copper are essential antioxidants that relieve the body of oxidative stress which has been strongly associated with infertility (Schaefer & Nock, 2019). Furthermore, sufficient vitamin A is essential for the production of high-quality oocytes, while specific B vitamins are essential for the development and maturation of oocytes. Moreover, Vitamin B9, also known as folic acid or folate plays a critical role in oocyte development, maturation and implantation (Gaskins et al., 2012). Women of reproductive age, and those who have issues with conception, often have insufficient levels of micronutrients (Schaefer & Nock, 2019). Therefore, in preparation for pregnancy, adequate dietary acquisition of micronutrients and supplementation with multiple micronutrients, would improve the reproductive environment and ameliorate fertility in certain cases.

*The 1991 Medical Research Council Vitamin Study* established that taking adequate amounts of folic acid before conception reduced the possibility of neural tube defects (NTD) by approximately 72% (Bestwick, Huttly, Morris & Wald, 2014). More than 70 countries, including the US, Australia and Canada, have adopted a mandatory folic acid fortification protocol to ensure adequate dietary intake of folate by women (Bestwick et

al., 2014). However, more than 120 countries, including all nations in the European Union, have not adopted mandatory folate fortification, despite the existing evidence regarding its health benefits. In the UK, an assessment of the extent of folic acid supplementation conducted between 1999 and 2012 revealed a failure in the supplementation program that led to significant health inequalities (Marks et al., 2018). In 2021 the decision about the addition of folic acid to UK nation's non-wholemeal wheat flour has been made. The folic acid fortification aims to reduce the birth defects such us NTD and improve public health (GOV.UK, 2021).

Pregnant women are particularly susceptible to iron deficiency, which is the most common global nutritional deficiency and the most common aetiology for anaemia (Loy et al., 2019). In 2011, one in three non-pregnant women were anaemic, and approximately 50% of these cases were believed to be caused by iron deficiency (Loy et al., 2019). Iron deficiency before and during gestation may pose a risk for a woman and her baby and significantly interfere with the pregnancy outcomes, resulting in complications such as low birth weight, preterm delivery or mortality of the woman and/or the baby (Scholl, 2011). Although iron supplementation during gestation has been extensively implemented globally to prevent iron deficiency anaemia during pregnancy, there is increasing evidence to suggest that efforts should be concentrated on adolescent and pre-pregnant women. Women who enter the gestation period with an iron deficiency are highly susceptible to anaemia and the associated adverse pregnancy outcomes (Viteri & Berger, 2005). The WHO advocates intermittent iron and folate supplementation for all women of reproductive age during menstruation in countries that experience greater than 20% prevalence of anaemia. The following recommendations aim to curb anaemia and increase iron reserves, with a recommended tolerable Upper Intake Level (UL) of 45 mg of iron daily (WHO, 2011). Evidence from research conducted in countries such as Egypt, India, Vietnam and Cambodia has revealed that the policy has been successful in reducing the average prevalence of anaemia (Nguyen et al., 2016). In high-income countries, the preconception guidelines do not recommend the universal supplementation of iron. Iron supplements are only advised when a deficiency is diagnosed, or if a woman is at a considerable risk of iron deficiency. Moreover, the UK guidelines do not endorse routine iron supplementation, even in pregnancy if the gestation is normal. However, certain critics argue that this is acceptable due to a low prevalence of iron deficiency anaemia in the UK (Pavord et al., 2012).

Iodine is an essential mineral for the synthesis of thyroid hormones, which are actively involved in metabolism, growth and development (SACN, 2014). During gestation, there is a physiological increase in thyroid hormone synthesis to support the additional demands of the developing foetus, therefore, increasing the woman's iodine requirements. If there is insufficient iodine, the developing foetus is vulnerable, and severe iodine deficiency can lead to poor brain development and cretinism (Pearce, 2013). Therefore, maternal intake and supplementation of iodine pre-pregnancy and during pregnancy are crucial for the foetus. Despite this knowledge, iodine deficiency remains high globally, and Europe is the region with the highest percentage of individuals with inadequate iodine intake (approximately 44%) (De-Regil et al., 2015). The WHO/United Nations Children's Fund (UNICEF)/ICCIDD endorses an intake of 150 μg of iodine per day for the general population (Zimmermann, 2013). However, for pre-pregnant and pregnant women, the European Food Safety Authority (EFSA) advises that the daily intake is increased to 200 μg (EFSA, 2014).

#### 4.1.1.2. Maternal body weight in preparation for pregnancy

Being underweight or overweight during the pre-pregnancy period influences the well-being of a woman and her baby. In a study that included a cohort of pregnant women, Doherty et al. (2006) evaluated the effect of the body mass index (BMI) before pregnancy on the outcomes of the pregnancy. Of a total of 2,827 women recruited for the study, 188 (6.6%) were obese. The women who were obese before pregnancy were found to have an increased risk of developing a medical illness during pregnancy, including hypertension, gestational diabetes and preeclampsia (Doherty et al., 2006). Moreover, the obese women were more susceptible to complications such as postpartum haemorrhage, the need for labour induction and caesarean section. The neonates of such mothers were more likely to be hypoglycaemic and require neonatal resuscitation. Conversely, the foetuses of the women who were underweight pre-gestation were at a higher risk of foetal growth restriction. A high BMI before pregnancy has also been associated with a higher risk of maternal hypertension (Motedayen, Rafiei, Rezaei, Tavirani, Sayehmiri & Dousti, 2019) and depression (Bodnar, Wisner, Moses-Kolko, Sit & Hanusa, 2009) during pregnancy.

To the best of the author's knowledge, no randomised clinical trials were found that indicated the benefits of preconception weight loss on foetal and maternal anthropometric measurements or health outcomes. However, various observational studies emphasised

the benefits of preconception weight loss. In a population-based study of 226,958 pregnancies in Canada, women who lost approximately 10% body weight experienced at least a 10% reduction in pregnancy complications such as diabetes, preeclampsia, preterm birth, foetal macrosomia and stillbirth (Schummers, Hutcheon, Bodnar, Lieberman & Himes, 2015). Furthermore, a 20–30% reduction in the pre-gestation BMI was necessary to decrease the rates of newborn mortality, shoulder dystocia and caesarean delivery. Similarly, Yi, Li, and Zhang (2015) and Galazis et al. (2014) established that obese women who lost weight through bariatric surgery pre-pregnancy had notably lower rates of gestational hypertension, preeclampsia and foetal macrosomia, although this was offset by small-for-gestational-age (SGA) babies. The prevention, identification, assessment and management of obesity is well recognised by the UK professional body NICE, which developed the dedicated guidelines Obesity prevention [CG43] (NICE, 2006) and Weight management before, during and after pregnancy [PH27] (NICE, 2010), as well as tools and resources (NHS, 2010) that offer practical recommendations and support for healthcare providers and local commissioners.

#### 4.1.1.3. BMI classification and nutritional status

Although the BMI is a simple and internationally accepted anthropometric measurement for estimating the nutritional status of an individual, it has been much critiqued because it does not distinguish body fat from lean tissue. Due to an apparent error when using the BMI to estimate total body adiposity, several researchers have regarded the measurement as ‘merely an imprecise mathematical estimate’ (De Lorenzo, Soldati, Sarlo, Calvani, Di Lorenzo & Di Renzo, 2016). Furthermore, several studies have reported a high cardiometabolic risk in individuals presumed not to be obese as per the BMI but who were obese as per their body fat composition (Gómez-Ambrosi et al., 2012). Since adiposity is presumed to predict mortality, more accurate measurements such as the body fat percentage (BF%), the fat mass index (FMI), dual-energy X-ray absorptiometry (DXA), bioimpedance analysis, and total body water content have been postulated (De Lorenzo et al., 2016). However, due to the convenience, safety and low cost involved in using the BMI, the measurement is still acceptable, particularly from a public health perspective. Moreover, additional measurements such as waist circumference, waist-to-height ratio and skinfold thickness can be combined with the BMI to improve body fat estimation, even in pre-pregnant women (De Lorenzo et al., 2016).

**Challenges in weight management**

Despite evidence suggesting the risks of an extreme pre-pregnancy BMI, it remains a challenging subject for patients and healthcare providers. An array of socioeconomic, behavioural and environmental factors impact the maintenance of a normal BMI within the pre-pregnancy period. In an Australian-based cross-sectional study, Lang, Harrison and Boyle (2019) assessed the relationship between the preconception BMI and socio-demographic characteristics, knowledge and weight-related behaviour of pregnant women. Of the 223 women who participated in the study, half were either overweight or obese in the preconception period, and 49.6% of these women perceived their weight as standard. Moreover, only 8.1% of the women had sought professional support to lose weight before getting pregnant (Lang et al., 2019). In 2017, the UK Maternity Services Dataset revealed that 49% of women had excess weight at the beginning of pregnancy (GOV.UK, 2020c).

Duthie, Drew, and Elaine (2013) interviewed 19 nulliparous women and 7 obstetricians to establish their views on body weight before and during pregnancy. They observed a significant discrepancy between the women and their caregivers concerning body weight and gestational weight gain. Additional challenges that affect weight management in women pre-pregnancy are unplanned pregnancy (McKeating et al., 2015), low socioeconomic status (SES) (Cheney, Berkemeier, Sim, Gordon & Black, 2017) and inadequate knowledge regarding preconception weight management (Pandolfi et al., 2014). New weight management challenges emerged between 2020 and 2021 during the COVID-19 outbreak due to limited physical activity and reduced access to healthy food (WHO, 2020b).

#### 4.1.1.4. Management of maternal illnesses

In anticipation of pregnancy, the screening, diagnosis and management of maternal illnesses is a priority for primary healthcare providers. Diseases such as diabetes, thyroid disease, phenylketonuria and mental illnesses are among the critical medical conditions that should be evaluated and treated (WHO, 2013). Lassi, Imam, Dean and Bhutta (2014b) conducted a comprehensive systematic review of the literature to establish the implications of preventing and managing medical conditions pre-pregnancy on the health outcomes of women and their babies. The results of the review demonstrated that maternal pre-pregnancy pharmacologic diabetic management and glycaemic control was

a necessary intervention that reduced the rates of perinatal mortality by 69% and incidences of congenital defects by 70%. Moreover, adequate pre-pregnancy management of phenylketonuria (Lassi, et al., 2014b) and epilepsy (Borgelt, Hart & Bainbridge, 2016) has also been shown to improve maternal, foetal and neonatal health outcomes. Similar results were observed regarding the pre-pregnancy non-pharmacological management of mental illnesses, although the results were not statistically significant.

#### 4.1.1.5. Preconception care: planning for a pregnancy

**Counselling and recommendations to promote good health before pregnancy**

Education and counselling concerning the adoption of a healthy diet and lifestyle patterns may have long-standing implications for maternal and child health (Berglund & Lindmark, 2016). This is particularly important if a healthy lifestyle is not present at the beginning of a pregnancy. The pre-pregnancy period is a critical time for education and to ensure that the expectant parents are aware of their responsibility to create a healthy environment for their children to grow and develop (Oringanje, Meremikwu, Eko, Esu, Meremikwu & Ehiri, 2016). For instance in the UK, multivitamin supplementation is recommended only for certain groups of individuals who are at risk of deficiency, including those who are severely ill, those taking certain medications and expectant mothers, to avoid the harmful effects of excessive vitamins (NHS, 2019d). However, given that women may experience nutritional deficiency during pregnancy, and that evidence suggests the effectiveness of supplementation programmes for this group, there is an increasing need for pregnant women to be included in the supplementation category. In addition to supplementation, the fortification of common foods with micronutrients such as iron, folic acid, vitamins A, B6, B12, C and D has resulted in a considerable reduction in iron deficiency anaemia and other micronutrient deficiencies among women of reproductive age in low- and middle-income regions (Fox et al., 2019).

Various national guidelines and international policies on maternal and child health emphasise the importance and implementation of preconception counselling. The UK National Health Service has published an advice on preconception counselling and care, entitled *Clinical knowledge summaries (CKS): Pre-conception advice and management care* (NHS, 2019b). The health professional is expected to consider the general health parameters of all women, including women with pre-existing medical illnesses those of

advanced age. Similarly, the joint American College of Obstetricians and Gynaecologists (ACOG) and the American Academy of Paediatrics (AAP) guidelines for perinatal care emphasise the importance of preconception counselling and its significance in reducing maternal and child mortality (AAP & ACOG, 2017). Moreover, other pregnancy and delivery issues such as caesarean sections, complications due to underlying medical illnesses, old age pregnancies and inappropriate pregnancy intervals are reduced by effective pre-pregnancy counselling (Shahidi et al., 2011).

Young adults of both sexes are also important targets for counselling (Berglund & Lindmark, 2016). Education of teenagers at school to promote a healthy lifestyle before and during their reproductive ages is one of the most important strategies advocated. Preconception counselling directed at teenagers and young people should include aspects such as a healthy lifestyle, and safe sex and family planning. Oringanje et al. (2016) conducted a systematic meta-analysis of the literature to determine the implications of primary prevention interventions such as school- and community-based education concerning unintended adolescent pregnancy. A total of 53 randomised control trials (RCTs) were included in the study. The results demonstrated that education and the promotion of contraceptives significantly reduced the occurrence of unintended pregnancies. Since unwanted pregnancies are associated with inadequate preconception care and poor pregnancy outcomes (Johnson-Mallard et al., 2017), early teenage and adolescent interventions are justified.

Nutritional and weight management are part of the requirements that are addressed in the preconception period. However, preconception counselling should involve other important lifestyle aspects including smoking and alcohol use, physical activity, male partner involvement, fertility and psychological wellness.

**Preconception dietary patterns**

Wądołowska (2009) highlighted that unhealthy nutritional patterns, once adopted throughout the childhood and adolescent period, can become a behaviour that is repeated in adult life. Micronutrient deficiencies and inadequate protein intake caused by a restricted diet can develop due to the obsessive control of body size. This type of restricted diet generally consists of small amounts of dairy, wholegrains, legumes, fruits, vegetables and fish, and excess quantities of meat (including processed meats) and food products that contain large quantities of added sugars.

Poor nutritional intake results from learned behaviours, the type of food eaten in the family home, the workload, time at school, housework, little time for meal preparation, the influence of processed food advertisements and the modern diet (Wądołowska, 2009). Observation of commendable dietary and lifestyle habits by the parents provides proper guidance for children to facilitate passage of the good habits down the generation. Therefore, the preconception period is an important time for influencing future health (Stephenson et al., 2018). If a healthy dietary pattern is not present before pregnancy or at the beginning of pregnancy, this could be a long-term effect of an unhealthy pattern learned in early life. Addressing nutrition education at all stages of life may be the only successful strategy against poor nutrition in women of childbearing age.

**Drug and substance use**

Tobacco and other drugs are prevalent reproductive and developmental toxicants of concern for maternal and child health. Perry, Mulcahy and DeFranco (2019) studied the link between maternal preconception smoking of tobacco and congenital anomalies. In this population-based retrospective study of 1,436,036 live births, 6% of women smoked during the preconception period while 17.3% smoked before conception and through the first trimester. Smoking during the preconception period was associated with a 40% rise in the incidence of gastroschisis. The authors highlighted the role of public health measures in educating women on the significance of avoiding smoking, even before pregnancy.

Lassi, Imam, Dean and Bhutta (2014a) reviewed the literature to assess the potential effects of preconceptual exposure to alcohol, smoking, caffeine and environmental chemicals on maternal and child health. Preconceptual alcohol consumption was associated with a 30% increase in spontaneous abortions, however, these results were not statistically significant. Similarly, preconceptual smoking resulted in a three-fold increase in the occurrence of congenital heart diseases (Lassi et al., 2014a). Therefore, the preconception period provides a valuable opportunity to impact positively on the health of mothers and their babies through the identification of risks such as drug and substance use and the implementation of appropriate management strategies (Perry et al., 2019).

**Physical Activity**

There is increasing evidence to suggest that preconceptual lifestyle intervention should include guidance on physical activity to supplement dietary alterations. The addition of physical activity counselling during preconception care considerably reduces gestational weight gain (GWG), which has been correlated with poor health outcomes (Agha, Agha & Sandall, 2014). Additionally, a systematic review of the literature by Abbasi and Van Den Akker (2015) revealed a considerable decline in the level of physical activity of women during the transition to motherhood, therefore, predisposing them to lifestyle illnesses. Thus, active measures are required during the pre-pregnancy period to raise awareness and promote physical activity during pregnancy and thereafter.

The importance of preconceptual guidance concerning physical activity was reiterated by the LIFEstyle study group (2018). In this secondary analysis of an RCT, physical activities such as walking or cycling from/to work or school, vigorous leisure activities, activities at work and school and household leisure activities were studied. The results demonstrated that a 6-month designed preconception lifestyle intervention that included physical activity led to a significant improvement in the lifestyles of the participants compared to no intervention. However, diet or physical activity interventions are less effective if they are applied in isolation, and combined weight management programmes have been emphasised as an alternative (Johns, Hartmann-Boyce, Jebb & Aveyard, 2014)**.**

#### 4.1.1.6. Fertility

As previously mentioned, micronutrient supplementation and psychological factors during the preconception period have significant implications for fertility (Schaefer & Nock, 2019). In addition to preconception discussions on dietary, lifestyle and health factors, and the screening and management of chronic medical conditions, discussions concerning aspects of fertility are equally important (Lassi, Dean, Mallick & Bhutta, 2014). Fertility specialists are an important component of the multidisciplinary team required for the provision of preconception care. Preconception visits to a fertility specialist provide a suitable platform to discuss and optimise family planning and fertility services (Kermack & Macklon, 2013)**,** moreover would facilitate the identification of the at-risk groups and opportunity to promote future health through lifestyle management.

#### 4.1.1.7. Father's role

Significant attention has been paid to maternal preconception care while the male counterparts have been largely overlooked. Therefore, healthcare providers are urged to also provide counselling to prospective fathers during the preconception period (Gavin et al., 2014). An unhealthy lifestyle and poor health of the father has also been associated with high rates of congenital anomalies and other adverse pregnancy outcomes. In particular, the exposure of the father to toxins in the environment, the use of certain prescription drugs and smoking have been associated with complications such as low birth weight and congenital malformations (Agricola et al., 2016).

During a review of the Hungarian Preconception Service (HPS), Czeizel, Czeizel and Vereczkey (2013) examined the impact of paternal involvement during the preconception period regarding various aspects of maternal preconception care. Data from the HSP revealed that paternal involvement was successful in 81% of couples from 1984–2010. This involvement was crucial for certain medical aspects, including the early recognition of paternal infertility, diagnosis of sexually transmitted infections (STIs) and detection of unhealthy lifestyles. Moreover, paternal involvement was shown to facilitate the early initiation of interventions such as the treatment of infertility and STIs and the encouragement of a healthy lifestyle, including cessation of smoking. Therefore, although research on the health and lifestyle of the male partner during the preconception period is limited (Kotelchuck & Lu, 2017), the available evidence provides motivation for paternal involvement to be included in maternal and child healthcare policies. Moreover, the father's role is not solely confined to the pre-pregnancy period. The role of the father is important throughout the pregnancy and upbringing of the child. A father's lifestyle behaviours, including his dietary habits and whether he smokes cigarettes and engages in physical activity, significantly influence the general lifestyle of the family (Czeizel et al., 2013). Furthermore, several studies have indicated that children of fathers who are physically active are 3.5 times as likely to embrace physical activity compared with children of inactive fathers (Arlinghaus & Johnston, 2017). These findings highlight the significance of including the father in the process rather than focus all efforts and pressure on the mother.

### 4.1.2. During pregnancy: Mother's health perspective

The pregnancy state is usually considered a stage of specific health interest due to the high susceptibility and the high risk of toxic exposures owing to the physiologic and anatomical alterations that occur (Motosko, Bieber, Pomeranz, Stein & Martires, 2017). Optimal nutritional input and a healthy lifestyle are critical for seamless adaptation to the physiological changes as well as for the proper development of the foetus (Forbes, Graham, Berglund & Bell, 2018). Furthermore, pregnancy is also a stage of planning for life after delivery.

#### 4.1.2.1. Physiological and anatomical adaptations in pregnancy

Changes in the anatomy and physiology of a woman during pregnancy begin early in the first trimester and reach a climax at approximately full term (Bhatia & Chhabra, 2018). Pre-pregnancy status is regained several weeks postpartum. In a healthy individual, these changes are highly tolerable. However, in women with coexisting medical conditions, the changes may intensify complications and influence the outcomes of the pregnancy (Motosko et al., 2017). Dietary and lifestyle considerations are necessary for healthy women and those with underlying medical conditions (Forbes et al., 2018).

Most of the systems in the human body undergo changes during pregnancy. For example, in the cardiovascular system, there is a considerable increase in the volume of blood (approximately 20%) by the third trimester (Bhatia & Chhabra, 2018). Significant changes occur in the respiratory system, including increased carbon dioxide production (LoMauro & Aliverti, 2015), a rightward shift in the oxygen dissociation curve (Bhatia & Chhabra, 2018), a reduction in the expiratory reserve volume by approximately 25% and an increase in in the tidal volume by 45%, as well as other transformations regarding lung mechanics. The haematological system initiates a 20% increase in the mass of red blood cells (Bedson & Riccoboni, 2014), an increase in the white blood cell count to 15,000/ml and, in certain individuals, gestational thrombocytopenia occurs (Bhatia & Chhabra, 2018).

In the gastrointestinal system, a pregnancy-associated increase in progesterone levels causes a reduction in the tone of the lower oesophageal sphincter, resulting in an increase in a woman's predisposition to gastro-oesophageal reflux disease and vomiting (Soma-Pillay, Nelson-Piercy, Tolppanen & Mebazaa, 2016). Moreover, among other

changes, there is a decrease in the gastric emptying time and a 60% decline in the serum albumin concentration (Bhatia & Chhabra, 2018). The central nervous system experiences an increase in the cerebral blood flow and the blood-brain barrier permeability and a rise in the pain threshold due to increases in progesterone and endorphins (Bhatia & Chhabra, 2018). There is an increase in renal perfusion (Cheung & Lafayette, 2013) and a significant increase in urinary protein excretion (Bhatia & Chhabra, 2018). The endocrine system is characterised by an increase in thyroid hormones and reduced tissue sensitivity to insulin which predisposes the woman to thyroid abnormalities and diabetes (Calina et al., 2019). Most of the above-mentioned changes affect a woman's lifestyle, dietary considerations, degree of activity and, ultimately, the progress and outcome of the pregnancy (Soma-Pillay et al., 2016)

#### 4.1.2.2. Gestational weight gain

**Definition and implications**

Among the physiological changes that occur during pregnancy, the change in body weight is of direct relevance for this research, particularly because weight is a core anthropometric measurement of focus. In general, gestational weight gain (GWG) is estimated by subtracting a woman's weight measured during the initial prenatal visit from her weight measured during the final prenatal visit just before delivery (Kominiarek & Peaceman, 2017). Several developed countries (such as the US) implement the routine measurement of a woman's weight and BMI during pregnancy (Kominiarek & Peaceman, 2017). Moreover, the ACOG (2013) provides national guidelines no. 548, for the measurement of weight and GWG. These guidelines originate from those presented in the four BMI categories for weight gain during gestation and the expected ranges of total weight gain outlined by the US Institute of Medicine (IOM(a)) (IOM, 2009). However, the UK NICE guidelines do not support routine weight measurement of pregnant women unless clinical handling will be affected or if there is a concern regarding nutrition (NICE. [PH27], 2010). Moreover, the UK NICE guidelines do not provide national procedures for the monitoring of GWG.

GWG is an established predictor of poor pregnancy outcomes (Santos et al., 2018). During a study of 698 singleton pregnancies, Çalik, Yildiz and Erkaya (2018) evaluated the effects of the weight of a woman during gestation on maternal and neonatal outcomes. The results demonstrated that the rates of instrumental delivery, episiotomy,

caesarean section, prolonged phases of labour, low Apgar score and neonatal intensive care unit (ICU) admissions were higher among the women who had a higher BMI and GWG during pregnancy compared to those with a lower BMI. Numerous other studies have associated excessive GWG with complications such as increased rates of foetal macrosomia (Godoy, do Nascimento & Surita, 2015), gestational hypertension, preeclampsia, preterm delivery and diabetes mellitus (Voerman et al., 2019). These findings have been further detailed in comprehensive systematic reviews and meta-analyses (Goldstein et al., 2017).

Similar to excess GWG, suboptimal GWG results in numerous consequences regarding maternal and child health. In a US-based population study, Ukah et al. (2019) explored the relationship between suboptimal GWG and poor pregnancy outcomes. The study involved 722,839 participants and those with low GWG experienced higher rates of maternal death, perinatal death and neonatal morbidity. Similarly, in a study in rural China that involved 14,219 nulliparous women (Zhou et al., 2019), higher rates of neonatal mortality, infant mortality and early preterm birth were observed among women with low GWG during the second or third trimester.

**Predictors and management**

Various factors have been associated with disproportionate GWG during pregnancy. Nunnery, Ammerman and Dharod (2018) reported that women who were obese or overweight during the pre-pregnancy period had a higher probability of accumulating excessive GWG. Similar results were recorded by Goldstein et al. (2017) during a comprehensive meta-analysis. Moreover, nulliparous women were shown to have a higher probability of excessive GWG (Nunnery et al., 2018). Furthermore, women who had an unplanned pregnancy (Endres et al., 2015) and those who were separated, divorced or single (Nunnery et al., 2018) were shown to have higher rates of excessive GWG. Inadequate knowledge, inappropriate perceptions regarding weight gain during pregnancy and poor SES, were also associated with excessive GWG (Goodrich, Cregger, Wilcox & Liu, 2013). Factors such as smoking (Lindberg et al., 2016), African ethnic background and SES (Herring et al., 2016), and an extremely low pre-pregnancy BMI have been linked to inadequate GWG. Other notable challenges include dispelling the myths that encourage women to ‘eat for two’ and the improper attitudes of healthcare providers (Kominiarek & Peaceman, 2017). Considering the influence of GWG on

pregnancy outcomes, the low cost and ease of conducting body weight measurements and the availability of routine weight measurements and monitoring during pregnancy are not only acceptable but also critical. These findings provide various opportunities for public health policies to intervene to ensure appropriate GWG.

In general, approximately one-fifth of women attain adequate GWG, while almost half of women demonstrate excessive GWG (Timmerman, Walker & Brown, 2017). Therefore, healthcare workers must implement the appropriate measures to control this undesirable trend. Achieving the appropriate GWG is dependent on various individual factors, and the socioeconomic environment, lifestyle changes and improvements to health behaviours. During a Cochrane review of RCTs, Muktabhant, Lawrie, Lumbiganon and Laopaiboon (2015) explored the effectiveness of dietary and exercise interventions for reducing GWG and the associated adverse pregnancy outcomes. The meta-analysis of 49 RCTs that involved 11,444 participants revealed that, during pregnancy, nutritional interventions or exercise interventions, or both, reduced the occurrence of excess GWG. These interventions also reduced the occurrence of caesarean section deliveries, neonatal respiratory complications, foetal macrosomia and maternal hypertension. Several strategies have been recommended by various agencies for the appropriate management of GWG during pregnancy, including patient-centred counselling for behaviour changes, motivation interviewing, appropriate education, goal-setting and appropriate medical record management (Kominiarek & Peaceman, 2017).

#### 4.1.2.3. Metabolic adaptations in pregnancy

Besides weight, the metabolic changes that occur during pregnancy are also a significant area of focus in the context of lifestyle and diet. Most of these metabolic changes cause the weight fluctuations observed during pregnancy. Both anabolic and catabolic adaptations occur during pregnancy to support the requirements of the foetus, with a general shift from significantly anabolic functioning to a net catabolic functioning (Zeng, Liu & Li, 2017). The first and second trimester are characterised by a net anabolic state. The pregnancy state is associated with significant maternal hyperphagia that gradually increases throughout gestation (Faas, Melgert & De Vos, 2010). The hyperphagia results in the accumulation of metabolic substrate stores that account for the anabolism. Moreover, during early pregnancy, there is accelerated de novo lipogenesis coupled with enhanced lipoprotein lipase (LPL) activity that contributes to increased fat

deposition (Zeng et al., 2017). The increase in fat deposition occurs following decreased lipolytic activity since the maternal tissues show an augmented capacity to break down glucose and intracellular glycerol to provide energy for metabolism. Therefore, there is a net accumulation of body fat (Zeng et al., 2017).

Significant catabolism occurs during the second trimester of pregnancy. A considerable increase in lipolytic activity occurs, leading to a marked rise in maternal hyperlipidaemia (Spracklen et al., 2014). Low-density lipoprotein (LDL) cholesterol is estimated to increase by up to 50%, while triglyceride concentrations are estimated to increase twofold (Diareme et al., 2009). Due to the increased nutritional requirements of the rapidly developing fetoplacental unit, a complex system regarding the rapid transport and metabolism of glucose is developed (Zeng et al., 2017). This system has been postulated to contribute to the hyperinsulinemia associated with pregnancy, with an increased risk of insulin resistance, poor glycaemic control and, as a consequence, gestational diabetes (Q. Wang et al., 2016). In addition to insulin, other hormones are involved in metabolic changes during pregnancy. Oestrogen is an important hormone involved in hyperlipidaemia, while progesterone and other placental hormones have been associated with changes in lipid profiles and insulin resistance, respectively (Zeng et al., 2017). Through various mechanisms, other hormones such as leptin, ghrelin, cholecystokinin and neuropeptide Y promote hyperphagia during pregnancy (Faas et al., 2010), and this chronic and obsessive hunger can cause a woman to become overweight or obese.

#### 4.1.2.4. Nutrition, practical advice and nutritional assessment

Given the risks associated with excess and suboptimal GWG and the metabolic and physiologic changes that are associated with pregnancy, it is important to provide the correct nutritional advice to pregnant women. Therefore, adequacy in quality and quantity are key (WHO, 2018).

**Quality**

Recommendations regarding the various types of nutrients required during the stages of gestation vary according to the nutrition status and food traditions of the individual (Danielewicz et al., 2017). The WHO standards for antenatal care include 39 nutritional recommendations and five types of dietary interventions (WHO, 2018). The WHO advocates for healthy dietary habits and adequate physical activity during

pregnancy to prevent excessive GWG. In undernourished populations, the WHO promotes specific balanced protein and energy intake to prevent suboptimal GWG and the associated adverse pregnancy outcomes. Supplementation of folate and iron is recommended daily or intermittently, and vitamin A supplementation is recommended in regions where its deficiency is an issue of public health importance. However, caution has to be taken in supplementing vitamin A in pregnancy to avoid the teratogenic effects associated with excessive vitamin A intake (Tafti & Ghyselinck, 2007). Isotretinoin, a derivative of synthetic vitamin A, is responsible for a syndrome that results in malformations of the central nervous system, heart and thymus, as well as craniofacial defects. This teratogenic potential of vitamin A administration justifies a strict limitation in women who may become pregnant. The recommended dose of vitamin A in pregnancy is therefore 10,000 IU/day or less (Bastos Maia et al., 2019).

Calcium supplementation is recommended in populations with established low calcium intake. Supplementation of other micronutrients such as zinc, vitamin D and vitamin B6 is not recommended on a routine basis. The WHO further recommends that women with a high intake of caffeine should avoid consuming foods that contain this stimulant.

In the UK, more detailed guidance is provided via the NICE (2014) *Maternal and child nutrition recommendations* In addition to the general recommendations offered by the WHO, the NICE supplies healthcare providers with specific information regarding the counselling of women during pregnancy. For example, the NICE recommends five daily portions of fruits and vegetables and one weekly portion of oily fish. Moreover, the recommendations discourage foods such as liver, raw or undercooked eggs and meat, fresh shellfish and certain categories of cheese. Based on local data and local agencies, other guidelines are available for specific populations, such as the German National Consensus (Koletzko et al., 2013) and the Polish guidelines (Danielewicz et al., 2017). The WHO recommends the implementation of such local and evidence-based guidelines due to the variations in nutritional requirements among diverse populations and ethnicities (WHO, 2018).

**Quantity: energy, macronutrients and micronutrients**

Caloric intake is the primary determinant of GWG. Global approximations imply that energy requirements during gestation range from 7,710 to 9,260 kJ/day, which is

dependent on the ethnicity and socioeconomic background of the pregnant woman (Blumfield, Hure, Macdonald-Wicks, Smith & Collins, 2012). Savard et al. (2018) reported that the energy intake should increase by 340 kcal in the second trimester and 452 kcal in the third trimester to facilitate a positive energy balance.

Several researchers have established that at least 175g of carbohydrates (CHO) and 28g of fibre is sufficient for the growing foetus and the pregnant woman (Mustad, Huynh, López-Pedrosa, Campoy & Rueda, 2020). An increase in caloric intake is necessary to support the increased catabolism, which ultimately provides energy for the mother and the developing foetus (Mousa, Naqash & Lim, 2019). However, insufficient and excessive caloric intake is detrimental as it contributes to suboptimal and excessive GWG, respectively.

Changes in protein metabolism gradually shift throughout gestation to maintain maternal homeostasis, supplement the increase in foetal protein requirements, and prepare the body for lactation after delivery (Elango & Ball, 2016). Therefore, the protein turnover during early gestation is similar to that in the period before pregnancy, however, towards the second and final trimester, the protein turnover increases by approximately 15–25%. Thus, it is recommended that the total increase in protein intake is maintained at 15–25% of the pre-pregnancy intake. This recommendation has been endorsed by various studies, including a Cochrane review of 12 RCTs that involved a total of 6,707 women. The results of the study demonstrated that balanced protein/energy supplementation with less than 25% of energy from proteins was associated with a low risk of stillbirths and SGA infants (Ota, Hori, Mori, Tobe-Gai & Farrar, 2015). Furthermore, the results of a separate study suggested that a significant increase in protein intake (more than 25%) was associated with an increased risk of SGA, however, there was insufficient evidence to support these results (Mousa et al., 2019).

The fat intake of expectant mothers influences the pregnancy outcomes, and it modulates the growth and development of the child (Savard et al., 2018). Thus, the energy requirements of expectant mothers increase throughout the pregnancy period, as previously mentioned. The recommended primary sources of energy for women are foods that contain fatty acids. Fatty acids are essential as they provide energy and regulate the expression of transcription factors. The fatty acids include saturated fatty acids (SFA), polyunsaturated fatty acids (PUFA) and monounsaturated fatty acids (MUFA) (Savard et al., 2018). As documented in The Healthy US-Style Eating Pattern, the recommended

amount of oil for a diet that consists of 2000 calories per day is 27g (HHS & USDA, 2015). The International Federation of Gynecology and Obstetrics (FIGO) created diet recommendations for women of childbearing age based on the WHO guidelines for adults. These guidelines state that the total energy from fat should not exceed 30%, and unsaturated fats are promoted. Furthermore, less than 10% of the total energy should be obtained from the consumption of SFA and 6–10% should be obtained from PUFA (Hanson et al., 2015).

The level of fatty acids in a woman's tissue during pregnancy and lactation are closely related to her diet, reserveability and metabolic use of fatty acids (oxidation, synthesis, transport, etc.) (Bos et al., 2010). MUFA and PUFA are commonly regarded as 'healthy fats' and are derived from plant sources, although PUFA can also be obtained from cold-water fish, shrimp, lobster and haddock (Bédard, Northstone, Henderson & Shaheen, 2020). According to Gillingham, Harris-Janz and Jones (2011), expectant mothers are advised to consume MUFA-rich foods because they are involved in modulating the sensitivity of insulin and the control of glycemic levels. MUFA-rich foods also help to control blood pressure in pregnant women and contribute to a healthy blood lipid profile. Additionally, Gillingham et al. (2011) reported that excessive intake of SFA can increase insulin resistance and decrease the glucose transporters found in fat cells.

Experts have established that fish, which are generally lower in saturated fats and high in long-chain PUFA (LC-PUFA), play an important role in a balanced diet (EFSA, 2010). The intake of LC-PUFA can influence the gestation period of the mother. For example, a study by Christian et al. (2016) established that the consumption of LC-PUFA, particularly those lower in docosahexaenoic acid (DHA), can lead to a shorter gestation period or the birth of a premature baby. Moreover, the results of the study revealed that the increased consumption of LC-PUFA may induce sleep disturbance in expectant mothers and this can be detrimental to the wellbeing of the mother and the child. In a series of randomised controlled clinical studies, the effects of supplementing pregnancies with n-3 LC-PUFA from fish oil or single-cell oils on pregnancy outcomes were examined. These studies included a daily supply of DHA ranging from 150–200 mg and approximately 1200 mg (or up to 2.7 g overall) of n-3 LC-PUFA per day. Omega-3s were deemed necessary for the baby's neurological and early visual growth. Nevertheless, the typical Western diet is significantly lacking in these critical nutrients. The assumption that the pregnant women were weaned of omega-3s enhances the dietary deficit of this

fat, and the foetus requires omega-3s for the growth of its nervous system (Hollander, Brami, Konikoff, Fainaru & Leikin-Frenkel, 2014). Furthermore, deficiency of this fat during pregnancy increases the risk of the development of postpartum depression in the mother (Caut, Leach & Steel, 2020).

**The Mediterranean Diet**

The Mediterranean Diet (MD) is characterised by an increased intake of legumes, vegetables, nuts, fruits and fish (which contain low amounts of SFA and high levels of PUFA and antioxidants), and decreased amounts of red wine and red meat (Fung et al., 2005). According to Zaragoza-Martí et al. (2018), adherence to an MD lowers the risk of preterm birth and preeclampsia, and it plays a role in preventing the mother from particular diseases during pregnancy such as gestational diabetes. The scoring of adherence to an MD is primarily determined using the revised scale developed by Trichopoulou et al. (Abreu et al., 2015). The scale is based on nine foods or components: dairy products, vegetables, alcohol, legumes, fat, vegetables, meat, meat products, fish and nuts (Abreu et al., 2015).

The importance of various micronutrients during pregnancy and the significance of supplementation with micronutrients such as folic acid, iron and vitamins has been previously discussed. During pregnancy, health providers should be aware of possible nutrient deficiencies in certain risk groups. For example, pregnant women who follow a vegan or vegetarian diet are potentially predisposed to nutritional deficiencies. Plant-based foods have inadequate levels of vital micronutrients including iron, zinc, iodine, calcium, omega-3 and certain B vitamins (Sebastiani et al., 2019). Therefore, additional supplementation with potentially deficient nutrients is necessary during pregnancy. Other high-risk groups for special consideration include the women inhabitants of cold climates (vitamin D deficiency), the already nutritionally compromised women and women of ethnic minority groups (Kominiarek & Rajan, 2016).

**Nutritional assessment during pregnancy**

A nutritional assessment is crucial to establish the nutritional status of a woman and estimate her dietary needs (Dunlevy, 2015). The BMI and other anthropometric measurements are essential in providing information regarding the past nutritional status of a woman. However, the exact nutritional intake of particular key nutrients is often

estimated through nutritional reviews using a provider- or self-administered questionnaire (IOM, 1990). Although this method may not provide an accurate estimation of the mother's nutritional status, nutritional reviews that utilise a food frequency or diet history questionnaire may help to detect nutritional deficiencies, hesitation regarding weight gain (body weight concerns) or eating disorders (IOM, 1990). The nutritional review questions can be tailored to a variety of settings based on dietary traditions and other socio-demographic parameters. The identification of dietary deficiencies and undesirable dietary habits of the mother, father, or household, in general, would facilitate the appropriate counselling and recommendations.

#### 4.1.2.5. Nutrition-related pregnancy outcomes

**Obesity**

Obesity occurs as a result of a complex interaction between dietary habits, general physical inactivity, genetic characteristics and aspects in the environment (Hruby et al., 2016). Therefore, nutrition, as a known modifiable risk factor for obesity, is related to maternal obesity and the associated pregnancy outcomes. As previously mentioned, GWG is a confirmed determinant of pregnancy outcomes. Although excessive GWG and obesity are closely related in the context of pregnancy, there is a slight difference because a person is regarded as obese if they have a BMI of 30 or greater, whereas GWG refers to a change in weight during gestation. The implications of obesity during the pre-pregnancy period on the outcomes of the pregnancy were previously mentioned. Moreover, most of these implications are similar to those that occur when obesity arises during pregnancy or persists throughout pregnancy. Therefore, obesity poses a challenge to health providers and patients.

During the prenatal period, foetuses of women with a high BMI throughout pregnancy tend to show advanced rates of structural abnormalities, including congenital heart disease, abnormalities associated with neural tube development, defects of the limbs and hydrocephaly (Block et al., 2013). Furthermore, obesity poses a significant threat to clinicians concerning the diagnosis of these abnormalities. In a study by Dashe, Mcintire and Twickler (2009), in which 10,112 standard obstetric ultrasound examinations were analysed, the detection of foetal anomalies was at least 20% less in obese mothers compared to those with a healthy BMI. Some conventional non-invasive prenatal tests (NIPTs) for detecting congenital diseases such as Down's syndrome (the Harmony test)

heavily rely on cell-free foetal DNA fractions ranging from 3-4% and above to facilitate the accuracy of results. In obese mothers, factors such as increased apoptosis, necrosis of adipose tissue that increases maternal DNA in circulation (Haghiac et al., 2012), and increased blood volume that dilutes the foetal DNA (Wang et al., 2013) reduce the yield of cell-free foetal DNA, which impairs the accuracy of the NIPT (Juul et al., 2020). Obesity in pregnant women has also been associated with high rates of hypertension, preeclampsia, preterm delivery and gestational diabetes, among other complications (Mariona, 2016).

The labour and delivery processes are more complex for women who are obese compared with those who have a BMI that is within the normal range. The occurrence of labour is associated with the increased expression of genes for the placental corticotrophin-releasing hormone (CRH), a hormone that controls several complex mechanisms during the labour process (Carlson, Hernandez & Hurt, 2015). This process is distorted in obese mothers, necessitating induction and predisposing them to preterm labour. In these cases, the women tend to have a prolonged first phase of labour (Kominiarek et al., 2011) and are at an increased risk of failure of labour following a previous caesarean delivery (Siddiqui, 2013). Obesity not only increases the need for operative vaginal delivery but also complicates the process because the dorsal lithotomy position required for this procedure is challenging to achieve comfortably in an obese parturient woman (Mariona, 2016). Similarly, maternal obesity increases the chances for caesarean delivery and simultaneously complicates the surgery due to difficulties in creating the correct incisions, extracting the baby and suturing the surgical wound (Mariona, 2016). Upon discharge, the patients are unable to access the incision site for cleaning and, therefore, have trouble maintaining proper hygiene and faster wound healing (Mariona, 2016).

Nutritional interventions impact the prevention of maternal obesity from preconception. The measures that have been highlighted regarding weight management pre-pregnancy and the prevention of GWG, therefore, contribute to the prevention of maternal obesity (Cheney et al., 2017). However, dietary interventions vary considerably nonetheless, according to individual and socio-demographic factors. Flynn et al. (2016) to investigate the adequacy and effectiveness of the dietary intervention options for maternal obesity, revealed significant methodological variability regarding the interventions. Furthermore, the results demonstrated that the observed lack of consensus

concerning the appropriate standard intervention was a key obstacle for the development of standard clinical guidelines and the application of the evidence in the clinical and public health fields.

Tebbani, Oulamara & Agli (2018) reported that GWG is one of the complex biological processes that support the normal growth and development of the foetus. It is used to predict the probability of adverse outcomes concerning the wellbeing of the infant and the mother. Significant weight gain is observed during the second and third trimesters due to a reduction in the symptoms of emesis and an increase in the volume and size of the uterine wall and other maternal organs (Tebbani et al., 2018).

Both inadequate and excessive GWG can have severe impacts on the health of the mother. Complications that may result from excessive GWG include hypertension, an increased risk of a cesarean section birth, abdominal adiposity and retention of weight, and diabetes (Tebbani et al., 2018). Inadequate GWG is also associated with particular risks such as preterm birth and the delivery of an infant with a low birth weight (Santos et al., 2018). Such outcomes may subsequently affect the psychological and emotional health of the mother. Therefore, to predict the risk of complications, it is essential to prepare GWG charts to monitor weight changes among expectant mothers (Santos et al., 2018).

**Gestational diabetes**

Gestational diabetes mellitus (GDM) is hyperglycaemia that is first recognised at 20 weeks gestation and onwards (Mustad et al., 2020). During gestation, GDM is associated with health issues such as hypertension and preeclampsia. In a population study that spanned 10 years, Nerenberg et al. (2013) demonstrated a high occurrence of preeclampsia in women with GDM compared to women with normal blood sugar levels. Moreover, the authors recommended that the surveillance and management of GDM should be escalated to prevent the development of preeclampsia. The occurrence of maternal hypertension and preeclampsia is even higher in women who are obese or have excessive weight gain (Weissgerber & Mudd, 2015). A systematic review and meta-analysis of 37 articles that reported an association between GDM and the occurrence of foetal macrosomia revealed a pooled odds ratio of 5.49 (Tabrizi et al., 2019). Foetal macrosomia increases the need for instrumental delivery and caesarean section and leads to a higher risk of postpartum haemorrhage, shoulder dystocia and premature birth (Kamana, Shakya & Zhang, 2015). Farrar et al. (2016) analysed 207,172 women and

explored the association between maternal serum glucose concentrations and adverse perinatal outcomes. The results revealed a linear correlation between the serum glucose concentration and adverse pregnancy outcomes, even in women who did not have GDM, emphasising the need for appropriate glycaemic control in all pregnant women.

Similar to the case of maternal obesity, diet also plays a crucial role in GDM. While an adequate intake of energy, in the form of CHO, is encouraged for the catabolic processes that occur in the mother and growing foetus, care should be taken regarding the amount and quality of the CHO (Mousa et al., 2019). Most dietary CHO, including glucose, sucrose and cooked starches, undergo rapid digestion and absorption in the gastrointestinal tract and cause a rapid increase in blood sugar levels (Mustad et al., 2020). However, certain CHO such as wholegrains are difficult for the body to digest and absorb due to their structural composition, leading to a modest increase in blood sugar. The undigested components of the CHO are transferred to the colon where they are involved in promoting bowel movement and stimulating incretin secretion, among other functions. Evidence suggests that a maternal postprandial rise in glucose increases the delivery of glucose to the foetus; this contributes to the adiposity and size of the foetus and results in macrosomia via the Modified Pedersen's Hypothesis (Kamana et al., 2015). Furthermore, studies have shown that the period of pregnancy is characterised by increased cravings for sweet CHO foods that rapidly increase blood sugar levels (Chortatos et al., 2013).

Most guidelines, including those provided by the NICE (2015a) and ACOG (Committee on Practice Bulletin No. 190-Obstetrics, 2018), recommend restricting the intake of CHO in mothers with GDM (to limit the consumption of CHO that cause a rapid rise in high-CHO (high glycaemic index) or substituting slowly digested low-CHO (low glycaemic index). However, various RCTs have demonstrated a lack of consistent effects regarding the influence of strategies aimed at the maternal intake of CHO on pregnancy outcomes. For example, Moreno-Castilla et al. (2013) reported that a low-CHO diet intervention for pregnant women with GDM did not reduce the insulin requirement and resulted in a similar pregnancy outcome as the control group. Similarly, Moses, Barker, Winter, Petocz and Brand-Miller (2009) and Ma et al. (2015) did not observe tangible differences between the study group and controls concerning the maternal and foetal outcomes of women with and without GDM who adopted low glycaemic index dietary habits. Additionally, Han, Middleton, Shepherd, Van Ryswyk and Crowther (2017) did not reveal a significant number of advantages for the women and babies, except for a

potential reduction in the risk of a caesarean section in women who adopted the Dietary Approaches to Stop Hypertension (DASH) diet. Conversely, a study by Yamamoto et al. (2018) demonstrated that dietary intervention improved maternal glycaemic control, although the study focused on glycaemic control as the primary outcome.

Overall, most of the RCTs that evaluated CHO dietary intervention in women with GDM were limited by small sample sizes (Mustad et al., 2020). Moreover, the observed effects on foetal macrosomia and other neonatal, maternal and infant outcomes were inconsistent. Therefore, there is insufficient evidence to refute the implementation of the recommendations provided in national and international guidelines. Furthermore, the interventions should not be implemented in isolation and should be combined with other interventions such as engagement in physical activity (NICE, 2015a).

**Nausea and vomiting**

Nausea and vomiting in pregnancy (NVP) is a ubiquitous condition, with most studies reporting its prevalence at approximately 80% (Chortatos et al., 2013). The severity of NVP varies, from insignificant nausea to severe nausea and vomiting. In its worst form, the condition is known as hyperemesis gravidarum and may warrant hospitalisation and in extreme cases, can lead to mortality (Ebrahimi, Maltepe & Einarson, 2010). For most women, NVP generally begins in the first trimester, between the $4^{th}$ and $6^{th}$ weeks of gestation, and peaks between the $8^{th}$ and $12^{th}$ weeks of gestation and diminishes by the middle of the second trimester (Crozier, Inskip, Godfrey, Cooper & Robinson, 2017). Previous studies have established various factors that predispose women to NVP, which include pregnancy at a young age, multiparity, smoking, and a low level of education and SES. However, the results from these studies were inconsistent (Chortatos et al., 2013).

Gestational diet is significantly affected by NVP. Latva-Pukkila, Isolauri, and Laitinen (2010) conducted a study to examine the variations in the dietary intake and clinical features of pregnant women with NVP compared to those without. The women who had NVP consumed considerably higher amounts of CHO. Moreover, the total dietary intake of micronutrients such as vitamin B12, zinc and magnesium was considerably less in the women who had NVP, and these nutritional differences persisted throughout the pregnancy. In a study of 2,270 women in the UK Southampton Women's Survey (SWS), Crozier et al. (2017) used an administered food frequency questionnaire to assess the dietary intake and symptoms before and during pregnancy. The data obtained

from the questionnaire were used to determine the health status of the women before pregnancy, at 11 weeks' gestation and at 34 weeks of pregnancy. The data were also used to assess the occurrence and severity of NVP. The results showed that an increase in the severity of NVP was associated with a decrease in the intake of foods such as vegetables, breakfast cereals, beans and citrus fruits and an increase in the intake of soft drinks and white bread. The findings from the above-mentioned studies underscore the need for appropriate nutritional monitoring in pregnant women, particularly in those with NVP. Moreover, severe NVP should be treated adequately to minimise the impacts on the woman's diet and subsequent pregnancy outcomes. The transient nature of the symptoms and the alteration in the dietary intake underscores the significance of establishing an adequate nutritional status during the preconception period and before the onset of the symptoms (Crozier et al., 2017).

**Maternal infections**

Pregnant women are at a considerable risk of acquiring and suffering from the complications of certain micro-organisms associated with food. Several of these infections are accompanied by adverse pregnancy outcomes, including pregnancy losses, prematurity, neonatal sepsis and neonatal mortality (Moran, Verwiel, Khomami, Roseboom & Painter, 2018). Listeriosis, caused by *Listeria monocytogenes* bacteria, is a rare but severe food-borne illness commonly observed in pregnant women. The CDC estimates that pregnant mothers are 10 times more predisposed to the disease than the general population (CDC, 2015). The results of a systematic literature review by Moran et al. (2018) showed that listeriosis was highly associated with the intake of high-risk meat products, dairy products and certain fruits during pregnancy. Raw or soft-cooked eggs have been highly associated with outbreaks of Salmonella infections (Einarson, Tam, Erebara & Koren, 2010). Listeriosis and Salmonella infections have also been associated with seafood, while honey has been associated with botulism due to contamination with spores of *Clostridium botulinum* bacteria (Einarson et al., 2010).

The WHO insists on ensuring general food safety precautions for pregnant women (WHO, 2012). Listeriosis and salmonellosis are food-borne diseases of serious concern in pregnancy. The risk of infection with *L. monocytogenes* can be significantly reduced through proper handling and cooking of dairy products and meat (CDC, 2015). It is advised that pregnant women should not avoid deli meats or soft-ripened cheeses, as long as they are consumed in moderation and obtained from reputable stores. Cottage cheese,

hard cheeses, cream cheese and shelf-stable foods have not been associated with listeriosis and are, therefore, safe for consumption (CDC, 2015). Raw and undercooked eggs and products made with eggs (such as salad dressings and mayonnaise) should be avoided in pregnancy to minimise the risk of salmonellosis, unless the eggs have been pasteurised. Moreover, similar to any other food for human consumption, appropriate hygiene, and food handling should be adhered to, to reduce the risk of diarrheal diseases (WHO, 2012).

#### 4.1.2.6. The role of gut microbiota

The gut microbiota comprises trillions of non-pathogenic bacterial and viral micro-organisms (Carding, Verbeke, Vipond, Corfe & Owen, 2015). These micro-organisms form an important defence mechanism against intestinal colonisation and maintain several essential metabolic functions such as the production of certain vitamins. They also facilitate the digestion of fats, carbohydrates and proteins.

There is increasing evidence to suggest that gut microbiota potentially influence the development of maternal obesity and the consequent metabolic risk for the offspring (Kozyrskyj, Kalu, Koleva & Bridgman, 2016). Turnbaugh et al. (2006) suggested that dysbiosis induces the excessive harvesting and storage of energy, thereby contributing to obesity. Experiments conducted on obese rats demonstrated that the microbiota in the rats did not have the gene coding for leptin, a hormone that promotes satiety (Cani et al., 2008). Research has further demonstrated that the intestinal microbiota plays a significant role in regulating fat storage (Ridaura et al., 2013). Moreover, microbiome dysbiosis is believed to indirectly influence metabolic function through a 'brain-gut' axis, in which neuronal functions that favour metabolic syndrome are activated in a dysbiosis setting (Edwards, Cunningham, Dunlop & Corwin, 2017). The results of the above-mentioned studies suggest that dysbiosis plays a role in the development of obesity. The significance of this mechanism is important in pregnancy, during which an impaired glucose tolerance results in obesity. Maternal obesity and glucose intolerance during pregnancy have been explored in previous sections of this review. Therefore, dysbiosis indirectly contributes to pregnancy and obstetric complications such as preeclampsia, haemorrhage and caesarean delivery, among others.

#### 4.1.2.7. The role of other factors

**Physical activity**

The physiological and psychological changes in pregnancy discussed earlier significantly promote a sedentary lifestyle with a reduced level of physical activity. In one research, part of the Pregnancy, Infection and Nutrition study of 1482 pregnant women, the level of reported physical activity was assessed in the second and the final trimester (Borodulin et al., 2008). The level of physical exercise was reportedly decreased as the pregnancy progressed. Only a trivial percentage of the participants attained the required level of physical activity by the third trimester. Similarly, information from National Health and Nutrition Examination Survey (NHANES) revealed that only 15% of women attained the two and a half of moderate-intensity activity weekly that is nationally acceptable minimum in the US and by the WHO (Evenson & Wen, 2010). A similar trend has been observed in studies based on the Swedish (Löf, 2011) and Asian populations (Padmapriya et al., 2015). The Swedish study, pregnant ladies, spent more of their time sleeping, sitting, lying and reclining and less time on walking and climbing staircases compared to the non-pregnant counterparts.

Various studies have confirmed the overwhelming advantages of physical activity when a woman is pregnant. In a meta-analysis of literature from 12 intervention trials, Streuling et al. (2011) established that physical activity during gestation reduced the occurrence of GWG. The occurrence of GDM is also significantly cut down by active engagement in physical activity. Mørkrid et al. (2014), in a population-based research, recorded an inverse association between the level of engagement in physical activity (steps covered per day) in early gestation and the occurrence of GDM, even after adjusting for socio-demographic features such as ethnicity, age, parity, socioeconomic status and physical activity. Recreational physical activity has also demonstrated a remarkable decrease in the occurrence of GDM (Wang, Guelfi, & Yang, 2016). However, some researchers have cited a lack of adequate proof to justify the effectiveness of engagement in physical activity during gestation in preventing GDM. Systematic reviews and meta-analyses by Aune, Saugstad, Henriksen and Tonstad (2014) and Kasawara et al. (2012) demonstrated that early pregnancy physical activity for pregnant women might be protective against preeclampsia. Some exercises prevent and reduce lumbopelvic pain and low back pain that is commonly experienced in pregnancy (Davenport et al., 2019).

The psychological benefits conferred by physical activity on pregnant women has also been established. Results from the NHANES reported an inverse association between engagement in physical activity in pregnancy and symptoms and signs of depression (Loprinzi et al., 2012). In a RCT to establish if a supervised exercise program was effective in minimising depression among pregnant women, Perales et al. (2015) established that the exercise program was effective not only in cutting down the incidences of depression but also the level of depression among the women. Pregnant women who actively engage in physical activity also tend to consider themselves as having better health status compared to their sedentary counterparts (Barakat et al., 2011).

The UK NHS encourages women to maintain the regular daily physical activity or exercises (running, yoga, walking, sport) when they get pregnant, so long as they are comfortable (NHS, 2020b). For ladies who were not physically active prior to getting pregnant, it recommends that they begin with a maximum of 15 minutes of continuous physical activity, about 3 episodes every week, which can be progressively increased to 30-minutes-a-day sessions. Just like the WHO, RCOG recommends at least one and a half hours of moderate-intensity exercise a week throughout the pregnancy (RCOG, 2017). Other international guidelines for physical activity in pregnancy are relatively in line with the UK endorsements. For instance, the ACOG encourages a physical activity program for pregnant women that involves 20 to 30 minutes of moderate-intensity physical activity per day for most days of the week (ACOG, 2020). The Netherlands, Australia and the Canadian National guidelines are more or less similar to the RCOG and ACOG recommendations (Downs et al., 2012).

**Socioeconomic factors and the environmental exposures**

Similar to many other medical outcomes, SES is an important element for determining pregnancy outcomes. Evidence suggests that the inequalities associated with healthcare for pregnant women of low SES correspond to an increased occurrence of health implications such as hypertension and preeclampsia (Wang & Geng, 2019), GDM, pregnancy loss, preterm labour, obstetric haemorrhage, and stillbirth (M. K. Kim et al., 2018). Women in such settings have little possibility of affording or receiving adequate prenatal care (Lee et al., 2016). In a study that explored the socioeconomic differences regarding the utilisation of obstetric services in the Netherlands, Posthumus et al. (2016) demonstrated potential inequalities concerning the utilisation of obstetric services and a disservice, particularly in reference to economically deprived individuals. Moreover, a

low SES has also been associated with other predictors of adverse health outcomes including malnutrition, drugs and substance use, psychological stress and exposure to a toxic environment. In contrast, a high SES is generally associated with good physical and mental health (Wang & Geng, 2019).

**Age**

At the opposite end of the spectrum, a considerable increase in the age of pregnant women has been observed in recent decades, particularly in developed countries (Londero, Rossetti, Pittini, Cagnacci & Driul, 2019). In the UK, the percentage of live births to women aged 35 years and older increased from approximately 8.7% in 1990 to approximately 19.9% in 2009, and the trend has been increasing since then (Kenny et al., 2013). The most recent publication by the UK Office for National Statistics indicated that by 2018, the average age of mothers and fathers in the UK had increased for the 10th consecutive year, and there was a record total rise in the parental age, by approximately 4.2 years, since 1974/75 (Office for National Statistics, 2019). This trend has repercussions for the health of the mother and child, in the form of a range of unwanted pregnancy outcomes, including low birth weight, preterm delivery, caesarean section, macrosomia and stillbirth (Kenny et al., 2013). Moreover, increasing maternal age is a recognised risk factor for pre-eclampsia and eclampsia (Soomro et al., 2019). Therefore, maternity service provisions should pay special attention to maternal and paternal ages and increase surveillance and counselling as necessary.

Teenage pregnancy has been associated with adverse pregnancy outcomes, partly because of the complications associated with physical immaturity, but largely due to associated socioeconomic issues (Ganchimeg et al., 2013). Pregnancy in adolescence has been commonly associated with low education status of the mother, welfare dependency, single parenthood and other socioeconomic disadvantages later in life (Wall-Wieler, Roos & Nickel, 2016). Adolescent pregnancy poses a significant risk of caesarean section, low birth weight and preterm delivery, among other adverse outcomes. The adverse outcomes are associated with a low SES, inadequate prenatal care and insufficient weight gain during gestation (Kawakita et al., 2016).

**Alcohol and substance use**

The deleterious effects of drugs and substance use in pregnancy on the development of the foetus and the outcomes of the pregnancy have been well established.

Alcohol use in pregnancy has been associated with various adverse outcomes including miscarriage (O'Leary, Jacoby, D'Antoine, Bartu & Bower, 2012), preterm delivery, stillbirth and infant mortality, congenital malformations, and low birth weight and SGA (Ornoy & Ergaz, 2010). Behavioural counselling is the primary treatment for substance use among pregnant women (Forray, 2016). Chang et al. (2005) investigated the effectiveness of brief intervention, a form of behavioural counselling, on the treatment of alcohol use in pregnant women, with the inclusion of their male partners. The women who had the highest levels of alcohol use significantly decreased their consumption after brief intervention sessions that included their partners. Motivational interviewing has also demonstrated significant effectiveness in women at risk of an alcohol-exposed pregnancy (Rendall-Mkosi et al., 2013).

Cigarette smoking during pregnancy has been associated with damage to the neurovascular structure of the umbilical cord, ectopic pregnancy, low birth weight, placental abruption, preterm delivery and infant mortality (Scherman, Tolosa & Mcevoy, 2018). Moreover, the smoking status can have a direct influence on the newborn's feeding method. Lechosa Muñiz et al. (2019) conducted research at a public hospital in Spain and established that mothers who smoked were less likely to breastfeed their children. The authors also stressed that counselling through education should address the repercussions of smoking for all women, before and during pregnancy.

Behavioural counselling techniques have also shown considerable effectiveness regarding prenatal cigarette smoking (Forray, 2016). However, most researchers recommend a combination of behavioural interventions and other treatment options, such as nicotine replacement therapy, to maximise the benefits. The NICE guideline [NG92] (2018) and the Saving Babies' Lives Care Bundle (SBLCBv2) (NHS England, 2019) advises screening all pregnant women by testing them for levels of carbon monoxide (CO) before asking about tobacco smoking. This measurement aids in establishing the risk of exposure to this toxic gas and the risk of poisoning, as well as improving the referral pathway during and after antenatal care for all women who smoke. In the UK, during pregnancy, women receive the Very Brief Advice (VBA) on smoking and are encouraged to accept behavioural support to stop smoking (NICE, 2018). A study by the Greater Manchester NHS (2020) highlighted that midwives, maternity support workers, obstetricians, sonographers, paediatricians/neonatologists, GPs, practice nurses, health

visitors (HVs) and family nurses all play an important role in supporting pregnant women to stop smoking.

For example, a study by Pollak et al. (2007) demonstrated the effectiveness of combining nicotine replacement therapy (NRT) and cognitive behavioural therapy (CBT). Moreover, the results showed that this combination of therapies was three times more effective than CBT alone at attaining smoking cessation during early (7 weeks) and late (38 weeks) gestation. In a more comprehensive study, a systematic review of the literature was conducted to assess the effectiveness and safety of behavioural and biological treatments for tobacco use in adults, inclusive of pregnant women (Patnode et al., 2015). Behavioural counselling and nicotine replacement in pregnant women who smoked was effective, with a significant reduction in preterm deliveries and an improvement in the birth weights. NRT has been postulated to be harmful to the pregnancy. In a study by Pollak et al. (2007), the recruitment of study subjects was suspended early during the research because an interim analysis showed higher rates of adverse pregnancy outcomes in the group that was subjected to CBT plus NRT compared to the group that was subjected to CBT alone. However, the results of a separate study suggested the use of NRT is safer than continued smoking (Diamanti et al., 2019).

Research has shown that caffeine may have adverse effects in pregnancy. It has been associated with complications such as intrauterine growth restriction, low birth weight, miscarriage and impairment in the cognitive development of the offspring (Qian et al., 2020). These effects occur as a result of various mechanisms including the impairment of uteroplacental circulation, the effects of poor foetal cardiovascular development and the dysregulation of some steroid hormone-regulated genes. The WHO recommends that pregnant women who consume greater than 300 mg of caffeine per day should reduce their intake to minimise the harmful effects on the pregnancy (WHO, 2017). Even lover limits are recommended by other organisations, for example, the EFSA recommends a maximum of 200g of caffeine per day (which equates to approximately two cups of ground coffee) for pregnant women (EFSA, 2015). This is reiterated by the NHS, which states a limit of 2 cups of instant coffee per day (NHS, 2018), and the ACOG, which states a limit of one 12-ounce cup of coffee per day (ACOG, 2019). The habitual intake of small amounts of caffeine (as recommended above) during pregnancy has not been shown to increase the incidence of low birth weight babies or miscarriages (EFSA, 2015).

The smoking of tobacco and the use of drugs and substances in pregnancy almost exclusively begins before pregnancy. Therefore, the interventions that occur during the pre-pregnancy period, if sustained throughout the pregnancy, can result in a reduction in the use of these drugs and the associated adverse outcomes.

**Psychological issues during pregnancy**

The symptoms and signs of depression and anxiety are common in pregnant women. Estimates of the prevalence of symptoms vary depending on the criteria applied in the studies. The ACOG estimates that between 9% and 10% of pregnant women meet the diagnostic criteria for depression at a certain period during gestation, and a greater percentage of women show several symptoms of depression during pregnancy (ACOG, 2018b). The NICE estimates that approximately 13% of women experience depression, 13% of women experience anxiety, and certain women experience both conditions during pregnancy (NICE, 2020b). There is sufficient evidence to suggest that psychological issues in pregnancy, particularly depression and anxiety, predispose a woman to adverse outcomes including hypertension and pre-eclampsia (Vianna, Bauer, Dornfeld & Chies, 2011), low birth weight, preterm delivery and SGA (Class, Lichtenstein, Långström & D'Onofrio, 2011). The pathophysiological mechanisms of these complications are diverse and include intrinsic hormonal factors such as alteration of the hypothalamic-pituitary-adrenal (HPA) axis (González-Ochoa, Sánchez-Rodríguez, Chavarría, Gutiérrez-Ospina & Romo-González, 2018), and extrinsic factors such as comorbid substance and drug abuse and the socioeconomic structure (Forray, 2016).

Although effective treatment plans exist for most psychiatric illnesses, including depression and anxiety diseases, various challenges limit the management of these conditions during pregnancy. The symptoms of mental disturbance in pregnancy are diverse and can overlap with the typical and expected pregnancy-related symptoms (Van Ravesteyn, Lambregtse-Van Den Berg, Hoogendijk & Kamperman, 2017). Therefore, it may be challenging for clinicians to screen for and diagnose the conditions. The Edinburgh Postnatal Depression Scale (EPDS), which is a validated and highly accepted method for screening for depression, does not include symptoms such as lethargy and appetite changes as these cannot distinguish between a pregnant woman who has depression and one who does not (Biaggi, Conroy, Pawlby & Pariante, 2016). Women may be hesitant to communicate certain symptoms, such as irritability or sadness, due to the stigma associated with depression and the general expectation that women are happy

during pregnancy (Moore, Ayers & Drey, 2016). Moreover, pharmacotherapeutic treatments in pregnancy are associated with known and unknown risks for the developing foetus (Chaudron, 2013).

The recently updated NICE guidelines on maternal mental health encourage healthcare providers to promote mental health and prevent the devastating effects of psychiatric conditions in pregnancy (2020b). The guidelines encourage preconception management and prevention measures and recommend ways to mitigate a wide range of psychological disturbances during pregnancy and postnatally, including the careful use of psychotropic drugs. Non-pharmacological therapeutic options, such as CBT and psychotherapy, are recommended. Dietary recommendations such as minimising caffeine intake and eliminating cigarette smoking and alcohol use are also included. Moreover, an analysis of the UPBEAT Cohort of Obese Pregnant Women revealed that appropriate dietary and lifestyle interventions, including glycaemic control, contribute to the optimisation of maternal mental health (Wilson et al., 2020).

### 4.1.3. After pregnancy: A mother's health perspective

Pregnancy, delivery and the postpartum process are memorable moments for a woman due to diverse physical, psychological and social repercussions. The postpartum period, defined as the period between 1-hour and 42 days post-delivery, is regarded as a critical time for the mother's and newborn's health. The newborn aspect of the postpartum period will be addressed in subsequent sections of this review.

Numerous physiological and anatomical variations occur in the systems of the mother's body during the postnatal period (Bhatia & Chhabra, 2018). To understand the changes that occur, the postpartum period is classified into three phases (Romano, Cacciatore, Giordano & La Rosa, 2010). The initial phase is the acute phase, which spans the first 6–12 hours after delivery. Immediate childbirth complications are common during this phase and include haemorrhage, eclampsia, embolism and uterine inversion. The second phase, i.e. the subacute phase, lasts for approximately 2–6 weeks and is a critical period for metabolic, body system and psychological recovery (Romano et al., 2010). Several chronic complications such as cardiomyopathy and postpartum depression occur during this period. The final phase can last up to 6 months post-delivery, and the body gradually recovers to the pre-pregnancy state. Throughout this period, the mother must also adapt to the newborn's care routine, including lactation.

#### 4.1.3.1. Breastfeeding

In general, a lactating woman may require an additional 500 kcal/day and an additional 25g/day of protein compared to a non-lactating woman (Kominiarek & Rajan, 2016). The micronutrient requirements are generally higher during this period than in pregnancy, except for phosphorus, calcium, vitamin D, vitamin K and fluoride (Ballard & Morrow, 2013). The extensive benefits of breastfeeding for the infant are well known and are discussed in a subsequent section of this review. Breastfeeding has substantial health benefits for the mother and the infant, and there is sufficient evidence to suggest that prolonged lactation facilitates the loss of the weight gained by the mother during the gestation period. The hormonal changes that are caused by lactation, including the release of prolactin and the withdrawal of oestrogen and progesterone, are thought to contribute to the mobilisation of fat stores, resulting in weight loss (Wiklund et al., 2012). In a study by Tahir et al. (2019) that compared the post-delivery weight loss of cohorts of women with a prolonged full breastfeeding period and those with a shorter full breastfeeding period, the results revealed that a prolonged period of full breastfeeding (3 months or more) increased the potential in those women to lose weight and return to their pre-pregnancy weight. Similar results were obtained by Sámano, et al. (2013) and Wiklund et al. (2012) that examined cohorts of adolescent and adult mothers. In the long term, women who practised prolonged exclusive breastfeeding were observed to weigh up to 8 kg less than their non-breastfeeding counterparts at six years after giving birth (Sharma, Dee & Harden, 2014).

The risk of diabetes mellitus is significantly reduced in women who breastfeed. In a systematic review of prospective case studies that included a total of 273,961 participants, Aune et al. (2014) established an inverse association between the duration of lactation and the occurrence of diabetes. In women who developed gestational diabetes, a breastfeeding period of greater than six months significantly reduced the risk of continuation with the disease as postpartum diabetes (Jäger et al., 2014). Breastfeeding has also been shown to reduce the risk of other chronic conditions such as hypertension, hyperlipidemia, cardiovascular diseases (Binns, Lee & Low, 2016) and breast cancer (Zhou et al., 2015). Moreover, several psychological benefits of breastfeeding have been identified including a reduced risk of anxiety and depression and promotion of maternal-infant attachment (Krol & Grossmann, 2018). However, the results of other studies have revealed an association between the low levels of oestrogen that occur during

breastfeeding and the occurrence of osteoarthritis in women after menopause (Park, 2017). Nevertheless, there is insufficient evidence to support the causal association, and the risks that accompany inadequate breastfeeding significantly outweigh the risk of osteoarthritis (G. Yan et al., 2019).

Similar to the WHO, the *Infant Feeding Survey-UK 2010* (IFS) recommendations on breastfeeding encourage exclusive lactation of the infant for six months and continued lactation for a minimum of two years as other foods are introduced to the infant (NHS. 2012). The UK has one of the lowest rates of breastfeeding in Europe and globally. The IFS indicated that approximately 34% of UK mothers were breastfeeding at six months (NHS, 2012) compared to 49% of mothers in the US and 71% of mothers in Norway (The Lancet, 2016). The UK survey demonstrated that the breastfeeding rates decreased consistently, from 81% at birth to 69% at the end of the first week, and by six weeks, only 55% of mothers were breastfeeding. Moreover, only 1% of mothers were exclusively breastfeeding (without mixed feeding) at six months (NHS, 2012).

The low prevalence of breastfeeding in the UK has been attributed to various factors. Maternal worries, the opinions of friends and family and myths concerning whether breastmilk is sufficient for the infant may convince mothers to supplement breastmilk with formula (NHS, 2012). In these cases, the production of maternal milk is compromised, resulting in secondary lactation failure and leading to early cessation of breastfeeding. Societal attitudes may also result in a woman feeling uncomfortable to breastfeed her child in the presence of other people. Moreover, a low level of education of the mother, a low SES, a lack of support from the partner, being a member of a black or minority ethnic group and a young maternal age have all been associated with low rates of breastfeeding initiation and maintenance (Simpson, Quigley, Kurinczuk & Carson, 2019). Therefore, public health interventions must be streamlined towards such groups. Non-initiation of breastfeeding and early weaning have been attributed to work-related issues for many employed women. For such women, an unsupportive work environment (such as an unavailable or short paid maternity leave) and a lack of breastfeeding spaces and facilities may hinder breastfeeding (Ogbuanu, Glover, Probst, Liu & Hussey, 2011). Although the UK provides an allowance of 52 statutory maternity leave weeks, which includes 26 weeks of ordinary maternity leave and 26 additional weeks of maternity leave (GOV.UK, 2016), many employed women return to work as early as 12 weeks after giving birth.

After giving birth, it is often difficult for women to lose the weight gained during the gestation period, and obesity amongst women of childbearing age is a global pandemic that causes several preventable chronic diseases. Therefore, breastfeeding education and support should be prioritised during preconception counselling, pregnancy and postpartum care. Public health policies and investments must be implemented so the financial insecurity that occurs due to unpaid maternity leave will no longer be an obstacle for women who wish to breastfeed their children. Simultaneously, community-based health promotion is required to address the most common limitations and the many benefits of prolonged breastfeeding.

#### 4.1.3.2. Nutrition and lifestyle after pregnancy

Establishing a healthy diet and lifestyle in the postpartum period is crucial to promote the health status of the mother and the child in the short and long term. In the short term, a healthy diet is necessary to adequately support lactation (Segura, Ansótegui & Díaz-Gómez, 2016). The nutrients in breastmilk consist of those obtained from the dietary intake of the mother and the nutrient reserves in the body. The content of certain nutrients in breastmilk, such as CHO, protein, fats and calcium, does not change significantly, regardless of the mother's diet. However, the amount of micronutrients such as vitamin A, vitamin D and thiamine is entirely dependent on the dietary intake of the mother. Since breastmilk is the essential source of nutrients for the baby, the mother should consume a mixed diet containing satisfactory amounts of micronutrients. The dietary habits of the mother in the postpartum period significantly influence weight retention (Boghossian, Yeung, Lipsky, Poon & Albert, 2013). In the long term, the appropriate nutritional intake prevents the future development of obesity and the accompanying non-communicable diseases such as type 2 diabetes, cardiovascular diseases, and hypertension (Van Der Pligt et al., 2016).

Although many women adopt an appropriate diet during pregnancy, their dietary habits often discontinue after the delivery of the baby (McDonald et al., 2011). In comparison to the pregnancy period, less attention is paid to the postpartum period by mothers and healthcare providers. The formal face-to-face contact that occurs between the mother and the healthcare staff is generally inconsistent during the postpartum period compared with the pregnancy period, during which consistency is highly observed. For example, in Australia, standard guidelines do not exist concerning the scheduling of

routine postpartum clinic visits for women (Van Der Pligt et al., 2016). In the UK, the NICE guidelines promote a greater number of clinic visits for women during gestation compared to the postpartum period (2010). Moreover, the NICE postnatal visit guidelines emphasise breastfeeding and care for the newborn where the health of the mother is neglected. This inconsistent, fragmented and inadequate postpartum care requires aggressive intervention measures in this specific population to promote and sustain healthy dietary habits after pregnancy.

In a pilot RCT conducted to investigate the feasibility of a 4-month dietary plan that promoted vegetable intake among postpartum women, face-to-face nutrition education, phone calls and pamphlets were used to promote dietary habits (Falciglia, Piazza, Ritcher, Reinerman & Lee, 2014). The control group only received handouts that contained guidelines on healthy diets. The group that received the intervention included a greater percentage of women who met the goal regarding vegetable intake (25.8%) compared to the control (8%). Similarly, in a separate RCT that was conducted to evaluate the effectiveness of nutrition guidance on women in the postpartum period, the results showed that education facilitated the abandonment of unhealthy postpartum dietary practices and reduced the prevalence of postpartum health complications (Liu et al., 2009). Therefore, these results suggest that aggressive nutritional education is effective at improving dietary habits among postpartum women. Thus, the NICE guidelines urge healthcare providers to implement postnatal checks between 6 and 8 weeks to promote healthy dietary habits among women post-delivery (2010). These visits are important opportunities to encourage women to continue a healthy lifestyle adopted during pregnancy.

Postnatal smoking is a subject that requires further attention. Women who are pregnant or planning a pregnancy, and mothers of infants and young children and their families are advised to follow the NICE guidelines on this topic (2018). The previously mentioned resources have highlighted the requirement for ongoing support to improve the health of the mother and child as well as the breastfeeding rates.

#### 4.1.3.3. Postpartum weight retention

In general, the majority of women mostly regain their pre-pregnancy physical state; many women do not completely lose the weight they acquired during gestation. As much as 80% of mothers retain 1.4 kg to 5 kg of the weight they gained during pregnancy

up to 1 year after childbirth, and up to 50% of women retain 5 kg or more (Martin, Macdonald-Wicks, Hure, Smith & Collins, 2015). This weight retention increases the potential for a woman to become overweight or obese, resulting in associated risk factors in a subsequent pregnancy and throughout her lifetime (Nunnery et al., 2018). Obesity is a worldwide healthcare issue the WHO is attempting to increase awareness regarding unhealthy body weight and that this can significantly increase the risk of severe outcomes for patients with coronavirus disease (COVID-19) (WHO, 2020b). These new health risks, which appeared in 2020 due to COVID-19, have highlighted the importance of weight control and the requirement for intervention to prevent excess weight gain amongst women of childbearing age.

Various risk factors predict the occurrence of excessive postpartum weight retention. Excess GWG has been established as a significant predictor of subsequent overweight or obesity. During a 5-year national prospective study of 774 mothers, Endres et al. (2015) established that excessive GWG was highly associated with the persistence of excess weight after delivery, and the retained weight contributed greatly to the occurrence of obesity at one year after delivery. Similar results were obtained in a study by Haugen et al. (2014), which demonstrated that a GWG greater than that recommended by the IOM(a) resulted in the retention of greater than 2 kg of weight at 18 months post-delivery for all weight classes. Therefore, the factors that cause excessive GWG, as previously described in this review, promote postpartum loss of weight gained during a gestation. Other risk factors include a short duration of breastfeeding (He et al., 2015), multiparity, a low level of education of the mother (Endres et al., 2015) and the lifestyle of the mother after delivery.

Although modification of a woman's lifestyle during the pre-pregnancy period and in pregnancy is effective at preventing excessive GWG and subsequent postpartum weight retention, post-pregnancy lifestyle management strategies also contribute to the deterrence of weight retention after delivery and the associated adverse health outcomes throughout a woman's lifetime (Martin et al., 2015). The dietary intervention described above (including the adoption of a low glycaemic index diet) promotes weight loss after delivery (Schmitt, Nicholson & Schmitt, 2007). Similarly, engagement in physical activity during the postpartum period has been shown to significantly impact weight retention (Van Der Pligt et al., 2016). Moreover, evidence from comprehensive systematic reviews of RCTs that evaluated the measures implemented to reduce

postpartum excess weight gain indicates that the successful studies involved physical activity and dietary interventions (Farpour-Lambert, Ells, Martinez De Tejada & Scott, 2018). Thus, it is recommended that moderate-intensity physical exercise is adopted throughout pregnancy and even during the postpartum period.

### 4.2. Child health perspectives

#### 4.2.1. Importance of the perspective and Barker's Hypothesis

In recent decades, there has been an increase in chronic diseases in children and adolescents, with some persisting into adulthood. This trend has prompted extensive research on the origin of such illnesses, and several researchers have highlighted the wide-ranging socio-demographic origins of chronic diseases in children, adolescents and adults (Garbarski, 2014). Consequently, a comprehensive model known as 'Barker's Hypothesis' was developed to describe how the foetal environment and maternal parameters during pregnancy, and childhood exposure, influence the health status of an individual throughout his or her lifetime (Calkins & Devaskar, 2011). Moreover, developing and understanding this structure is important for global and national policies that target maternal and child health, as well as the prevention of chronic diseases such as obesity and diabetes.

The Foetal Origins of Adult Disease (FOAD), commonly referred to as Barker's Hypothesis is a result of observations that were made during revolutionary research conducted by David Barker. According to this so-called "fetal origins" hypothesis, insufficient nutrition while in the mother's womb 'programmes' the foetus to develop a metabolic state that may predispose it to diseases later in life (Almond & Currie, 2011). Therefore, the FAOD based on is underlined by the hypothesis of 'developmental plasticity', which postulates that a particular genotype, under the influence of various intrauterine exposures, has the potential to develop a variety of phenotypes. Thus, diversity is exploited to enable a perfect fit between the phenotype and the surroundings (Fall, 2013). For example, when a foetus is starved in utero, it undergoes adaptations via the alteration of the structure and function of different tissues to ensure intrauterine and extrauterine survival (Kwon & Kim, 2017). Moreover, in this case, there is an increased likelihood of obesity and associated cardiovascular diseases and diabetes in adulthood (Almond & Currie, 2011). The key ideas presented in the FAOD hypothesis concern the persistent consequences of the status of the foetus and an extended period of latent health

implications. This concept of abuse that occurs during the intrauterine period and results in a perpetual physiological response is referred to as programming. Figure 1 illustrates the elaborate framework of the foetal response to malnutrition that results in programming.

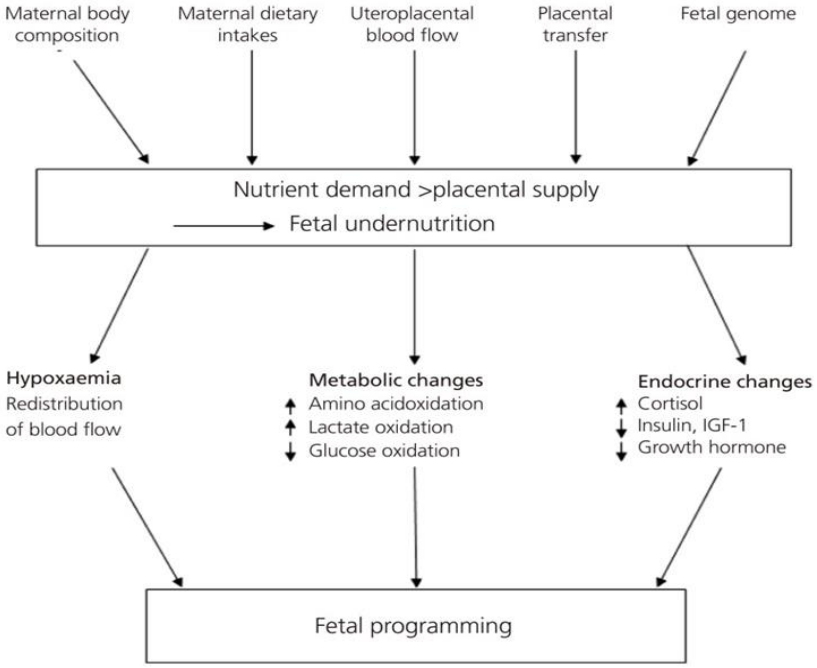



Figure 1. Adaptation of a foetus to undernutrition, with resultant foetal programming. IGF: insulin-like growth factor. Retrieved from (Kwon & Kim, 2017).

There is increasing evidence to suggest that epigenetic alterations of the foetal genome during development, due to an inappropriate maternal nutritional status, may result in a permanent genetic imprint (Cassidy & Charalambous, 2018). This mechanism has been associated with specific effects such as insulin functioning and adipose tissue metabolism, and with the occurrence of lifestyle illnesses later in life such as diabetes and obesity (Calkins & Devaskar, 2011). This component of the FAOD hypothesis, commonly referred to as metabolic imprinting, is the process of reactive metabolic response during which the early-life exposure to a specific nutritional state in a critical period of development persists through adulthood (Jahan-Mihan, Rodriguez, Christie, Sadeghi & Zerbe, 2015).

The results of extensive population analyses support the FAOD hypothesis. Barker, Osmond, Kajantie & Eriksson (2009) reviewed findings from a birth cohort that consisted of 13,345 individuals who were born in Helsinki between 1934 and 1944. They also

analysed data from a cohort of 7,086 individuals who were born in the decade before 1934. The results demonstrated that the individuals who developed coronary artery disease, hypertension and diabetes were most likely to have had slow growth and development during their intrauterine life. Moreover, the individuals who had a cerebro-vascular accident (stroke) tended to have had slow growth in the womb and during infancy and early childhood. Similar findings were recorded in studies that evaluated prenatal exposure to the Dutch famine, and in the Leningrad siege study (Calkins & Devaskar, 2011). Reviews of large birth registries revealed that the effect of intrauterine exposure on cardiovascular disease and diabetes was not free from possible confounders including smoking, physical activity, diet, socioeconomic position and genetics. Furthermore, foetal exposure was not limited to nutritional deficiency, but other factors such as infections, drugs and toxins, inflammatory processes and hypoxia also significantly influenced the adult phenotype (Calkins & Devaskar, 2011).

Due to the interconnected environmental influences, both in the womb and after delivery, the FAOD hypothesis is influenced by correlational factors that are difficult to exclude in historical data (Skogen & Øverland, 2012). Moreover, several critics have raised the issue of reliability, since Barker's studies were based on historical and longitudinal information. The cost-effectiveness of interventions aimed at women to limit intrauterine exposure compared with the traditional interventions that target children, adolescents and adults in the general population to prevent chronic diseases is yet to be established. Therefore, the FAOD is better understood and regarded as a component of the broader life course, instead of an independent premise (Skogen & Øverland, 2012). However, these critiques are insufficient to warrant cessation of the public health focus regarding foetal interventions for the prevention of chronic diseases (Almond & Currie, 2011).

### 4.2.2. The influence of maternal pre-pregnancy health status, nutrition and lifestyle: A child's health perspective

As previously mentioned, the pre-pregnancy period has been established as an opportunity for intervention regarding maternal health. The pre-pregnancy diet and lifestyle, and the associated implications for the mother including malnutrition, obesity, and diabetes, has a strong influence on the health of the foetus and the offspring beyond delivery and into childhood (Li et al., 2013). Human physiology and biochemistry reflect

an individual's diet, lifestyle and environment (Guasch-Ferré, Bhupathiraju & Hu, 2018). During an analysis of the literature in preparation for this review, a considerable knowledge gap was noted regarding evidence to support the influence of maternal pregestational health, nutrition and lifestyle, and interventions concerning the health of the offspring in extrauterine life. Most studies focused on the implications of being overweight or obese pre-gestation.

#### 4.2.2.1. Effects on the growth and development of the offspring

There has been a significant increase in obesity on a global scale, particularly childhood obesity, and how maternal pre-pregnancy factors influence the health of the offspring has been a focus of research. Obesity and health status in the pre-pregnancy period, and the fact that this predisposes a woman to excessive GWG, was previously highlighted in this review. Moreover, most studies have explored the effects of pre-pregnancy obesity in conjunction with excessive GWG to evaluate the influence on the foetus and subsequent health of the child. In a cohort study of 1,263 pairs of mothers and their offspring, Leng et al. (2015) established that the pre-pregnancy weight of the mother was a vital determinant of the growth of the foetus. Furthermore, the results demonstrated an association between maternal pre-gestation obesity and excessive GWG, and the predisposition of the foetus to macrosomia and large-for-gestational-age, with an odds ratio of approximately 3. Similar findings were obtained by Akgun, Keskin, Ustuner, Pekcan & Avsar (2017). The adverse complications of foetal macrosomia and large babies, and the potential benefits of weight management before pregnancy have been addressed in earlier sections of this paper.

The consequences of the pre-pregnancy weight of the mother are not limited to the foetus and they extend beyond delivery. Jin et al. (2016) conducted a study to evaluate the independent and combined influence of a woman's BMI, pre-pregnancy weight and GWG on the growth of the infant in the initial three years of life. A total of 826 pairs of mothers and their offspring were recruited for the study. The results demonstrated that the babies of mothers who were overweight or obese in the pre-gestation period or those who had excessive GWG continuously recorded higher BMI Z-scores (standard scores) in the initial three years of life compared to the others. Moreover, a high BMI score of the babies was associated with the mothers who were overweight or obese in the pre-gestation period, independent of excessive GWG. Therefore, excessive GWG

strengthened the effect of obesity in the pre-gestation period. In a separate study of 38,539 expectant mothers, the pre-gestation BMI and GWG were positively correlated with the birth weight and length-for-gestational age (Li et al., 2013). Moreover, the potential for a high weight-for-age Z-score (standard score) or being overweight or obese at 1-year post-delivery was significantly higher in children born of women who had excessive GWG and pre-gestation obesity.

The impact of maternal pre-pregnancy BMI extends beyond the obesity of the offspring. Emerging evidence suggests a possible connection between a woman being overweight or obese in the pre-gestation period and the cognitive and behavioural development of the offspring. Data from the US Collaborative Perinatal Project conducted between 1959 and 1976, which included 30,212 participants, revealed that maternal pre-gestation obesity was associated with a lower IQ score of the offspring, with an average deficit of approximately 6.5 points (Van Lieshout, Taylor & Boyle 2011). Other studies have established a positive correlation between the pregestational BMI of mothers and the occurrence of symptoms of attention deficit hyperactivity disorder (ADHD) in their children (Rodriguez et al., 2008). Similarly, Tanda, Salsberry, Reagan & Fang (2013) reported a correlation between preconception obesity and a poor cognitive test score in the offspring, even after other possible confounders such as the familial background and other intrauterine exposures were corrected for. Furthermore, the WHO has emphasised that there is a higher risk of developing obesity for children with at least one parent or carer who has excess body weight (WHO, 2020b). Thus, the household lifestyle patterns may play an integral role in early care and provide an initial opportunity for intervention to optimise the growth and development of the offspring.

#### 4.2.2.2. Effects on the metabolome of the offspring

The FAOD has prompted various studies to appraise the causal consequences of pre-pregnancy and pregnancy factors concerning the metabolic profile of the offspring. Ferreira et al. (2017) analysed three European birth cohorts to establish an association between maternal pre-gestation BMI and the cardiometabolic profile of the offspring. The maternal and paternal BMIs were positively correlated with various adverse cardiometabolic patterns of the offspring, including very-low-density lipoprotein (VLDL)-lipoproteins and VLDL-cholesterol (VLDL-C). Moreover, the authors established a negative correlation between the maternal BMI before pregnancy and the

high-density lipoprotein (HDL) in the offspring; this lipoprotein protects against cardiovascular diseases. However, the study did account for the influence of maternal foetal fuels, such as glucose and amino acids. In a separate study, Gaillard et al. (2014) observed that a high BMI of the mother and father was associated with low childhood HDL and high childhood insulin levels. Similarly, Oostvogels et al. (2014) established a positive correlation between the maternal pre-gestation BMI a poor metabolic score of the offspring, which included HDL-Cholesterol (HDL-C), triglycerides and fasting blood glucose.

The beneficial effects of pre-pregnancy weight management for improving foetal development and pregnancy outcomes were previously highlighted in this thesis. However, during this literature review, no studies were identified that associated pre-pregnancy weight interventions with a decrease in obesity in the offspring. This may be due to the difficulty in instituting and sustaining interventions and monitoring the progress of women from pre-pregnancy to delivery. It may also be due to a high percentage of unplanned pregnancies which may complicate a comparison of the interventions. However, hypothetically, public health interventions that target this group of women should result in positive effects and prevent obesity in the population (Doherty et al., 2006).

#### 4.2.2.3. Pre-pregnancy undernutrition

Much research has focused on overnutrition and obesity in mothers and its influence on the development of the foetus and child, however, the undernutrition of women in the pre-pregnancy period also has significant implications for the development of the foetus and the subsequent physical and neurological development of the child. During a study in Croatia of 4,678 pairs of pregnant women and their offspring, Jeric et al. (2013) investigated how a low BMI during pregnancy influenced foetal growth and development. Neonates of underweight mothers had significantly lower mean weights at birth compared to those born of mothers of an optimal nutritional status. Similarly, the occurrence of small-for-gestational-age neonates was twice as high among women who were underweight compared with women of adequate nutritional status. Moreover, the results of other studies revealed an association between pre-pregnancy undernutrition and intrauterine growth restriction (IUGR) and preterm birth (Doherty et al., 2006).

Low birth weight children born of undernourished mothers tend to demonstrate 'catch-up' growth as the body's natural reaction to overcome nutritional deficiency (Calkins & Devaskar, 2011). This compensatory exponential growth has been associated with an increased risk of obesity and other cardiovascular diseases later in life. Jornayvaz et al. (2016) conducted the CoLaus Swedish population study and demonstrated that middle-aged individuals who were registered as having a high weight at birth had a significantly increased occurrence of obesity, diabetes and leptin levels compared to those who were registered as having an optimal weight at birth. Similar findings were established during a meta-analysis of the literature to establish the short term and long-term implications of the catch-up growth of low birth weight neonates (Martin, Connelly, Bland & Reilly, 2017). The results revealed that catch-up growth had potential short-term health benefits for the infant, including decreased hospitalisation and mortality. However, in the long term, catch-up growth was associated with an increased risk of being overweight or obese, as well as cardiovascular risks. Other studies revealed that pre-gestation undernutrition was associated with poor intellectual and neurocognitive development of the offspring (Li et al., 2018).

Although malnutrition (undernutrition) is commonly associated with a low (or sometimes normal) BMI, obese individuals may also be undernourished (Sharma, Mogensen & Robinson, 2019). Certain women may have nutritional deficiencies despite being obese. Although few studies have focused on nutritional deficiencies in obese women and children, it is important to consider the nutrition of all individuals in clinical settings. For example, regarding the management of pre-gestation obesity, no studies were detected during this literature review that specifically evaluated the influence of pre-pregnancy interventions for undernutrition on the growth and development of the offspring.

#### 4.2.2.4. Maternal pre-pregnancy diabetes

Uncontrolled maternal diabetes mellitus before pregnancy can have numerous effects on fertilisation, pregnancy and after delivery. The impact of maternal hyperglycaemia on the intrauterine development of a foetus (including consequences such as large-for-gestational-age, congenital malformations, macrosomia, caesarean sections and neonatal mortality) and the benefits of glycaemic control in women with diabetes during the pre-pregnancy period have been previously highlighted.

### 4.2.3. Maternal determinants of foetal growth and development during pregnancy: A child's health perspective

#### 4.2.3.1. Foetal growth and development

After fertilisation, prenatal development commences and progresses in complex and metabolically demanding stages, from the germinal stage (spanning from 0–2 weeks) through the embryonic period (from 3–8 weeks) to the foetal stage (from 9 weeks to delivery). The germinal stage, which occurs during the pre-implantation period, is characterised by rapid division of the cells of the zygote resulting in a ball of cells that travels along the maternal fallopian tube to the implantation site at the uterus. Several experimental studies have suggested the extreme vulnerability of this stage regarding severe exogenous and endogenous abuse (Musumeci et al., 2015). Insufficient nutrients or nutritional deprivation during this period not only leads to the termination of the blastocyst (Williams, Seki, Vuguin & Charron, 2014) but also impaired somatic development (Zerfu & Ayele, 2013) and significant interference of the metabolic processes.

Organogenesis occurs in the embryonic period. In this period, the embryo is generally highly sensitive to teratogenic exposure, which often leads to congenital malformations (Alwan & Chambers 2015). Exposure to toxic substances such as alcohol, tobacco, and to infections and radiation exerts a maximal effect during this period. Organogenesis is a nutritionally consumptive process, and deficiencies during this rigid timeline may also impair organ development (Lowensohn, Stadler & Naze, 2016). Specific nutrients are often required in significant amounts during the formation of organs. For example, folate is required during the closure of the neural tube at approximately week 28 to complete the formation of the brain and the spinal cord. Similarly, adequate maternal intake of vitamin A is necessary for the general organogenesis of almost all organs since it is critical for the proliferation, differentiation and apoptosis of cells; these are the primary cell processes that occur during organogenesis (Gutierrez-Mazariegos, Theodosiou, Campo-Paysaa & Schubert, 2011). However, excessive vitamin A intake during this period has been associated with malformations in the cardiovascular and central nervous systems as well as an increased risk of spontaneous abortion (Bastos Maia et al., 2019).

In the foetal period, further growth and development of the organs occur, and the organs begin to establish physiological functions. Nutritional deficiencies during this

period, particularly those that involve macronutrients, have been associated with foetal growth restrictions (Morrison & Regnault, 2016). Maternal malnutrition that specifically involves inadequate protein intake, excessive fat intake and insufficient micronutrients have been associated with poor development of the kidneys (Wood-Bradley, Barrand, Giot & Armitage, 2015), while protein deficiency has been associated with poor development of the endocrine organs (Morrison & Regnault, 2016). Iron is required for neuron growth, synaptic formation and other processes during the development of the brain. Therefore, iron deficiency in the later stages of brain development results in insufficient development and significant neurocognitive impairment, particularly in specific regions such as the basal ganglia (Moos, Skjørringe & Thomsen, 2018). Genetic imprinting is a critical component of Barker's hypothesis and is associated with nutritional deficiencies at this stage or at other critical periods of development.

#### 4.2.3.2. The role of the placenta and the nutritional requirements of the foetus

The foetus is highly reliant on the placenta for nourishment and protection. The placenta is an organ that serves as an essential interface between the woman and the developing offspring. It acts as a surface for physiological exchange between the mother and the foetus and has endocrine and metabolic functions to provide appropriate substrates to the developing foetus (Burton & Fowden, 2015). The physiological exchange function of the placenta, in part, involves the transportation of toxic metabolic wastes from the foetus to the mother for excretion (Burton & Fowden, 2015). The metabolic and nutritional requirements of the foetus are met through an effective utero-transplacental transport system (Brett, Ferraro, Yockell-Lelievre, Gruslin & Adamo, 2014). Therefore, other than maternal nutrient availability, the foetus relies on the placenta for optimal nutrition. Consequently, various placental factors influence the growth and development of the foetus. For example, factors such as the size and weight of the placenta are essential determinants of the efficient transportation of nutrients and other substances between the foetus and the mother (Roland et al., 2012). If the placenta does not attain the appropriate size, the growth and development of the foetus may be restricted, while excessively large placentas have been associated with foetal hypoxia and macrosomia (Brett et al., 2014). The foetus to placenta weight ratio is an important marker of the efficiency of the placenta’s transport function (Wallace, Horgan & Bhattacharya, 2012).

The consequences of maternal obesity for the foetus are believed to be promoted by several placental abnormalities that are associated with a high BMI. In animal models, obesity has been associated with increased delivery of nutrients to the foetus, with a subsequent increase in the birth weight (Rosario, Kanai, Powell & Jansson, 2015). Moreover, maternal obesity and diabetes have been associated with abnormalities in placental arteries and oxidative stress in placental tissues which may impact the functioning of the placenta (Desoye, 2018). Similarly, the position of placental implantation may also affect the functioning of the placenta and the subsequent foetal outcomes. In one study, an anterior position of the placenta was associated with an elevated risk of preeclampsia, GDM, foetal growth restriction and foetal death (Zia, 2013). The results of other studies have demonstrated an association between the placental position and adverse pregnancy outcomes such as preterm delivery and SGA (Weiner et al., 2016). Furthermore, a higher maternal BMI has been shown to worsen the pregnancy outcomes in women with an abnormal placental position (Arditi, Purisch, Friedman & Gyamfi-Bannerman, 2019).

Maternal abuse during pregnancy has been associated with changes in the uteroplacental and foetal milieu, and this can harm the developing foetus. According to Dimasuay, Boeuf, Powell and Jansson (2016), the placental unit senses and reacts to alterations in the maternal environment by changing its anatomy and physiology, a process that can potentially interfere with the flow of blood, nutrient delivery and placental endocrine functions (see Figure 1). Consequently, the growth and development of the foetus would be altered, and foetal programming may result in adverse effects even after delivery. The placental nutrient-sensing model explains how these responses are effected on the foetus in response to nutritional changes in the maternal compartment (Jansson & Powell, 2013). Various signals from the mother including hormones, oxygen concentrations and the concentrations of various nutrients, are sensed by the placenta. The placenta's transport function and its growth may be inhibited in the case of hypoxia or a reduced nutrient concentration, thereby, limiting the growth and development of the foetus. Conversely, excessive nutrient delivery to the placenta may signal it to enhance delivery to the foetus, resulting in overgrowth of the foetus. Figure 2 illustrates the placental nutrient-sensing model. Exposures during pregnancy, including insufficient or excess nutrients and substance use, are maternal signals in this model with implications for the foetus.

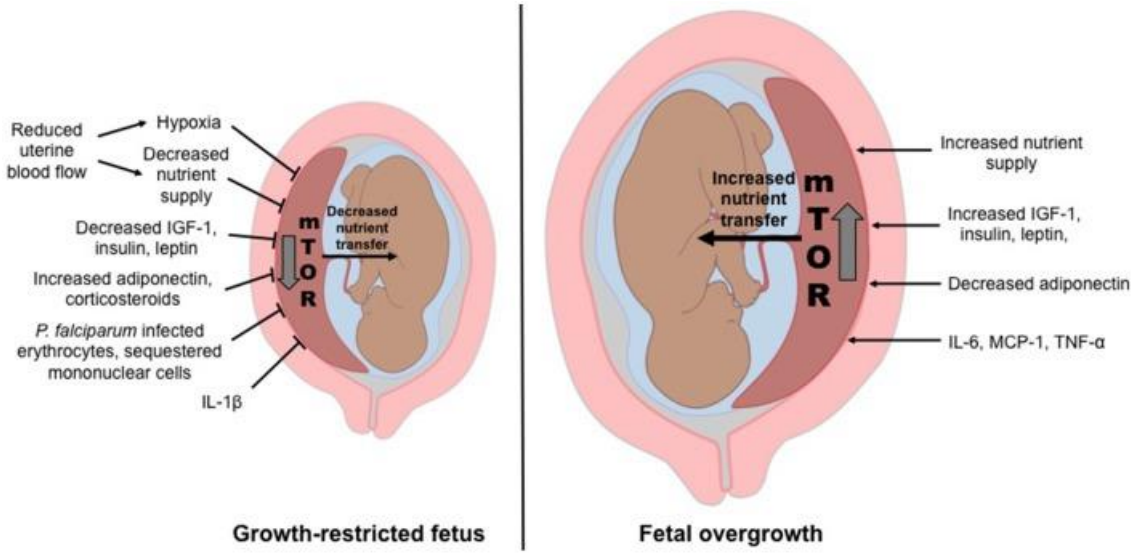



Figure 2. The nutrient-sensing model of the placenta.

The mechanistic target of the rapamycin (mTOR) receptor serves as one of the signalling pathways for information integrated by the placenta following signals from the mother. Consequently, the growth of the foetus corresponds to the quantity and quality of supplies from the mother through growth restriction or overgrowth, depending on the stimuli. Retrieved from (Dimasuay et al., 2016)

#### 4.2.3.3. The monitoring of foetal growth and development

Considering the complex issues that occur during intrauterine life and the wide-ranging consequences of the mistreatment therein that may persist throughout the life of the offspring, the monitoring of foetal growth and development is now an essential practise among obstetricians. Monitoring is conducted to identify abnormalities concerning the growth and development and guide the implementation of interventions to avoid severe and lasting complications (Ohuma, Njim & Sharps, 2018). Various methods are used to monitor foetal growth, including abdominal palpation of the foetus, fundal height measurements from the pubic symphysis, serum biochemistry and ultrasonography. Ultrasonography is a particularly important method of monitoring foetal growth. It is used to ascertain the gestation age and diagnose various conditions in pregnancy, including IUGR, foetal macrosomia, congenital malformations, placental abnormalities and multiple pregnancies, among other conditions (Kim, Singh, Moran, Armbruster & Kozuki, 2018).

Various ultrasonic parameters are used in the monitoring of foetal growth. The biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC) and femur length (FL) are often combined to establish the estimated foetal weight (EFW),

which is an essential parameter in foetal growth monitoring (Milner & Arezina, 2018). In common obstetric practice, the Hadlock formula (which utilises the BPD, AC and FL) and the Shepherd formula (which utilises the BPD and AC) are often used. However, these measurements are not entirely accurate. For example, the Hadlock formula has a specificity and sensitivity of approximately 93% and 62%, respectively, for the recognition of foetal macrosomia, while the Shepherd formula has a specificity and sensitivity of 99% and 21%, respectively (Warska et al., 2018). Consequently, new parameters have been developed to augment these measurements and improve the predictive value of obstetric ultrasounds, including measurements such as liver and kidney dimensions, cheek-to-cheek diameter and cerebellar diameter.

Substantial evidence from a meta-analysis of RCTs emphasises the importance of the routine sonographic monitoring of foetal development. Whitworth, Bricker and Mullan (2015) conducted a systematic review and meta-analysis of RCTs to ascertain the influence of routine early pregnancy ultrasonography compared to selective obstetric ultrasonography regarding the diagnosis of congenital malformations, multiple gestations, clinical interventions and the influence on foetal outcomes. The results of 11 studies involving 37,505 participants demonstrated that routine ultrasonography increased the detection of multiple gestations and major foetal malformations by 24 weeks. It also reduced the incidence of labour inductions due to post-term pregnancy. Ultrasonography was not associated with any adverse implications regarding the physical or cognitive development of the foetus. However, there was no significant association between routine obstetric ultrasounds and reduced pregnancy outcomes.

Foetal growth parameters based on ultrasonographic biometry vary considerably throughout populations. These variations prompted the INTERGROWTH-21st project, which resulted in the development of a set of international standards, based on WHO recommendations, upon which foetal growth can be compared (Papageorghiou et al., 2018). Moreover, findings from the WHO *Multicentre Growth Reference Study* guided the establishment of the WHO population-specific limits, which are used globally (Kiserud et al., 2018). The UK NICE recommends [CG62] at least two ultrasound scans for women with uncomplicated gestation (NICE, 2019). The first scan, at 10–13 weeks gestation, should consist of a dating scan to establish the gestation age, identify whether there are multiple gestations, confirm foetal viability and establish whether there are any gross anomalies. The second scan, a foetal anomaly scan, should be conducted at 18–20

weeks to guide interventions. Additional scans may be required if there are concerns regarding foetal growth restrictions (NICE [CG52], 2019b) but, for most women in the UK and in Jersey having healthy pregnancies, universal third trimester ultrasound in uncomplicated pregnancies is not current practice [CG62] (NICE, 2019).

The guidelines advise against routine ultrasonography to estimate the size of the foetus if a large-for-gestation-age foetus is suspected. It also recommends the application of customised growth charts (from the WHO) to plot and monitor the fundal height and measurements from ultrasonography. Customised foetal growth charts provide appropriate standards for the assessment and monitoring of foetal growth and early detection of growth-related complications (Gardosi et al., 2018). Such charts ought to be standardised based on evidence to ensure effectiveness. Physiological variation in growth patterns between different ethnicities and regions in the world mean that the charts need to be optimised for use for the specific country, group or region. A standard customised chart facilitates the detection of both growth restriction and foetal macrosomia. In the UK, standardised antenatal growth charts from Saving Babies' Lives, Version Two, are used to identify foetuses at risk of IUGR and being small for gestational age (NHS England, 2019; RCOG, 2014). This results in such babies being recognised antenatally, and the associated risk of stillbirth is reduced significantly because it provides an opportunity to consider the timely delivery of the baby at risk.

The impact of maternal dietary and lifestyle factors on foetal growth has been highlighted previously in this review. Important implications such as intrauterine growth restriction, foetal macrosomia and congenital malformations can be easily detected using anthropometric measurements via ultrasonography. Several studies have demonstrated a correlation between these ultrasonographic findings and maternal lifestyle and diet parameters. O'Brien, Louise, Deussen & Dodd (2018) conducted a trial to ascertain the association between the eating habits of women and the growth and adiposity of foetuses using foetal ultrasound biometry and adiposity estimations. The results of the study, which included overweight and obese women, demonstrated a negative correlation between an increase in total energy intake and foetal mid-thigh lean mass. Simultaneously, an increase in the maternal Healthy Eating Index (HEI) was correlated with a decrease in the subscapular fat mass of the foetus. In a separate study, the maternal protein and carbohydrate intake significantly influenced foetal ultrasound abdominal and

mid-thigh fat estimation, suggesting that nutritional interventions during pregnancy may influence the body composition of the foetus (Blumfield et al., 2012a).

#### 4.2.3.4. Types of delivery

Spontaneous vaginal delivery (with no intervention or limited intervention) is the natural and preferred type of delivery by clinicians. Interventions during childbirth, including caesarean sections, should be limited by strict regulations to instances where natural birth is not possible or is associated with significant adverse birth outcomes for the woman and the offspring (Prosser, Barnett & Miller, 2018). Although the WHO recommends a caesarean section rate of below 15% in any given setup, the rates are significantly higher in most countries, resulting in an increase in global concern (Betrán et al., 2016). There is escalating apprehension regarding increasing rates of short- and long-term complications due to caesarean sections. The risk of maternal death is significantly higher in caesarean deliveries compared to vaginal deliveries. Moreover, caesarean section is associated with a dose-response increase in the rate of complications such as rupture of the uterus, stillbirth and subsequent ectopic pregnancy (Sandall et al., 2018). The procedure alters neonatal physiology and affects immune development in the offspring, resulting in an increased risk of atopic conditions such as asthma. Several studies have suggested an association between caesarean sections and altered growth and development of the offspring, including high rates of stunting (Saaka & Hammond, 2020) and obesity (Goldani et al., 2013). Other studies have reported an association between caesarean sections and altered cognitive development (Polidano, Zhu & Bornstein, 2017).

Although the present-day increase in caesarean sections has largely been attributed to non-clinical reasons such as fear of litigation, perceived safety, and maternal requests and reimbursement (Feng, Xu, Guo & Ronsmans, 2012), there has also been an increase in obstetric risks that escalates the requirement for operation. The earlier sections of this paper have highlighted the association between the maternal lifestyle and dietary factors in the pre-pregnancy period and during pregnancy with an increased risk of caesarean section; these lifestyle and dietary factors include a woman being overweight or obese, excessive GWG, gestational diabetes and socioeconomic and environmental exposures. Several studies have reported a potential decrease in the rates of caesarean sections following dietary and lifestyle interventions, particularly in high-risk pregnancies. In a Cochrane review of RCTs designed to assess the implications of various dietary

interventions on the outcomes of pregnancy, the adoption of a DASH diet during pregnancy was observed to significantly reduce the rate of caesarean sections (Han et al., 2017). Therefore, such interventions could potentially protect the offspring against the additional risks associated with interventional deliveries such as caesarean section.

#### 4.2.3.5. The influence of maternal factors on the Apgar score

The Apgar score is an essential scoring system (though not anthropometric) that has significant implications regarding neonatal and child health. Maternal factors that are directly or indirectly associated with nutrition and lifestyle have been associated with a low neonatal Apgar score. For example, Zhu, Tang, Zhao, Qu and Mu (2015) demonstrated that a high BMI and overweight status of a mother increases the potential for the neonate to score less than seven at 1 minute. This is because such maternal factors increase the risk of macrosomia, IUGR, gestational diabetes, preeclampsia and other factors that may lead to foetal distress.

#### 4.2.3.6. The Role of Microbiota

The establishment of the microbiome of the newborn is thought to begin during the prenatal period (Oh et al., 2010). The results of recent studies have disputed the traditional belief that the intrauterine environment is sterile. Conversely, there is sufficient evidence to suggest that the intrauterine environment is colonised by various micro-organisms which play a role in the foetal microbiota (Dunn, Jordan, Baker & Carlson, 2017). Maternal gut and vaginal microbiota are thought to be the primary sources of the microbiota of the offspring, and the transfer of micro-organisms occurs within the uterus, during delivery and breastfeeding. Although the mechanism of translocation of the micro-organisms from the maternal gut to the uterine cavity is unclear, Solt (2015) postulated that haematogenous translocation is highly likely. Vaginal bacteria also ascend directly to the uterine cavity (Witkin, 2015).

Mueller et al. (2015) established that maternal dysbiosis induced by antibiotic use in pregnancy was associated with an 84% higher risk of obesity in the offspring. Furthermore, perturbations in the maternal microbiota are thought to influence the long-term neurodevelopment of the offspring (Borre et al., 2014).

The delivery process is an important event for the establishment of the gut microbiota and the development of the immune system of the offspring (Garcia, Yee,

Gilbert & Dsouza, 2018). A caesarean delivery denies the offspring adequate exposure to the vaginal microbiota, thereby, resulting in caesarean section-associated dysbiosis. Consequently, children born via caesarean section are more susceptible to immune-related disorders compared to those born vaginally (Kristensen & Henriksen, 2016). Black, Bhattacharya, Philip, Norman and Mclernon (2016) established that the risk of hospitalisation with asthma was greater in a caesarean section study group than in a vaginal delivery group. Similarly, the results of a population study in Denmark revealed an increased risk of coeliac disease, ulcerative colitis, juvenile arthritis and lower respiratory tract infections among children who were born through caesarean delivery compared with those born vaginally (Kristensen & Henriksen, 2016).

Human breast milk is also considered an important source for the microbiome of the offspring. It confers lifelong gut health to the infant through the action of the micro-organisms and bioactive components in the milk (Granger et al., 2021). The factors that are associated with a reduction in the quality and diversity of the breast milk microbiome include maternal obesity, caesarean delivery and maternal dysbiosis (Borre et al., 2014). Further studies are required to quantify the extent to which breast milk influences the microbiota in the offspring's gut. The role of breastfeeding in the health of the child is broadly described in a subsequent part of this chapter.

### 4.2.4. Feeding methods: A child's health perspective

After delivery, a child's health is highly dependent on provisions from the caregiver, including adequate nutrition, safe food and water, vaccinations and sick and well-baby clinic visits. The initial 1,000 days of life (beginning from conception to 2 years) is recognised as a crucial period for physical growth and neurodevelopment (Fewtrell, Michaelsen, van der Beek & Elburg, 2016) and is, therefore, a period of significant vulnerability (Schwarzenberg & Georgieff, 2018). Breastfeeding, weaning and dietary habits are important events regarding the health, growth and development of the child (Vail et al., 2015). These factors are important, particularly because a child's dietary patterns fluctuate significantly with regard to the underlying nutritional and energy constituents (Smithers et al., 2012).

#### 4.2.4.1. Breastfeeding

In addition to the previously mentioned benefits of lactation for the mother, the physiological process also provides significant benefits for the offspring. Breastfeeding is the natural and advisable mode of ensuring adequate nutrition for the infant to promote his or her growth and development (Shamir, 2016). Much of the health benefits of breastfeeding are attributed to various nutritional and bioactive components in the milk. The exact constitution of the macronutrients in breast milk varies among women and periods of lactation, however, it is broadly maintained within a range that is adequate for the child (Kominiarek & Rajan, 2016). Mature breast milk is estimated to contain approximately 6.7–7.8 g/dL of lactose, 0.9–1.2 g/dL of protein and 3.2–3.6 g/dL of fat, in addition to energy values of approximately 65–70 kcal/dL (Ballard & Morrow, 2013). The factors that significantly affect the macronutrient constitution of human breast milk include the maternal BMI (Bzikowska-Jura et al., 2018), frequency of breastfeeding, return of menstruation, protein intake, maternal malnutrition and parity (Shamir, 2016). Micronutrients such as iodine, vitamin A, B vitamins and vitamin D are often available in concentrations sufficient for the infant. However, these are generally dependent on the mother's nutritional stores and dietary intake (Ballard & Morrow, 2013). It is recommended that breastfeeding mothers continue to consume multivitamins during this period to maintain an optimal supply. The concentrations of vitamin D in breast milk are often insufficient, particularly in women with low exposure to sunshine, and an injection of this vitamin for the newborn is recommended (Dawodu et al., 2014). Important immune and bioactive substances are also present in breast milk, including immunoglobulins, macrophages, cytokines and growth factors which are critical determinants of a newborn's health, growth and development (Shamir, 2016).

Infection prevention has often been regarded as the most important benefit of breastfeeding (Eidelman & Schanler, 2012). Infections such as gastroenteritis and otitis media are significantly reduced through breastfeeding (Ardiç & Yavuz, 2018). A meta-analysis conducted by Yan, Liu, Zhu, Huang and Wang Yan (2014) revealed that breast milk is highly protective against childhood obesity. The American Academy of Paediatricians suggests that breastfeeding is associated with a 15–30% decrease in the rate of obesity in adolescence and adulthood compared with no breastfeeding (Eidelman & Schanler, 2012). Breastfeeding has also been associated with a reduction in the occurrence of other chronic illnesses such as hypertension, cardiovascular diseases and

certain types of malignancies (Binns et al., 2016). The results of a separate meta analysis revealed that breastfed infants had improved cognitive function scores compared to their formula-fed counterparts, and the neurodevelopmental outcomes persisted through childhood and adolescence (Shamir, 2016). Although there are conflicting results regarding the role of breastfeeding in reducing allergic diseases such as asthma and eczema, it is widely accepted that it does play a role (Kramer, 2011). Breastfeeding also improves mother-to-child bonding, which is important for neurobehavioral development (Liu, Leung & Yang, 2014). Most of the above-mentioned benefits cannot be achieved through infant formula or other infant food. Moreover, although modern infant formula has been developed to mimic the nutritional characteristics of human breast milk, it does not conform to the composition and performance of breast milk (Martin, Ling & Blackburn, 2016). During the global COVID-19 outbreak, even greater emphasis has been placed on the protective role of breastfeeding against respiratory diseases. The WHO (2020a) has demonstrated that breast milk not only supports a child's growth, development and long-term health outcomes (such as the prevention of obesity) but also provides antibodies and other immunological benefits that can confer protection against COVID-19.

Although numerous health agencies (including in the UK) endorse the concept of exclusive breastfeeding for the initial six months after delivery and continued lactation up to two years of age, the breastfeeding rates in the UK remain low according to the IFS (NHS, 2012). Several of the barriers to adequate breastfeeding have been previously highlighted, including issues associated with services, professional responsibilities, misinformation, perceived milk insufficiency and cultural barriers. Moreover, certain maternal lifestyle patterns significantly influence milk production and breastfeeding. For example, women who smoke cigarettes tend to breastfeed less and wean sooner than those who do not (Napierala, Mazela, Merritt & Florek, 2016). Other maternal factors that have an impact on breastfeeding include nipple piercings, insufficient dietary intake of macro- and micronutrients (Kent, Prime & Garbin, 2012) and inappropriate food restrictions during lactation (Jeong, Park, Lee, Ko & Shin, 2017). Most of these barriers are modifiable through the various interventions that are discussed in subsequent sections of this review. However, in certain instances, alternatives to breastfeeding are essential. These include women who take cytotoxic medications or other drugs that are potentially toxic to the baby, women who give birth to preterm infants and may need extended

hospitalisation and not produce sufficient milk and certain maternal diseases (Lawrence, 2013), or mothers who are unwilling or unable to breastfeed (Brady, 2012). The needs of women who are obliged or decide to adopt bottle-feeding also require consideration.

Following the unanimous global acceptance of breast milk as the standard and safest diet for infants, less focus has been placed on alternative infant feeds. Extensive studies have been conducted on mothers who feed formula to their infants, however, the primary focus of these studies was to determine the reasons women chose not to breastfeed and to promote breastfeeding (Lakshman, Ogilvie & Ong, 2009). Therefore, there is a considerable knowledge gap regarding the appropriate use of formula and other alternatives to breastfeeding, and the few studies identified during this review that focused on this topic are outdated. The IFS conducted in England revealed that approximately 50% of women who used powdered formula failed to adhere to key recommendations regarding the prevention of infections and the avoidance of overconcentration (Lakshman et al., 2009). Several researchers have established a positive correlation between high amounts of protein in formula and the occurrence of obesity (Weber et al., 2014) or diabetes (Stuebe, 2009) in childhood. Furthermore, various studies have shown that breastfeeding combined with formula feeding, particularly before breastfeeding is well established, is associated with a shorter period of breastfeeding and an increased risk of a child being overweight or obese (Holmes, Auinger & Howard, 2011). The recognised disadvantages of formula include the risk of cross-contamination and infant infection (Cho et al., 2019).

#### 4.2.4.2. Weaning and complementary feeding

Since the quality, amount and type of food that children eat is entirely dependent on the caregivers, the dietary habits, attitudes and behaviours of the caregiver determines the child's nourishment. Consequently, factors such as the caregiver's educational status, SES and ethnic identity are likely to influence the child's nutrition (Lindsay, Sussner, Greaney & Peterson, 2011). As the child grows, breast milk alone may no longer be sufficient to provide the appropriate nutritional requirements, therefore, weaning is necessary. The weaning period has been highly associated with an insufficient nutrient intake that leads to growth faltering (Vyas, Kandpal, Semwal, Chauhan & Nautiyal, 2014). The timing of weaning and the introduction of solid food has been an issue of contention. The early introduction of solid food has been associated with an increased risk of an infant being

overweight or obese (Pearce, Taylor & Langley-Evans, 2013). In Europe, factors such as low SES, young maternal age, maternal drug and substance use, formula feeding and maternal employment demands have been associated with the early introduction of solid food (Caroli et al., 2012). Additionally, formula- and bottle-fed children are more likely to be introduced to solid food early due to factors such as the mother perceiving that the infant is not satisfied with formula alone and inappropriate education and perception regarding the introduction of solid food (Clayton, Li, Perrine & Scanlon, 2013).

The appropriate timing of weaning, adequate quality and quantity of weaning food, and appropriate hygiene are essential for a healthy baby. Whether a baby is breastfed or formula-fed, the WHO endorses that complementary foods are introduced at approximately six months of age, as lactation continues up to 24 months (Vail et al., 2015). However, these recommendations have been questioned in several high-income nations where there are fewer worries regarding the availability and safety of food. The AAP and the European Society for Paediatric Gastroenterology, Hepatology and Nutrition suggest that weaning may be safely achieved between 4 and 6 months after birth (Vail et al., 2015). However, the UK NICE *Maternal and child nutrition* insists on the WHO recommendation of 6 months (2015b). The WHO *Complementary feeding* states that complementary foods must be timely, suitable, safe and adequately fed. Moreover, it provides recommendations concerning the frequency, amount, types, nutritional components and consistency of complementary foods to be presented depending on the infant's age and factors such as ethnicity, breastfeeding status, birth weight and HIV status (WHO, 2021).

#### 4.2.4.3. Nutrition and lifestyle during early childhood

As a child grows beyond the age of breastfeeding (approximately two years of age), his or her growth and development are dependent on the dietary habits acquired from the ecological niche which is comprised of the family, peers, community and media, among other parties (Scaglioni et al., 2018). The dietary habits adopted by a child at a young age tend to persist throughout his or her life. A study conducted by Montaño, Smith, Dishion, Shaw and Wilson (2015) to evaluate the influence of parental behavioural support on children's dietary habits, established that positive behavioural support predicted the quality of a child's diet during the subsequent year. A narrative review conducted by Scaglioni et al. (2018) established that the dietary habits learnt in childhood tend to persist

into adulthood. Habits such as fussiness, inappropriate dietary variety and inappropriately high responsiveness to food cues are established in childhood and tend to increase the risk of obesity as an individual ages.

There is growing public health concern concerning the role of the media in promoting inappropriate diets and dietary habits. A causal association has been established between the commercial advertisement of food products and the diets of children, particularly regarding an increased intake of snacks and sugary foods and a reduced intake of vegetables and fruits (Kovács et al., 2015). In addition to these advertisements, screen time on tablets or smartphones and social media have predisposed children, adolescents and young adults to obesity and cardiovascular diseases through mechanisms such as limitation of physical activity, an increased intake of high-calorie snacks and a reduction in the amount of time spent sleeping (Robinson et al., 2017). Therefore, parental dietary habits and early childhood eating behaviours are excellent targets for the implementation of interventions to improve health and lifestyles, even at a population level. No strict global recommendations exist concerning the children's diet (WHO, 2021a). However, the WHO emphasises an increased intake of vegetables, whole grains and nuts and a restricted intake of energy from total fats. The WHO also encourages the consumption of unsaturated over saturated fats and recommends that individuals limit their intake of sugars. Public Health England (PHE) discourages excess sugar consumption amongst children and highlights the risks of unhealthy weight gain in young people (GOV.UK, 2020c).

The NHS recommends that children aged from 2 to 5 should graduate to the family diet, as illustrated in the Eatwell Guide (NHS. The Eatwell Guide, 2019a). The NHS also provides special tips and considerations concerning offering foods to children, including the foods that are best to avoid (2019b). The quality standard [QS98] aims to improve diet before, during and after pregnancy as well as the nutrition for babies and pre-school children, giving special attention to challenged families (NICE, 2015b). Similarly, PHE *Childhood obesity: a plan for action* provides comprehensive dietary proposal to reduce childhood obesity, specifically in children between the ages of 2 and 15 (GOV.UK., 2017). The *Making Every Contact Count* (MEEC) programme is an additional public health initiative launched that promotes changes in health behaviours and provides specific advice for families regarding dietary habits and lifestyles (GOV.UK., 2020b).

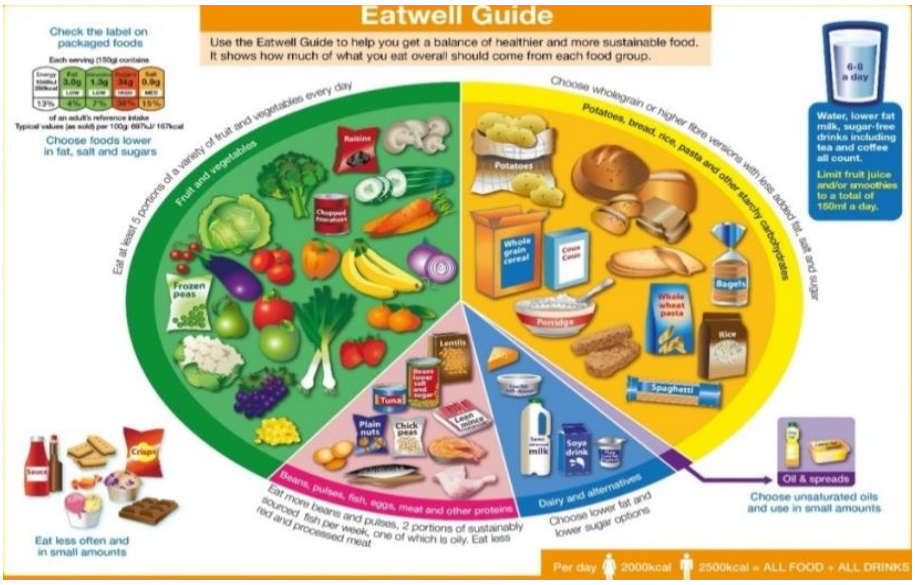



Figure 3. The Eatwell Guide.

The five main food groups that should be included in the diet and the balance that should be achieved throughout the day. Retrieved from (NHS, 2019a) on May 27, 2020.

### 4.2.5. Selected anthropometric measurements of newborns and infants: A child's health perspective

The periodic measurement of various anthropometric parameters of neonates, infants and children are central to the monitoring of their nutritional and health status. The core anthropometric measurements include weight, height or length, BMI, skinfold thickness, and head, waist, hip and limb circumferences (Casadei & Kiel, 2020). For a newborn, the weight, length, chest circumference and head circumference are essential anthropometric measurements. As the child grows, a combination of anthropometric measurements is used to improve sensitivity and specificity when diagnosing health conditions. For example, a child's height-for-age is used to diagnose stunting, and weight-for-age is used to diagnose a child that is underweight (Casadei & Kiel, 2020). The Mid-upper arm circumference (MUAC) is an important measurement for diagnosing wasting and establishing the general nutritional status, while the BMI-for-age measurement can be used to determine obesity in older adults.

No WHO or NICE recommendations exist regarding the scheduling of clinic visits specifically for anthropometric measurements. However, the WHO recommends that weight, length/height and BMI measurements of an infant or child are obtained during each visit to the clinician, including during immunisation schedules, well-baby visits, or

when they are sick (WHO, 2008). Figure 4 illustrates the public health recommended structured expected assessments for children in the UK (Donaldson & Rutter, 2018).

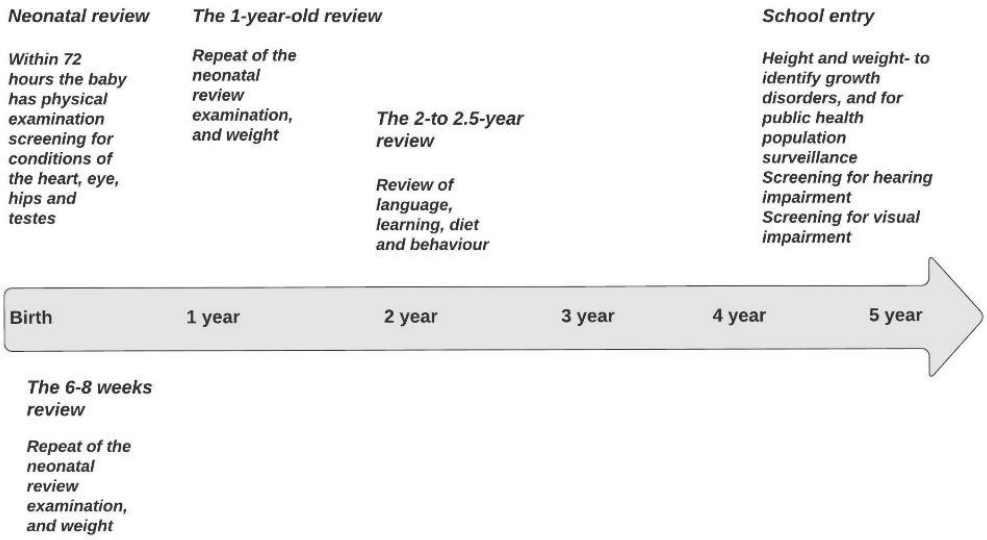



Figure 4. Structured childhood assessments in the UK

Retrieved from 'Donaldson's Essential Public Health' (Donaldson & Rutter, 2018).

Significant discrepancies exist in the anthropometric measurements among races and ethnic groups. The WHO emphasises considerations for race, ethnicity and sex when plotting anthropometric measurement charts. In 2006, the WHO developed adjusted growth charts for international use in various populations and ethnic groups (de Onis, Garza, Onyango, Rolland-Cachera & Société, 2009). The UK utilised the WHO charts as a basis to establish the UK-WHO growth charts that are currently in use (Wright et al., 2010). The charts contain centile lines for infants from 2 weeks of age and recommend the monitoring of the current weight in relation to the birth weight for neonates below two years of age. The UK-WHO guide also provides advice for plotting the measurements for preterm infants including measuring procedures and plotting techniques. If height and weight centiles are known, the guide recommends measurement of the BMI and monitoring from the age of 2 years; it also provides charts for adult height prediction. The 'Children's public health – 0 to 5 years '*Interim national reporting process for the universal health visiting service*' details how the health visiting model can be used to support the growth and development of children through community settings and in-depth focus of the antenatal health promotion (GOV.UK, 2019). The care settings highlight

early-life care, as mentioned above, regarding the structured childhood assessments in the UK (Figure 4), however, there is a gap in the anthropometric measurements between the final assessment at age 2 to 2 ½ and school-age entry. Thus although the National Child Measurement Programme between the Reception and final years of primary school (NCMP) (GOV.UK, 2020d) is well established in UK, further research may be required regarding the measurement of various anthropometric parameters for the prevention of obesity and the development of unhealthy lifestyles before school age begins. The NCMP is discussed in a subsequent part of this review.

#### 4.2.5.1. The influence of parental factors on various anthropometric parameters of neonates, infants and children

Maternal dietary choices, lifestyle and SES have significant implications for the anthropometric measurements of neonates, infants and children. Correlations between several of these factors and the neonatal birth weight (low birth weight) and obesity in the offspring (through Barker's hypothesis and otherwise) were previously highlighted in this thesis. Most of the studies that specifically evaluated the impact of these maternal factors on the anthropometric measurements of the offspring indicated a positive correlation. In a study that included 812 pregnant mothers, Hajianfar, Esmaillzadeh, Feizi, Shahshahan and Azadbakht (2018) observed that women who adopted a 'Western' dietary pattern (which has significantly high amounts of fruit juices, sugars, sweets, desserts and saturated fats) during pregnancy had a higher risk of giving birth to low birth weight babies compared to women who adopted 'traditional' or 'healthy' dietary pattern. Similarly, a health-conscious diet demonstrated a protective effect against low birth weight in a study conducted in Ghana (Abubakari & Jahn, 2016). In a separate study, a high intake of saturated fats and a high glycaemic index diet in the second and first trimesters, respectively, were associated with a high BMI and adiposity in the offspring (Horan, Donnelly, Mcgowan, Gibney & Mcauliffe, 2016).

The dietary inflammatory index (DII) is a novel tool that is used to characterise dietary intake based on inflammatory potential (Shivappa, Steck, Hurley, Hussey & Hébert, 2014). This tool is becoming increasingly significant, particularly due to the increasing evidence of chronic inflammation in diseases such as diabetes, hypertension and obesity (Galassetti, 2012). Sen et al. (2015) studied the correlation between maternal DII in pregnancy and various pregnancy outcomes. The authors observed an association

between the maternal DII during gestation and a GDM diagnosis and maternal plasma C-reactive protein (CRP, a biochemical indicator of inflammatory processes). Moreover, maternal DII was associated with a lower birth weight in the offspring of obese women. The consequences of a high maternal DII persisted beyond the intrauterine life, with the offspring of the women who had a high DII registering a lower possibility of breastfeeding for at least one month postpartum. An elevated maternal CRP was correlated with a low birth weight in the Generation R Study, however, the study did not account for the influence of maternal dietary intake (Ernst et al., 2011). Future research is required to facilitate an understanding of the implications of DII and pregnancy outcomes and to establish possible interventions.

The results of a study by Mourtakos et al. (2015) demonstrated that excessive GWG, insufficient engagement in physical activity and cigarette smoking during the gestation period were highly correlated with a high BMI and obesity in children eight years after birth. Furthermore, parental height has been correlated with the household SES, with a high instance of obesity in the offspring of groups with a lower SES being partially explained by the lower caloric requirements of individuals who have short stature (Horan et al., 2016). In a study conducted in Saudi Arabia, maternal exposure to second-hand cigarette smoke was associated with lower birth weight and a shorter birth length of the offspring (Wahabi et al., 2013). All the above-mentioned findings highlight various multidirectional windows of opportunity for public health intervention measures that target parental factors to influence the anthropometric measurements of the offspring.

### 4.2.6. Childhood and the origin of preventable diseases throughout the lifecycle: A multidirectional opportunity for prevention

Beyond the FOAD hypothesis, metabolic programming also occurs in postnatal life (Velkoska & Morris, 2011). Although there is much evidence to suggest that a high maternal BMI and exposures during foetal life have strong implications for the phenotype of the offspring (compared with overnutrition in childhood and exposures after delivery), there is also evidence to suggest that postnatal overnutrition significantly amplifies the effects of the prenatal exposures (Chen, Simar, Lambert, Mercier & Morris, 2008). Figure 5 illustrates the cycle of obesity and diabetes, and how maternal and prenatal factors interact with postnatal overnutrition to influence the adult phenotype. *The Bogalusa Heart Study*, conducted in the US, revealed that approximately 50% of individuals who were

overweight or obese in adulthood had been overweight when they were children (Deshmukh-Taskar et al., 2006).

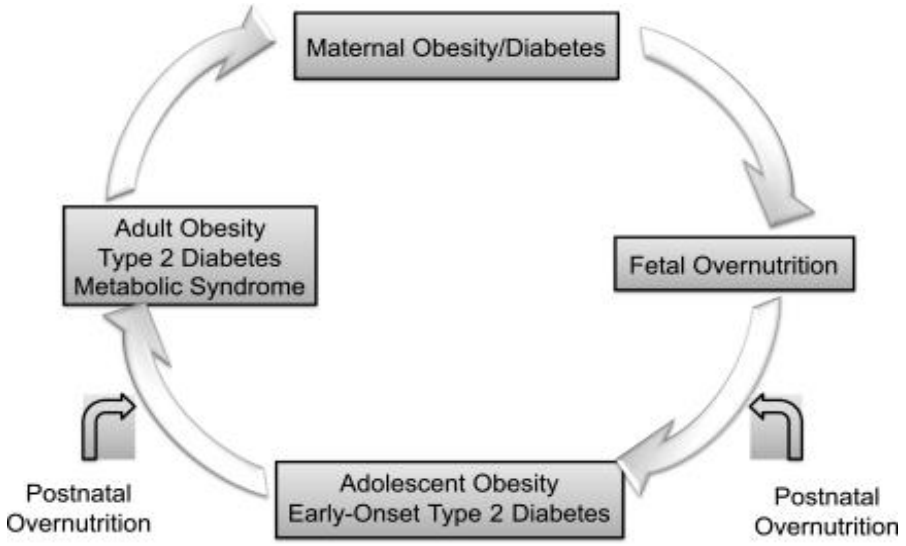



Figure 5. The vicious cycle of obesity and diabetes.
Retrieved from 'Maternal Environment and the Transgenerational Cycle of Obesity and Diabetes' (Dabelea & Crume, 2011).

Similar to overnutrition, undernutrition in early life has been associated with obesity in adulthood and the risk of chronic and lifestyle illnesses such as hypertension and diabetes (Black et al., 2013). This risk is even higher for children who rapidly gain weight during their initial two years of life (Holt, Kaviani, Sheth & van Driel, 2018). Furthermore, childhood undernutrition is associated with lower educational achievement and, consequently a lower income and poverty in adulthood (de Onis et al., 2013). Since poor, undernourished, stunted women are likely to deliver low birth weight babies (who are at risk of being underweight or obese in postnatal life), the negative impact of undernutrition influences the growth and development of the subsequent generations, and the cycle of malnutrition is sustained in populations (Holt et al., 2018).

The malnutrition-disease cycle provides a strategic opportunity for the prevention of common diseases at various stages, and the period of childhood offers a unique juncture to break the cycle. Several effective interventions can be initiated in the preconception period or during pregnancy and have been highlighted in the previous sections of this review. The 1991 *Baby-Friendly Hospital Initiative* is a notable intervention by the

UNICEF and the WHO (UNICEF, 2016). The initiative involves ten stages that are aimed at encouraging breastfeeding and discouraging breast milk substitutes, and maternal education on breastfeeding is incorporated. Studies conducted on this initiative have revealed a dose-response association between the extent of the implementation of the initiative and the breastfeeding outcomes (Pérez-Escamilla, Martinez & Segura-Pérez, 2016). Therefore, such global interventions (as well as other public health interventions that are discussed in the later sections of this paper) may prove successful at breaking the cycle.

While most of the well-recognised and researched interventions target the first 1,000 days of life, interventions that include education about healthy dietary and lifestyle habits are most significant for older children (Black, Pérez-Escamilla & Fernandez Rao, 2015) and with weight control especially among children with already developed excess weight could be a successful strategy for treating childhood obesity (Coppins et al., 2011). Primary prevention strategies that target childhood and lifestyle exposures have proved to be instrumental. For example, Brown, Kelly and Summerbell (2007) conducted a comprehensive review and observed that the implementation of school programmes that encourage healthy dietary behaviours and engagement in physical activity may be beneficial in preventing childhood obesity. Therefore, a wide-ranging life course approach that begins before conception and through an early life is required to successfully target transgenerational chronic lifestyle diseases.

#### 4.2.6.1. Selected anthropometric measurements of children – The National Child Measurement Programme

The NCMP is a programme that was initiated in England in 2006 to facilitate the monitoring of population trends in children through annual weight measurements in the initial and final years of primary school (GOV.UK, 2020d). The programme is part of the UK government initiative that targets the management of child obesity with support from PHE. Although initially designated as a surveillance initiative, several local authorities use the data to identify children with an above-normal weight-for-height and provide advice to their parents and encourage weight monitoring (Kovacs, Gillison & Barnett, 2018). Parents of underweight, overweight and very overweight children are made aware of the health risks and are provided with an opportunity to intervene and discuss the issue with their children. In a recent comparison of statistics obtained from the NCMP between

the 2006/07 and 2016/17 school calendar years, a significant increasing trend in the number of overweight and obese Year 1 girls and Year 6 boys and girls was observed (GOV.UK, 2020a). Moreover, the prevalence of obesity among white British Reception girls increased while the number of overweight and obese Reception boys decreased. The prevalence of Year 6 underweight girls and Year 6 children of both genders showed a significant decreasing trend. Due to the increasing obesity epidemic, well-guided and coordinated anthropometric measurement and surveillance (as demonstrated by the NCMP) can be crucial for the detection of health risks and informing lifestyle and dietary interventions. Moreover, pre-school children have increasingly been associated with inappropriate dietary habits (Kostecka, 2014), and this may provide an opportunity for the introduction of a well-coordinated programme before they reach school age and are included in the NCMP.

### 4.3. Migration, ethnicity and pregnancy outcomes

#### 4.3.1. General statistics: The migration and birth outcome data of ethnic minority women in Europe

As global modernisation increases, the rate of migration is also increasing. According to the International Organization for Migration (IOM(b)), approximately 258 million international migrants were counted in 2017, and there were even more local migrants (i.e. those migrating within their country of birth) (IOM, 2018). Consequently, migration has become an important determinant of health in populations (Castañeda et al., 2015). Various studies have conveyed undesirable maternal and child health outcomes for migrants and ethnic minority groups compared with natives. In a study by the WHO European Region, migrant women in Europe were reported to have a significantly higher incidence of adverse pregnancy outcomes, including abortions, instrumental deliveries and caesarean sections compared to the natives (Keygnaert et al., 2016). Furthermore, a meta-analysis conducted by Pedersen, Grøntved, Mortensen, Andersen and Rich-Edwards (2014) to establish the maternal risks of immigrants in Western Europe, confirmed that migrant women were twice as likely to experience maternal mortality compared to indigenous women. Similarly, a UK case-control study revealed that Black African, Black Caribbean, Bangladeshi, other non-white (non-Asian) and Pakistani immigrant women demonstrated a higher percentage of maternal morbidity (83%, 80%, 74%, 56% and 43%, respectively) compared to indigenous women, and no significant

confounding factors were detected (Nair, Kurinczuk & Knight, 2014). Projections show an increase in minority groups in future years with an associated increased risk of poor health outcomes, therefore, it is essential to understand the health and lifestyle risks that the women and children of such groups will encounter, in particular, an understanding of the FOAD and increasing rates of obesity and other lifestyle diseases is crucial.

### 4.3.2. The lifestyle and health risks of immigrant women in developed countries

Hypothetically, the prevalence of lifestyle diseases such as obesity and other cardiovascular risks are expected to be lower in migrants compared to the natives in a population, for two key reasons (Hao & Kim, 2009). Firstly, because of the 'healthy migrant effect', whereby migrants are expected to have overcome long, physically demanding processes and journeys and rigorous health check-ups before migration, which generally makes them a healthy population. Secondly, most migrants move from less developed countries where the nutrition habits and lifestyle are generally better than those of the developed countries where there is physical inactivity and high consumption of processed foods, sugars and fats, in addition to other lifestyle risk factors. This hypothesis has been supported by extensive studies conducted in the US (Wen, Kowaleski-Jones & Fan, 2013) and Europe (Leung & Stanner, 2011). However, after approximately 10–15 years of living in a developed country, the migrants tend to have greater lifestyle risks than the natives (Commodore-Mensah et al., 2018), primarily due to acculturalisation as a result of adaption to the behaviour and lifestyles of the host country (Delavari, Sønderlund, Swinburn, Mellor & Renzaho, 2013), but also due to prolonged exposure to stressful events or adverse circumstances (Abraído-Lanza et al., 2006). Moreover, during the recent COVID-19 outbreak, PHE published an *Excess Weight and COVID-19 Report* (PHE, 2020) which highlighted that the highest risk of infection and excess weight occurred among individuals from black and minority ethnic (BAME) backgrounds, particularly from deprived areas. Therefore, co-morbidity may play an important role in this community.

There is evidence to suggest a greater lifestyle risk for women in migrant populations and ethnic minorities compared to natives and ethnic majorities. In a study conducted in Sweden, immigrant groups of men and women demonstrated significantly greater lifestyle risks regarding cigarette smoking, physical inactivity and obesity compared to

the natives (Gadd, Sundquist, Johansson & Wandell, 2005). In a study conducted in the US, Mexican-born non-pregnant women of reproductive age demonstrated lower serum folate levels compared to their US-born counterparts (Marchetta & Hamner, 2016). Furthermore, a study conducted in the UK demonstrated migrants and ethnic minority populations tend to consume more salt than the natives (Leung & Stanner, 2011). There is also increased acquisition of unhealthy dietary habits by migrants who relocate to new countries. In a US-based study, women of Mexican origin who were born in the US demonstrated higher consumption of convenience food and sugary drinks compared to Mexican women who were born in Mexico (Sharkey, Johnson & Dean, 2011). Similarly, Somali women living in Sweden reported less participation in physical activity in Sweden compared to when they lived in Somalia (Persson, Mahmud, Hansson & Strandberg, 2014). Despite these reports, data from extensive studies conducted in the US and UK suggest that migrants generally have healthier lifestyles than the natives, including a healthier diet (Virudachalam, Long, Harhay, Polsky & Feudtner, 2014), lower fat intake (Leung & Stanner, 2011), lower alcohol intake (Rao, Schofield & Ashworth, 2015) and higher engagement in physical activity (Wen et al., 2013).

### 4.3.3. Disparities in health care access and utilisation by migrants

The health requirements of a patient are addressed via established primary, secondary and tertiary healthcare systems Moreover, a patient's socio-demographic characteristics are important determinants of healthcare use (Babitsch, Gohl & Von Lengerke, 2012). *The Andersen and Newman Behavioural Model* (ANBM) for health service utilisation is one of the most commonly employed frameworks for understanding healthcare use (Tesfaye et al., 2018). According to the ANBM, the three major components that influence utilisation are the predisposing, enabling and need factors. Migration and ethnicity are critical predisposing independent and cofounding factors associated with other aspects such as occupation, education and social relationships. Important enabling factors include financing and organisational factors that target immigrants and ethnic minority groups, and accessibility to facilities, while factors such as functional state, genetic predisposition and symptomatic presentation of illnesses among immigrants and ethnic groups are classed as need factors (Babitsch et al., 2012).

During a systematic review of the literature to describe the utilisation of healthcare amenities among immigrants and natives, Sarría-Santamera, Hijas-Gómez, Carmona and

Gimeno-Feliú (2016) identified considerable disparities and highlighted that immigrants registered reduced use of healthcare services compared to natives. Moreover, numerous immigrants in countries with comprehensible and universal healthcare services were observed to have equal utilisation of the services with the natives. However, several studies reported reduced utilisation among immigrants in certain countries. Overall, the findings showed usage differences within immigrant populations, emphasising the need factors of Anderson's model. Graetz, Rechel, Groot, Norredam and Pavlova (2017) conducted a similar review of the literature but specifically included studies that were based in Europe. The results demonstrated that the inequalities regarding the access to and utilisation of care expanded to include women's fertility and perinatal care as well as care for newborns and children.

The 'healthy migrant effect' has also been observed in maternal and child healthcare, albeit in origin- and outcome-specific manners (Keygnaert et al., 2016). Moreover, the differences regarding the access, utilisation and outcomes of maternal and child healthcare amenities vary among migrant and ethnic groups, suggesting an unevenness concerning care provision and quality. A narrative review conducted by De Freitas, Massag, Amorim and Frag (2020) demonstrated that maternal care for immigrants is often less accessible compared to the natives, particularly for asylum seekers and those of low SES. Migrant women tend to have less access to and utilisation of family planning and gynaecological health services. In Switzerland, the results of a study by Casillas et al. (2015) demonstrated that immigrants who lacked appropriate legal documentation had inadequate access to family planning facilities and higher rates of unplanned pregnancies and delayed prenatal care. Moreover, De Freitas et al. (2020) reported that migrants and ethnic minorities are often less involved in maternal care plans and services compared to natives. Craveiro (2001) conducted research on a Portuguese minority community in Jersey and identified a significant language barrier regarding healthcare delivery, including interactions in hospitals and health documents, which hindered the quality of the healthcare provided to members of the minority group who had a low level of literacy. These findings, coupled with the lifestyle and health risk factors that immigrants encounter, require unique interventions with special considerations for immigrants and ethnic minorities. As Graetz et al. (2017) highlighted, limited research-based evidence prevents a comprehensive view of the utilisation of healthcare services throughout Europe. Moreover, further research is required to identify barriers regarding the practical

use of healthcare services by migrants. The collection of available health and ethnic-specific data by smaller jurisdictions such as the island of Jersey may help to reduce disparities concerning access to and utilisation of healthcare services by migrants.

### 4.3.4. Unique anthropometrics of ethnic minority women and children

Anthropometric measurements and other predictors of lifestyle diseases vary considerably among ethnic groups. The results of a study by Carlsson et al. (2014) demonstrated significant variation in anthropometric measurements in women who were born in Middle Finland and the rest of the world compared to those who were born in Sweden. Additionally, in a study conducted in the US, the BMI limits for predicting diabetes varied by ethnic group, with Mexican American individuals demonstrating an estimated limit of 30.4 kg/m2 which was 2.7 kg/m2 greater than that of white men (Diaz, Mainous, Baker, Carnemolla & Majeed, 2007). Rahman & Berenson (2010) observed variations in the sensitivity regarding the use of the standard WHO BMI limit of 30 kg/m3 and body fat percentage limit of >35% to define obesity. The sensitivity of the two measurements was 53.9% among Hispanic women, 47.8% among non-Hispanic white women and 75% among non-Hispanic black women. The authors also indicated that by using the standard BMI classification, approximately half of the women of childbearing age could be identified as not having excess weight. Thus, the use of race- or ethnic-specific BMI limits would result in more accurate identification of obesity and health risks.

The results of a study conducted by Lear, James, Ko and Kumanyika (2010) revealed significant cardiovascular risks among Asian populations, including women whose waist circumference was much lower than that of European women. *The UK Millennium Cohort Study* revealed significant variations in birthweights among ethnic minority groups and showed that Black African and Caribbean individuals were 70g and 150g lighter than White people, respectively (Kelly et al., 2009). Additionally, in a separate UK-based study of children aged < 11 years, Lee et al. (2014) observed that Black African and Caribbean children were generally taller, weighed more and had a larger body size compared with those of other ethnic groups. Therefore, there is a requirement for special considerations regarding unique measurements among migrants and minority groups in clinical and public health contexts.

### 4.3.5. Interventions and the promotion of cross-cultural public health

The public health system has to overcome the challenge of offering essential services and health promotion to an increasing population that includes immigrants (Donaldson & Rutter, 2018). There is a national and local requirement for the development of multicultural and intercultural health promotion. Migrant populations and ethnic minorities should be included in local policies for maternal and child health, and greater attention should be paid to disparities concerning social indicators such as employment, housing and healthcare financing. In a review of migrant health policies, Peiro and Benedict (2010) highlighted that the EU-level *Consultation on Migration and Health* reported the need for a collective will and leadership to ensure that equity in health is a priority. Moreover, policymakers should take note of the inequalities experienced by the migrant population and develop multisectoral cooperation mechanisms to overcome the inequity. Special attention should be paid to specific migrant groups such as mothers and children when migrant health policies are being developed (Peiro & Benedict, 2010). During the development of health promotion and care delivery strategies, the language and literacy levels of migrants and ethnic minorities should be considered. For example, based on research conducted by Craveiro (2001) among Portuguese minorities in Jersey, the use of translators and interpreters is recommended in the care provision and public health promotion sectors to translate health promotion documents into languages that are understood by minority groups, and to facilitate the recruitment of Portuguese doctors and health professionals. All the above-mentioned interventions require an understanding of the local dynamics of migrants and ethnic minorities, which could be achieved through contextualised local research.

## 4.4. Interrelationship of maternal and child perspectives: A public health perspective

Considering the complexities involved in the provision and maintenance of maternal and child healthcare and the general life course implications, the meticulous provision and implementation of public health measures is not only important but also necessary. Public health interventions are generally targeted at those at risk of disease and those who are in the primary stages of disease (Gillam, Yates & Badrinath, 2012). The demarcation between public health interventions and preventive medical practice is indistinct. Traditionally, preventive practice was divided into primary, secondary and tertiary

prevention measures (Donaldson & Rutter, 2018). Primary preventive approaches seek to safeguard the health and wellbeing of healthy individuals in a population by halting the onset of a disease. The principal goal of such measures is to modify certain aspects of the environment or the status of the host or alter the behaviour of the host so that the development of diseases is not favoured (Donaldson & Rutter, 2018). For example in the UK the health visiting universal model of care runs their services to tackle health challenges through health promotion, prevention and early intervention dedicated to both individuals and communities (Institute of Health Visiting, 2019). Secondary prevention approaches are aimed at stopping the progression of a disease process in affected but asymptomatic individuals. Such measures are highly dependent on screening and diagnosis to allow for prompt interventions (Kisling & Das, 2020). Conversely, tertiary prevention is aimed at limiting complications and disabilities among individuals with established disease. Interventions at this stage particularly improve the quality of life of the individual.

Several constructs have expanded to include primordial prevention (prevention aimed at altering societal factors that influence the risk of a disease) and quaternary prevention (the prevention of overtreatment or excessive intervention) strategies (Ali & Katz, 2015). However, the traditional model is applied in this review, with a specific focus on primary and secondary prevention. The deleterious effects of health outcomes, particularly those pertaining to lifestyles, are often cumulative, thereby, endorsing primary prevention as the preferred and mainstay approach regarding public health perspectives. However, there is increasing evidence to suggest that certain health outcomes can be modified and reversed even at the secondary prevention level (Aminde, Takah, Zapata-Diomedi & Veerman, 2018). Regarding the health of women and children, primary, secondary and tertiary interventions provide multidirectional avenues for the prevention of morbidity and mortality among this group.

### 4.4.1. Opportunities for health improvement and public health strategies for women of reproductive age

#### 4.4.1.1. Primary prevention: Lifestyle and family planning

**Diet and lifestyle**

Women of reproductive age should have adequate exposure to health-related information and actively engage in health promotion to encourage healthy dietary and

lifestyle behaviours and attain optimum nutritional status in preparation for their future reproductive roles (Moos et al., 2008). Therefore, nutrition-specific programmes provide amenable public health intervention for the improvement of health in women of reproductive age. For example, nutrition education (NE) programmes are essential as they enhance appropriate nutritional intake among women of reproductive age via behaviour changes that include choosing the appropriate foods. Moreover, these programmes help to support and sustain these changes (Dunneram & Jeewon, 2015). Nutrition education has been defined as a collection of educational approaches and environmental support aimed at favouring voluntary nutritional behaviour changes to improve an individual's wellbeing. Figure 6 illustrates the three phases of an NE programme.

Brief behavioural counselling on nutrition and NE programmes have demonstrated significant improvement regarding the intake of fruits and vegetables among women of childbearing age. During an RCT, Rodriguez-Ramirez et al. (2015) observed that overweight Mexican women of reproductive age significantly reduced their energy intake following a comprehensive NE plan. Other studies revealed that NE decreased the occurrence of women who were overweight and increased dietary knowledge and behaviour among adolescent girls, particularly if the programme lasted for more than 12 months (Dunneram & Jeewon, 2015).

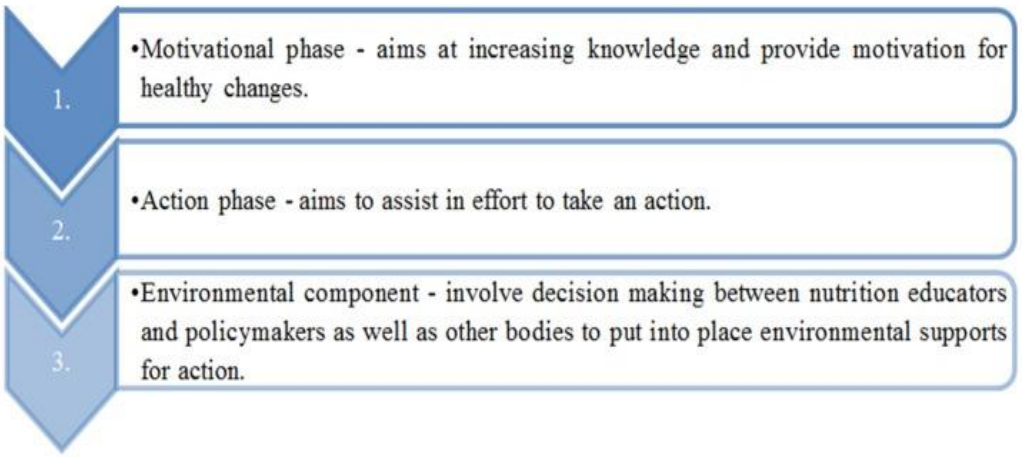



Figure 6. Components of a nutrition education programme
Retrieved from (Dunneram & Jeewon, 2015).

Research has demonstrated that various platforms for the delivery of nutritional information are effective, including community outreach, home visits (Osei et al., 2017),

school-based programmes and text messaging platforms (Lin et al., 2017). *The US Expanded Food and Nutrition Education Program* (EFNEP) is an example of an effective nationwide NE programme, although it is not specifically developed for women of reproductive age. The programme focuses on low-income families to enhance their knowledge, attitude and skills concerning the establishment of a healthy diet (USDA, 2020). Moreover, it provides a 'hands-on' approach to nutrition by actively engaging the people to translate the theoretical nutritional knowledge into practice. Similarly, *The Education Programme* by the British Nutrition Foundation, a private charity, provides school-based NE that is beneficial for adolescents and young women (BNF, 2018).

Micronutrient supplementation programmes are necessary and essential, even during the pre-conception period. Such nutrition-specific programmes have demonstrated considerable efficacy among pregnant women, and adolescents and women of childbearing age (Fox, Davis, Downs, Schultink & Fanzo, 2019). Extensive RCTs conducted in Ghana and Nepal indicated that vitamin A supplementation programmes were effective at improving pregnancy outcomes in communities (Kirkwood et al., 2010) while community- and school-based supplementation programmes for folic acid, iron, iodine, vitamin A and vitamin C demonstrated considerable success among adolescent girls in a separate population (Salam et al., 2016).

**Unplanned pregnancies and family planning**

Teenage and unplanned pregnancies result in various health concerns regarding the women, children and population at large, as previously discussed in this thesis. Donaldson and Rutter (2018) recommended the incorporation of the health sector, education sector, voluntary sector and social and youth services into public health programmes to reduce the occurrence of teenage pregnancies. Moreover, the authors recommended effective and well-publicised contraception and reproductive health advice programmes, including school-based programmes, that focus on young people. Furthermore, there is a requirement for easily accessible counselling and youth-friendly support services, as well as the appropriate training of professionals concerning the handling of sex and relationship education matters among young people (PHE, 2018).

#### 4.4.1.2. Secondary prevention

The early identification of various lifestyle and pregnancy risk factors is important to facilitate early interventions and improve the health of women and children (Stover, Hardee, Ganatra, García-Moreno & Horton, 2016). Therefore, frequent screening is extremely important in a population. Nutritional screening and assessments facilitate the timely detection of potential undernutrition or overnutrition among women, and these should be included in specific clinical protocols which would help create an action plan for an early detection of patients at risk of nutrient deficiencies (Reber, Gomes, Vasiloglou, Schuetz & Stanga, 2019). The ABCD methods of nutritional assessment include anthropometric measurements, biochemical or laboratory assessments, clinical assessments and dietary assessments. The ABCD method is a widely used approach in various public health programmes to evaluate the nutritional status of individuals and populations. Anthropometric measurements are common measurements such as weight, BMI, MUAC and waist circumference. The monitoring of these parameters in women of reproductive age facilitates the early identification of obesity and malnutrition.

Biochemical tests to measure blood sugar, haemoglobin level, vitamins and iodine are highly sensitive and reliable for the early detection of nutritional imbalances (Reber et al., 2019). However, these tests are expensive and several are invasive, hence, they are only endorsed for women who are at significant risk of a disorder, as part of a diagnostic examination of a sick woman or during the monitoring of nutritional therapy. A clinical evaluation of a woman's history and a physical examination are objective methods that can facilitate the detection of various dietary deficiency and lifestyle risks (Esper, 2015). For example, pallor may be indicative of an iron deficiency and the presence of glossitis may be due to a folate or vitamin B12 deficiency (Reber et al., 2019). The use of recall questionnaires, food intake checklists and dietary quality indices to assess the quality of diets, behaviours and patterns among women may reveal inherent unhealthy lifestyle habits and guide nutritional and behavioural counselling as well as public health promotion measures (Contento, 2011). Similar to biochemical assessments, clinical evaluations are also beneficial for high-risk women, and dietary assessments may be implemented as part of community- and school-based programmes from a public health perspective.

Preconception care services provide an excellent platform for the detection of dietary and lifestyle risk factors of women who are preparing for pregnancy. According to the

WHO, optimal preconception care involves the provision of medical, social and behavioural interventions to women and couples before pregnancy to improve their health status and reduce individual and environmental exposures that may affect the pregnancy outcomes (WHO, 2013). Public Health England advocates for a comprehensive preconception care pathway for all women, which is comprised of three pathways: universal preconception care before a woman becomes pregnant for the first time, targeted preconception care for the management of emerging health risks and care for a subsequent baby and beyond (PHE, 2018). Before an initial pregnancy, girls should have a healthy start in life that includes immunisations and other primary prevention measures, as mentioned previously. The education of girls, community-centred health promotion for girls, sexual health education and cervical screening are recognised programmes in the pathways developed by PHE (PHE, 2018). The second pathway that targets care for the management of emerging risks is a significant secondary prevention step from a public health perspective. Figure 7 illustrates the emerging risks that require intervention by PHE.

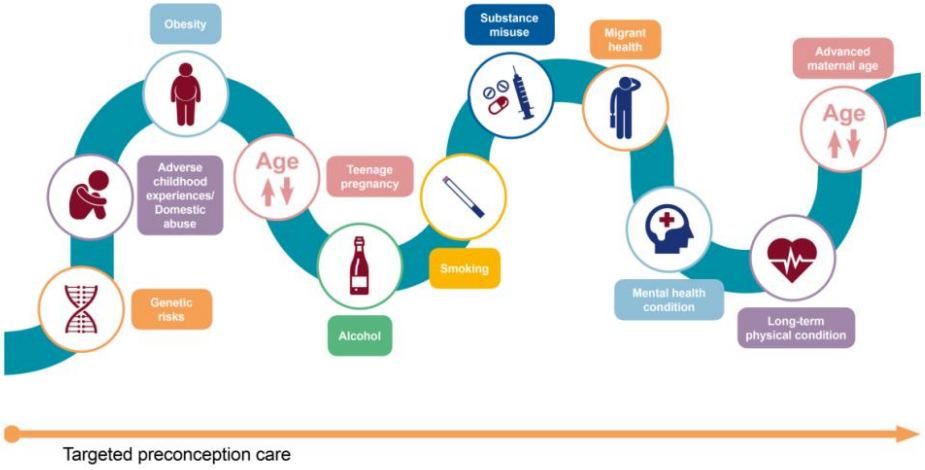



Figure 7. The second preconception pathway:

Managing emerging risks – Early interventions to manage emerging risks along the life course. From "Making the Case for Preconception Care" (PHE, 2018). Retrieved on 17th June 2020.

Chronic conditions are addressed through services such as obesity and weight management, diabetes and hypertension, cessation of smoking, alcohol and drug services and secondary care services for pre-existing physical conditions, among others. The final pathway of preconception care focuses on facilitating the transition to the next pregnancy, including care for chronic conditions that may have arisen as a result of the previous

pregnancy, including GDM and hypertension (Louis, Bryant, Ramos, Stuebe & Blackwell, 2019).

Nutrition and lifestyle changes are challenging topics of discussion for women. Changing habits and routines become more difficult as a woman enters pregnancy. Moreover, even if habits and routines are modified during pregnancy, the effects of pre-pregnancy exposures are often enduring (Forbes et al., 2018). Although there may be sufficient evidence from research, recommendations and strategized public policies that target women in the preconception period, the adoption of interventions among the target group is the primary focus of these efforts (Stephenson et al., 2014). Therefore, research and analyses conducted at a local level are key to the development of population-specific measures to facilitate the adoption of interventions in this population.

### 4.4.2. Opportunities for health improvement and public health strategies for enhancing maternal and child health during perinatal period

#### 4.4.2.1. Primary prevention

The primary prevention of maternal and child health conditions during pregnancy begins in the preconception period with the measures that were previously mentioned. Antenatal care (ANC) services provide an opportunity for interventions to improve the outcomes of the mother and baby (Donaldson & Rutter, 2018). The complete life-saving benefits of ANC are achieved with a minimum of four visits for uncomplicated pregnancies (additional visits are required for complicated pregnancies) (NICE [CG62], 2019). Antenatal care visits include advice on the appropriate diet and lifestyle during pregnancy, including alcohol and substance use, the screening and early detection of maternal medical illnesses that may influence the pregnancy, the monitoring of foetal growth and development and education and psychological preparation for parenting. Donaldson and Rutter (2018) emphasised the role of healthcare providers during ANC visits for providing public health advice to pregnant women regarding the composition of foods in their diet. Furthermore, the ANC visits provide an opportunity for the healthcare providers to promote withdrawal from modifiable risk factors such as smoking, alcohol, illicit substance use and psychological distress that may impact the growth of the foetus and the pregnancy outcomes. From a public health perspective, the success of maternal health programmes, including immunisations against certain infections such as tetanus, prophylaxis against infections such as malaria and supplementation for certain nutrients

such as iron, folate, vitamin D and calcium, is highly dependent on a successful ANC programme.

In the UK, the sharing of ANC among the general practitioners, midwives and obstetricians in the community and hospitals (Donaldson & Rutter, 2018) provides a multidirectional approach that is commendable from a public health perspective. Similar healthcare settings exist on the island of Jersey (Lemprière, 2013). The locally available Child & Family Services from FNHC deliver a significant part of the community care and together with a range of public sectors and voluntary agencies like Best Start Partnership (*The Best Start for Children.*, 2021) aim to represent the best interest of families and children during perinatal period and beyond (FNHC, 2020). This cooperation between the public, private, community and voluntary sectors could play an important role in influencing the current and future work planned to deliver the government strategy and policy around health improvement as early as possible for maternal and child wellbeing.

More collaborative antenatal, public health and already existing health visiting services partnership could be used to support the community health development (CHD) process and coordinate pre-pregnancy, pregnancy, birth, longer post-natal as well as the early years care and education for the public health initiatives and support Jersey Care Model at the local level. The Nursing and Midwifery Council (NMC) in 2021 drafted *Standards of proficiency for specialists community public health nursing* (NMC, 2021) where specialist community public health nurses (SCPHNs) including HVs have a unique role to recognise the needs and build positive relationships with people at home and within communities especially for the vulnerable groups in society. This would allow the local government to tackle the diet- and lifestyle-associated medical illnesses that have been highlighted in this review through clarity of roles and reducing any duplication in primary care.

#### 4.4.2.2. Secondary prevention

The early detection of medical illnesses that impact the health of the mother and baby and, consequently, future generations, is an essential aspect of public health. The simple ABCD approach to nutritional assessment provides substantial information that can be used to identify nutritional risks and lifestyle diseases such as obesity and gestational diabetes (Reber et al., 2019), thereby, enabling early intervention. For

example, the early detection of GDM would facilitate early interventions, including the administering of medications to prevent the lasting implications of uncontrolled hyperglycaemia (Donaldson & Rutter, 2018). Serial BMI measurements and the monitoring of GWG would facilitate the identification of excessive GWG and direct intervention could be applied as required. Furthermore, foetal growth monitoring would facilitate the detection of anomalies and the discernment of delivery complications if foetal macrosomia is observed. Specific interventions are approved for other illnesses and complications during pregnancy that have long-standing public health implications (Gülmezoglu et al., 2016). The NICE provides comprehensive guidelines for the identification and management of different conditions including the antenatal and postnatal mental health in the UK (2020b). However, the public health aspect of these interventions is better achieved through all-inclusive and comprehensive ANC and pregnancy care programmes that are tailored to the local dynamics to ensure accessibility for all pregnant women.

### 4.4.3. Opportunities for creating enduring positive behaviours in the offspring

#### 4.4.3.1. Primary prevention: Nutrition and lifestyle

As discussed previously, the vulnerabilities and the lifelong implications of the factors involved in the first 1,000 days of life highlight the importance of this period as a window of opportunity for public health intervention. Therefore, efforts to improve nutrition during this period will have lasting effects on the survival, health and wellbeing of the child. These effects persist into adulthood and future generations (Martorell, 2017) and can lead to difficult excess weight related life experience such us bullying and in the longer term to poor mental health (GOV.UK, 2020c). Since the first 1,000 days of life begins at conception, interventions that influence pre-pregnancy and prenatal maternal factors such as diet, obesity, a woman's microbiome and substance use can prevent undesirable outcomes in the offspring (Pietrobelli & Agosti, 2017). Comprehending the 'story behind the baseline' and indicators which are shaping the high percentage of obese and overweight children on local level is critical and as an Outcomes Framework for Early Childhood in Jersey (*Final Report: Produced as Part of the Early Childhood Development Programme*, 2018) outlined, data on eating behaviours of young children, information on ethnic/cultural differences in dietary habits or current trend of weight

among 2 year olds among many others is needed to plan successful partnership and prevention.

Routine, well-organised and population-focused public health campaigns should focus on increasing the uptake of breastfeeding in women immediately after birth (Donaldson & Rutter, 2018). These campaigns should be complemented with legal and social support systems that address the breastfeeding deterrents that were highlighted in a previous section of this review. For example, the UK laws provide statutory paid maternity leave of 52 weeks (to allow sufficient time for the mother to initiate and establish breastfeeding) (GOV.UK, 2016) and require employers to provide breastfeeding spaces for their employees. UK parenting education programmes, such as the Department of Health *Baby Steps programme*, focus on breastfeeding and other aspects of childcare education (Baugh, 2018). However, critics have raised concerns regarding the lack of comprehensive national breastfeeding, infant- and young-feeding or nutrition committees or policies in the UK, which may contribute to the low rates of breastfeeding in the country (Bosi, Eriksen, Sobko, Wijnhoven & Breda, 2016). Small-scale programmes, such as the *Baby Steps programme*, encounter challenges such as a lack of funding, infrastructural or strategic support (Johnson & Andersson, 2018). Moreover, concern has been raised regarding a lack of data to support the implementation of the WHO *Baby-Friendly Hospital Initiative* (Bosi et al., 2016) or its situational suitability and impact in the UK (Fallon, Harrold & Chisholm, 2019). Moreover for small places like the island of Jersey the locally available data related to breastfeeding rate in longer perspective ideally at 6 and at 9-12 months after birth or the limitations which breastfeeding women encounter as well as a statistics around percentage of women giving up breastfeeding on return to work (*Final Report: Produced as Part of the Early Childhood Development Programme*, 2018) would help to turn the curve of poor breastfeeding rate. While evidence-based global initiatives and guidelines exist to support breastfeeding, there is a requirement for such recommendations, laws, policies and guidelines to be modified based on local research findings to support the breastfeeding rate in Jersey.

Public health initiatives should also focus on the weaning period to ensure the appropriate weaning guidelines are applied at a local level. Since the early introduction of a high energy and high protein diet has been associated with childhood obesity, both community- and hospital-based initiatives should provide nutrition education to new mothers to discourage the early introduction of solid foods and high energy and protein

diets (Martorell, 2017). A range of provision such as child health clinics, breastfeeding support, introduction to solid food sessions, 9-12 month as well as 2 year development assessment and support at home are provided localy by FNHC team for all parents with children up to 5 years (FNHC, 2020) and are another opportunity for prevention and health promotion in the community. The results of an RCT conducted by Frongillo et al. (2017) revealed that intensive health promotion through mass media and community mobilisation was extremely effective at encouraging the appropriate feeding of infants and young children and improving child development compared to passive non-intensive methods of mass media campaigning and NE. The UK has implemented a comprehensive plan to mitigate childhood obesity, which highlights intensive dietary and lifestyle measures for children. The plan includes the implementation of the Soft Drinks Industry Levy (SDIL) called a 'sugar tax' on sweetened drinks (GOV.UK, 2018a), a reduction of the sugar content in products by 20%, the provision of healthy options for the public, facilitation of physical activity in children and improvements to the quality of food provided in schools (GOV.UK, 2018). The location and promotion of unhealthy foods products within stores matters and from April 2022, the government has confirmed further restrictions related to food and drinks high in fat, salt or sugar (HFSS) (GOV.UK, 2020e). Furthermore, to reduce purchases of HFSS products promoted as 'buy one get one free' or '3 for 2', which can tempt customers to buy more than they need, this type of offers will be restricted particularly in medium and large stores together with limited promotions in prominent locations in stores like at checkouts, store entrances and online to help reduce children's sugar intakes (GOV.UK, 2021a). Since the eating habits that are established in childhood are likely to persist throughout an individual's lifetime, the promotion of healthy dietary habits should be intensive rather than passive and all locally available forces could be used to work on creating positive behaviours in the offspring by closer cooperation with expecting and new parents. This work could be also extended where more education around healthy diet and lifestyle could be delivered to all scholl-aged children.

As a child begins to consume the foods included in the family diet, the 'family food environment' is a potential opportunity for the implementation of public health measures. As highlighted in this review, adults are role models for their children, and habits learnt from the parents often persist in future generations (Johnson et al., 2018). Therefore, public health initiatives for children should also focus on family diets and lifestyles. In

the UK, healthcare visits for children below the age of five years have been instrumental in promoting healthy habits among families (Donaldson & Rutter, 2018). Moreover, nutrition-specific public health initiatives for children should be complemented with nutrition-sensitive actions in the local community, including sanitation and hygiene actions, financial support and incentives and community-based NE programmes (Das, Salam, Imdad & Bhutta, 2016). Additionly, as highlighted above the health visiting care model (Institute of Health Visiting, 2019) and new standards for SCPHNs (NMC, 2021) create excellent opportunity to link locally available services and public health goals to tackle the nutrition and lifestyle inequalities effectively. This action can improve the 'family food environment' as well as support both the positive behaviours in the offspring and PHE's plan to tackle obesity.

#### 4.4.3.2. Secondary Prevention: Growth monitoring and anthropometric measurements

In the ABCD approach to nutritional assessment, anthropometric measurements are critical tools for the early detection of modifiable diet and lifestyle factors that may influence a child's health and the institution of early interventions. Measurements such as weight, height, BMI and MUAC provide vital information, not only for the treatment of the child but also to guide local public health and primary care interventions (Scherdel et al., 2013). The growth and development monitoring of a child involves frequent assessments of anthropometric measurements to observe changes over time compared with established standards for a specific population (Melkamu, Bitew, Muhammad & Hunegnaw, 2019). This facilitates the early identification of lifestyle risk factors such as undernutrition and obesity and promotes early interventions. In addition, from a public health perspective, there is a requirement to emphasise the importance of ethnic-specific anthropometric measurements at a local level, using guidance resulting from local research. The UK *Healthy Child Programme* includes anthropometric measurements as an essential process for children of school age (see Figure 4) to facilitate the identification of growth disorders and to aid in population surveillance (Donaldson & Rutter, 2018). The lack of a referral process to obtain help concerning eating disorders or an unhealthy weight highlights a gap in the healthcare settings, is a crucial matter for public health policies and may provide an opportunity for community health development projects. Based on the findings of the *UK Millennium Cohort Study*, Hawkins, Cole and Law

(2009) conducted the Millennium Cohort Study Child Health Group which emphasised policies and interventions that provide parents with a platform to support the early-life health of children, since risk factors for childhood and adult obesity can be recognised early in life.

### 4.4.4. Community health development

Community health development (CHD) is the process of the promotion of social and health contexts by healthcare practitioners, professionals and community members (Huang & Wang, 2005). Women and children are included in the vulnerable group of society and can be affected by adverse health conditions when appropriate health practices and approaches are not considered. The results of a study by Gram, Fitchett, Ashraf, Daruwalla and Osrin (2019) demonstrated that the health of vulnerable individuals can be improved by educating them about modifying their dietary patterns and lifestyles. Syme and Ritterman (2009) reported that community health development aids mothers and young children to achieve improved living standards, including the promotion of exercise to encourage the burning of extra calories by the body. Simultaneously, community health development educates mothers on how they should feed their children, the importance of vaccinations and the need for frequent screening. Through CHD, mothers can acquire the skills and knowledge needed for efficient health practices to promote their wellbeing and help them live a quality life.

According to the NICE guidelines (2021), for community development to be effective, community members should prioritise health and wellbeing initiatives. For example, nursing mothers should be involved in community health programmes to improve their health and learn the importance of other healthcare practices for the optimum health of their children. Mothers and other local individuals should be involved in developing policies that adhere to the culture and societal demands that help promote quality care (NICE, 2020a). Additionally, the community should be involved in the monitoring of community development programmes to improve the health of mothers and young children of various cultural backgrounds.

### 4.4.5. From research to practice: Challenges regarding the implementation of public health strategies and interventions

This literature review has demonstrated the extensive research that has been conducted on the influence of nutrition and lifestyle on maternal and child health and evidence-based interventions to improve the health of mothers and the growth and development of their offspring and the population at large. Moreover, the requirement for an understanding of local socio-demographic dynamics during the implementation of interventions has been established in this review. However, although knowledge is a prerequisite for the adoption of healthy dietary and lifestyle patterns, the implementation of that knowledge is equally, if not more, important (Contento, 2011). The challenges are well documented regarding the transfer of the knowledge obtained from research into practice (Di Ruggiero, Viehbeck & Greyson, 2018). There are complex food and lifestyle environments that include an extensive array of products. The information environment is complex and includes varied results from studies and confusing nutritional labels on food products. Biological influences also pose a challenge and include non-modifiable genetic risks that are beyond the scope of public health, resulting in the exposure of individuals to lifestyle diseases (Contento, 2011) The established cultural contexts and social preferences that significantly influence lifestyle choices are not easily modified through evidence-based public health initiatives. The diverse nature of populations including factors such as age, culture and literacy complicates the implementation of strategies, while inefficient material resources such as money, labour and legal power impede several of the strategies that seem attractive on paper (Donaldson & Rutter, 2018). The strategies and interventions are further complicated by multiple levels of implementation that must be addressed, including at a national, organisational, community, professional and individual level (McAteer, Di Ruggiero, Fraser & Frank, 2019). All the above-mentioned factors result in a challenging situation regarding decision-making and the establishment of policies.

McAteer et al. (2019) identified public health measure challenges concerning the targeting of the health of a population versus the health of individuals since high-quality RCTs are often conducted at an individual level (non-representative of the population) and are difficult to implement at a population level. Time and ethical constraints further inhibit extensive RCTs. Alternatives to RCTs, such as interrupted time series, controlled pre-post designs and stepped wedge designs are available, however, they are somewhat

costly and local-level evidence to influence policies is complex to obtain (Sanson-Fisher, D'Este, Carey, Noble & Paul, 2014). Therefore, this provides an opportunity for research at a local level. Furthermore, population-based health data provides a critical resource to inform decision-making at a local level. Local observational studies can reveal gaps in the implementation of policies, identify vulnerable groups, track the effectiveness of current policies and guide local goal-setting (Morrato, Elias & Gericke, 2007). Moreover, such contextualised research facilitates the development of local public health policies to overcome the challenges concerning the transformation of high-quality research into policy and practice at a local level, not only regarding maternal and child health but also for other aspects of healthcare.

## V. RESEARCH OBJECTIVES

### Research aim

**The primary aim of this research project** was to investigate the relationship between women's dietary patterns and selected anthropometric measurements and pregnancy outcomes for a mother and child within a cross-cultural community.

To achieve the primary aim, the following actions were undertaken:

1. Establishing the characteristics of women who attended the Maternity Unit at Jersey General Hospital (JGH) in 2017 and the resulting children.
2. Testing for a correlation between the period of time living in Jersey amongst native/UK and relocated women and maternal pregnancy outcomes.
3. Testing the impact of the period of time living in Jersey amongst native/UK and relocated women on a child's characteristics at birth and during the developmental assessment at 9–12 months after birth (follow-up).
4. Exploring the influence of maternal parameters such as age, weight before pregnancy and BMI before pregnancy, as well as total weight gained during pregnancy by week 34 for the child at birth and during the follow-up.
5. Determining any influence of the period of time living in Jersey on a mother's dietary patterns.
6. Establishing the Mediterranean diet score and pregnancy outcomes for a mother and child across aMED score levels.

**It was hypothesised that:**

In the context of public health, there is a meaningful association between women's dietary patterns and selected anthropometric measurements and pregnancy outcomes for a mother and a child, and this is influenced by the period of time living in Jersey.

**The research results should help to answer the following questions:**

1. Do women with different lengths of residency in Jersey and different ethnic backgrounds need an individual approach to improve their pregnancy outcomes?

2. How can maternal and early life health promotion could be planned and implemented to promote the best pregnancy outcomes for a mother and a child in Jersey?

# VI. RESEARCH DESIGN AND METHODS

## 6.1. Research Design

The study population consisted of pregnant women who attended the Maternity Unit at JGH and the resulting children. The women were from various ethnic backgrounds and were living in Jersey. The study at JGH was conducted over three years – between September 2016 and September 2019.

The following local services, organisations and health systems were involved in this research procedure and data collection:

- JGH, Jersey Antenatal Care, Jersey Maternity Unit, hospital system TrakCare, personal medical records;
- The Child Health System, administered by the Preventative Programmes Child Health Team;
- Family Nursing & Home Care (FNHC), the Jersey charity that provides developmental assessments for children in Jersey from birth.

The presented research was conducted under a memorandum of understanding between the University of Warmia and Mazury (UWM) in Olsztyn, ul. Oczapowskiego 2, Poland, represented by Vice-Rector for Science prof. Dr hab. Jerzy Jaroszewski and the Jersey General Hospital, The Parade, St. Helier, JE1 3QS, Jersey, the Channel Islands from 16th September 2016 (Appendix 3). This project was conducted collaboratively with the Maternity Unit and FNHC in Jersey.

Mr Neil MacLachlan, the lead consultant at the Department of Obstetrics and Gynaecology, JGH, agreed to act as Health & Social Services Department (HSSD) Sponsor for this research. The research was conducted under an HSSD honorary agreement between the author, Urszula Śliwka, and the Women and Children's Services Maternity HSSD in Jersey. Urszula Śliwka held a Research Fellow post with clinical attachment in JGH between September 2016 and September 2019.

## 6.2. Ethical considerations

The study, with Resolution no. 9/2015, was approved by the Bioethics Committee of the Faculty of Medical Sciences of the UWM in Olsztyn, Poland, on 12th March 2015. This research was additionally reviewed and approved by the Health and Social Services Jersey Ethics Committee on 11th May 2016 (Appendix 2).

The processing, sharing and publication of the results of the research were planned and conducted following the Data Protection (Jersey) Law 2005 and are in line with the Data Protection (Jersey) Law 2018.

### 6.3. Author's contributions and funding

This presented research project has been written by the author Urszula Śliwka. Funding was provided by the author, who is also a self-funded PhD student, and there were no additional sources of funding.

### 6.4. Author's personal interests

The undertaking of a professional doctorate has been primarily driven by the desire to extend my professional knowledge in the field of nutrition but also due to my interest in engaging and empowering individuals and communities. In particular, this includes the vulnerable subgroups of the population, and I believe that it is important to make changes that reduce the risk of preventable lifestyle diseases. I am grateful to have had the opportunity to spend the past 7 years developing and conducting this research project, as well as finalising this thesis. By conducting this study, I have gathered invaluable information concerning organisational and human-associated limitations and the complexity of pregnancy and early childcare settings. I am thankful for the possibility to cooperate with all related government and private bodies. From a personal development point of view, by conducting this challenging research I have obtained unique knowledge and skills that are critical for the development of successful health promotion programmes and interventions, particularly for cross-cultural communities.

### 6.5. Assessment of resources

The author ensured that all the resources required for the study were in place and readily available. The first area of consideration was accessibility to the study population. Thus, all the participants were from the region, allowing the author to interact, engage and communicate with them often. Secondly, sufficient time was allocated for the research to ensure that the recruitment process at the antenatal clinic and participant enrolment could be undertaken correctly and all the required data could be collected in a timely manner according to the PhD Project's Timeline (Appendix 1).

To encourage more women to participate in the study, the information sheet for participants (Appendix 8), leaflets, posters (Appendix 9), the informed consent form (Appendix 6) and the informed parental consent form (Appendix 7), the research notice for health professionals (Appendix 4), the research recruitment notice for patients (Appendix 5) the socioeconomic and demographic questionnaire (SDQ) and the food frequency questionnaire (FFQ) were available in three languages: English, Polish and Portuguese. This ensured that all materials required by the participants were comprehensible and easy to read for various levels of literacy and language skills.

The author also created a project website – www.pregnancy-study.co.uk – as a source of additional information, and this was also available in the three aforementioned languages. Facebook was used as the social media tool for the project (https://www.facebook.com/DietLifestyleProjectJersey/).

The following types of written communication were sent to all participants throughout the study:

- A congratulations card after each woman gave birth;
- A Happy First Birthday card;
- A Thank you letter (Appendix 10) a diet review based on the FFQ and a certificate of research participation was sent to each woman who completed all stages of the project (Appendix 11).

## 6.6. Research framework

### 6.6.1. Participant selection

Participation in the study was entirely voluntary. An information sheet presenting the detailed study framework was offered to each woman who expressed interest in participating. The participants were asked to sign an informed consent form. The parents or legal guardians of the participants under the age of 16 were asked to sign an informed parental consent form. The provision of consent was essential to allow the author to access hospital records regarding pregnancy details, the newborns' measurements and the 9- to 12-month-old babies' measurements from FNHC.

Only women with an uncomplicated pregnancy according to the NICE guideline [CG62] (2019) were considered as potential participants for this project. Women enrolled in this project were identified after their first appointment between the 10th and 12th weeks of pregnancy according to the study criteria outlined below. Only the midwife or

medical consultant who knew the woman's health status could determine whether she met the research inclusion and exclusion criteria. This allowed the health of the participant at each stage of the study to be confirmed. A one-to-one phone call interview with each potential participant was organised by the author as the recruitment procedure, and each woman was personally invited by the author to take part in the project.

**Inclusion criteria of the study:**

- an uncomplicated (healthy) and singleton pregnancy without gynecological diseases;
- before the 20th week of gestation;
- native-born Jersey, British, Polish or Portuguese living in Jersey, Channel Islands;
- a basic command of English;
- live born neonate.

**Exclusion criteria of the study:**

- any pathology known to alter food intake during pregnancy such as diabetes, heart disease, kidney disease, hypertension or depression;
- a specific clinical issue (mental health, HIV infection or Hepatitis B);
- an impairment that would limit communication during an interview, limit the patient's legal actions or limit their ability to provide full consent;
- insufficient language skills to communicate in English;
- unwillingness to participate in all stages of the research;
- unwillingness to have anthropometric measurements taken and used as data for the study.

### 6.6.2. Sample size

The project was designed based on numbers of women of childbearing age in Jersey according to data from the 2011 Jersey Census (States of Jersey Statistics Unit, 2012). Out of the entire population of 954 pregnant women in Jersey in 2017 (between January and December), 200 ladies were identified as potential participants. Participant enrolment and study sample collection are presented overleaf in Diagram 1.

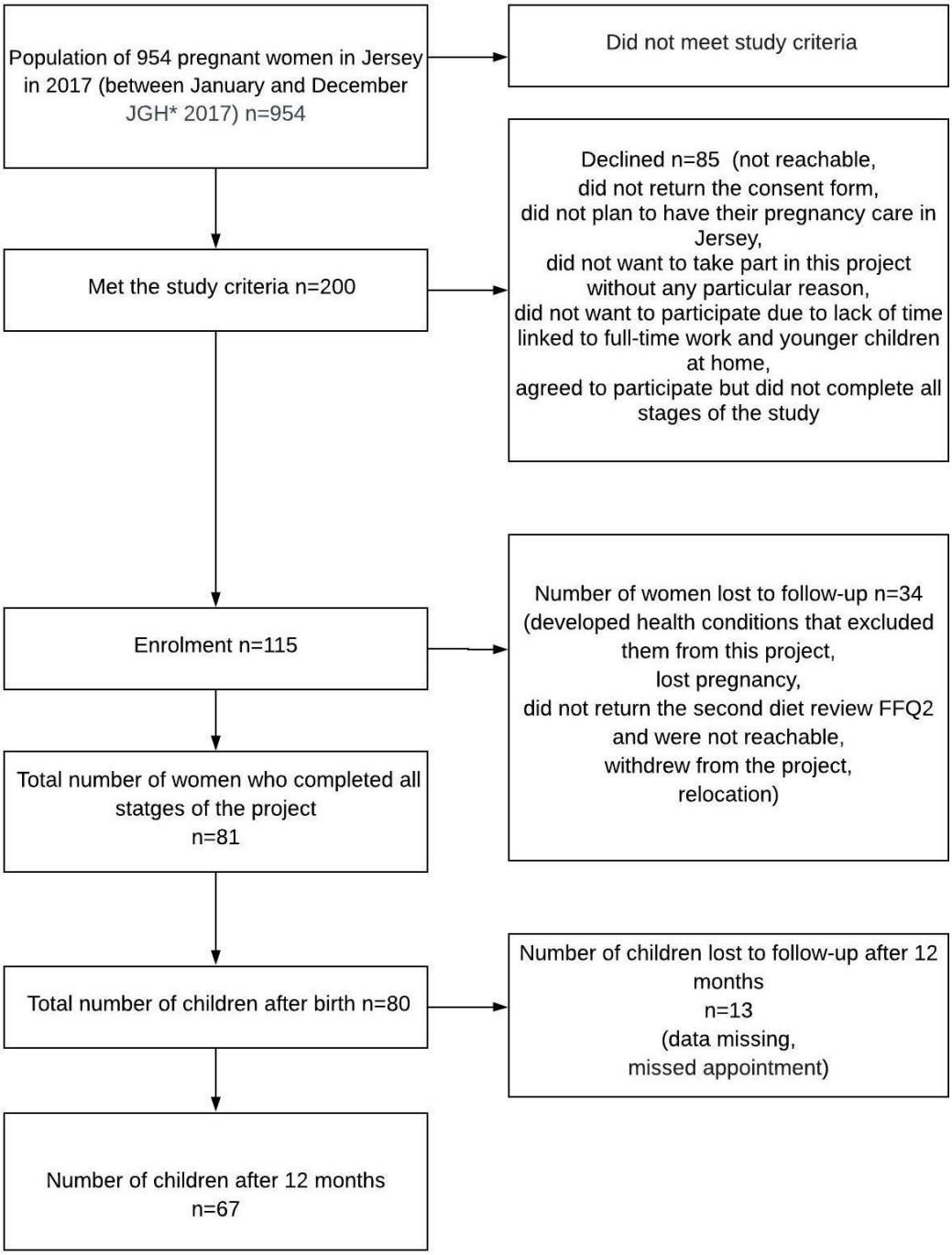



Diagram 1. Flow chart of the study sample collection

Among the 200 pregnant women identified as potential participants for this study, 85 were classified as declined. Within this group, there were women who were not reachable (n = 16), women who asked for the information sheet for participants but did not return

the consent form (n = 17), women who did not plan to have their pregnancy care in Jersey (n = 4), women who did not want to take part in this project for no particular reason and women who did not want to participate due to lack of time as a result of full-time work and having younger children at home (n = 42).

A total of 115 women agreed to take part in this research. Of these women, 81 completed all the stages of the research and 34 were lost to follow-up. Of those that were lost to follow-up, there were women who developed health conditions that excluded them from the project (n = 8), women who lost their pregnancy (n = 3), women who did not return the second diet review FFQ2 and were not reachable (n = 14), women who withdrew from the project (n = 3) and women who did not complete their full pregnancy care in Jersey due to relocation (n = 4).

### 6.6.3. Data collection

Data were collected according to the flow chart shown in Diagram 2. The data compiled included pre-pregnancy information collected at the beginning of pregnancy, information collected during weeks 12–20 and 28–34 of pregnancy, information collected after birth and information collected 9–12 months after birth.

For each woman and her baby who participated in this study, the research framework involved the following stages:

**The first stage** focused on patient identification and participant enrolment at JGH.

**The second stage** involved the collection of the following data between week 14 and week 26 of pregnancy:

- Pre-pregnancy weight;
- Maternal weight and height at appointment (8th–12th week of pregnancy);
- Pre-pregnancy diet (FFQ1);
- SDQ;
- Information about previous pregnancies and older children.

**The third stage** involved the collection of the following data from weeks 28 and 34 of pregnancy:

- Maternal weight at week 28;
- Maternal weight at week 34;
- Pregnancy diet assessment (FFQ2).

**The fourth stage** involved the collection of the following data after the birth:

- Gestation age of the baby;
- Apgar score;
- Birth length, newborn's weight for gestation age, head circumference;
- Feeding method during the first 48 hours after birth;
- Time and type of delivery.

**The fifth stage** involved the collection of the following data on 9- to 12-month-old children:

- Baby's weight and length measurements;
- Feeding methods during the first year of life.

**The sixth stage** involved a comprehensive substantive analysis of all the data obtained.

Pre-pregnancy information, data about diet before and during pregnancy, and information from the SDQ were obtained as the primary data.

The maternal anthropometric measurements collected as data for this study were primarily obtained by GPs, hospital health professionals or community midwives as part of the Jersey antenatal care and routine appointments for uncomplicated pregnancies. This data were then taken from the hospital TrakCare system and personal records and used as secondary data by the author. Information about the health status of infants after birth and feeding methods, as well as anthropometric measurements, were obtained by the hospital health professionals at the JGH as a part of the Jersey maternity care. The anthropometric measurements and feeding information of 9- to 12-month-old infants were taken by FCNH health visitors during routine appointments. This secondary data was obtained from the hospital TrakCare system, the Child Health System and the FCNH database.

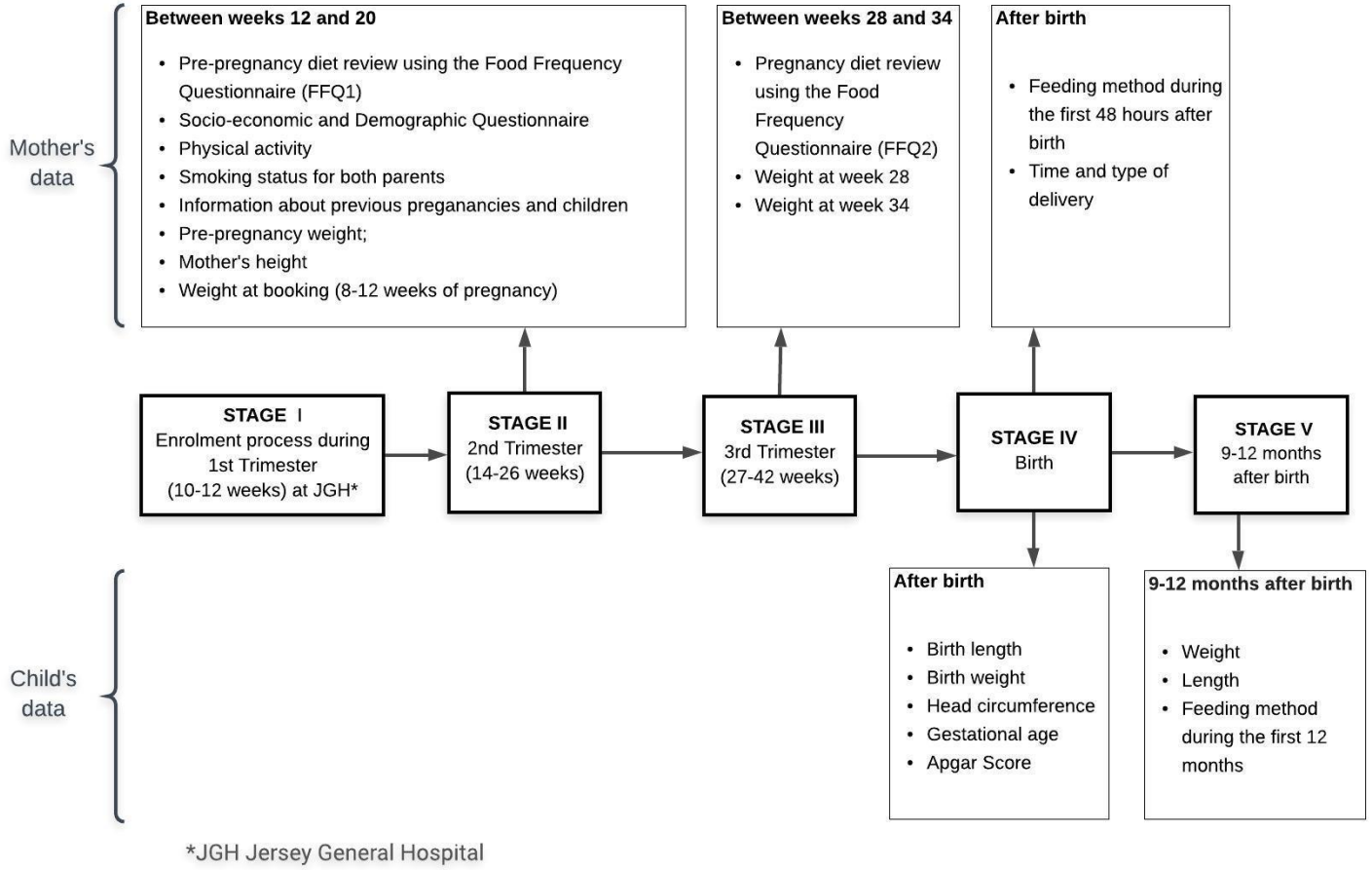



Diagram 2. Flow chart of data collection

## 6.7. Methods

### 6.7.1. The basic characteristics of the mothers and fathers

**The Socioeconomic and Demographic Questionnaire**

The socioeconomic and demographic questionnaire (SDQ) was developed to collect socioeconomic and demographic data for each patient, as well as the general lifestyle (level of activity) and smoking, education and employment status. Additionally, the nationality and amount of time the mothers had spent on the island, as well as the age, weight and height of the fathers, was obtained to create a population characteristic baseline for both parents.

Because the ethnic groups in the research cohort were too small to achieve the correct statistical power between the groups, the period of time the mothers had lived on the island was used to split the groups:

- Native and the UK
- Women who had lived on the island less than 10 years (Europe < 10y on the island)
- Women who had lived on the island more than 10 years (Europe ≥ 10y on the island)

**General lifestyle**

The self-reported pre-pregnancy level of physical activity was categorised as

1- Daily exercise
2- Exercise 2–3 times per week
3- Exercise once per week
4- Occasional exercise
5- Sedentary

### 6.7.2. Diet review

**Diet review of mothers**

The EPIC-NorfolkFFQ v.6 (EPIC-Norfolk Study, 1988) was used to obtain a retrospective diet review before pregnancy (FFQ1) and during pregnancy (FFQ2).

FFQ1 was used to assess the diet 3 to 6 months before pregnancy and was provided at the beginning of the pregnancy. The participants were asked by the author to fill in FFQ1 and return it to the author during the routine antenatal appointment at the Maternity Unit of JGH during week 20 of pregnancy. Advice on how to fill in the questionnaire was provided, however, the author did

not assist with this process in person. Once the FFQ1 had been returned to the author, any missing or confusing answers were addressed and clarified directly with the participants. The second questionnaire, FFQ2, was dedicated to diet during pregnancy and was sent by post to each woman's home address. The participants were asked to fill in this second diet review between week 28 and week 34 of pregnancy and return it to the Antenatal Clinic using the envelope and stamp provided.

**The EPIC-Norfolk FFQ**

The EPIC-Norfolk FFQ is used for the European Prospective Investigation into Cancer and Nutrition (University of Cambridge, 1988) that is conducted in 10 countries (Denmark, France, German, Italy, the Netherlands, Norway, Greece, Spain, Sweden and UK) and includes 521,000 participants. The EPIC FFQ has been validated for use in adults and has been recognised as reasonable for the review of the habitual diet (Bingham, 1997; Mckeown et al., 2001). This tool is a semi-quantitative paper-based FFQ that includes 130 food items. It was designed to record the average intake of foods during the previous year and includes an open section. During the present study, the FFQ took 30 to 60 minutes to complete, depending on the respondent, and was provided in a paper version. The full FFQ template of the EPIC-Norfolk FFQ v.6 used in the present study is available at http://www.srl.cam.ac.uk/epic/epicffq/.

The questionnaire was designed in two parts. Part 1, 'The Main Part', presents a list of 130 food items. The food items are either individual foods, combinations of particular foods or food types. Each item has a given portion size: a medium serving, standard unit or household measure. The study participants were asked to select an appropriate frequency of consumption for each item from nine frequencies, which were numbered from 1 to 9 – from 'Never or less than once per month' (1) to '6+ per day' (9). Part 2, 'Back of the FFQ', contains further questions that request more detailed information about food, e.g. food preparation and cooking methods.

The FFQ facilitates the examination of major sources of nutrients of particular interest, foods that contribute to the variability in intake between individuals in the population, and foods that are commonly consumed in the population. The FFQ used in this study was only modified from the original in Part 2 for question number 3, which was related to the consumption of the different types of cow's milk that are available in Jersey: Whole 4.5% fat milk-Yellow, Reduced 2.5% fat

milk-Green, 99% fat-free milk-Blue, Skimmed 0.1% fat milk-Orange. The part of this question that concerned types of milk other than cow's milk was left the same as it was in the original version.

In this study, the diet review in the form of the food frequency questionnaire was required to measure the intake of particular food groups and establish a specific dietary pattern. The FETA (Φετα) FFQ EPIC Tool for Analysis (Mulligan, Luben & Bhaniani, 2014) provided for EPIC-Norfolk FFQ was not used in this study, as the intention was to measure the dietary patterns related to food groups and habitual diets rather than nutrient profiles.

**Food groups**

The dietary review provided an idea of the dietary habits of an individual and the general study population based on a list of the 13 main food groups presented below (**in bold**) in Table 1. Several of the food groups were divided into sub-groups (shown in non-bold text; resulting in 18 groups) based on nutritional similarities to create a dietary pattern.

Table 1. Food groups

| **Food groups** | Products |
|---|---|
| **Meat and meat products** | Beef: roast, steak, mince, stew or casserole; Beef burgers; Pork: roast, chops, stew or slices; Lamb: roast, chops or stew; Chicken or other poultry; Bacon; Ham; Corned beef, spam, luncheon meats; Sausages; Savoury pies, e.g. meat pie, pork pie, pasties, steak and kidney pie, sausage rolls; Liver, liver pate, liver sausage; Meat soups (bowl) |
| Red and processed meat | Beef: roast, steak, mince, stew or casserole; Beef burgers; Pork: roast, chops, stew or slices; Lamb: roast, chops or stew; Bacon; Ham; Corned beef, spam, luncheon meats; Sausages; Savoury pies, e.g. meat pie, pork pie, pasties, steak and kidney pie, sausage rolls; Liver, liver pate, liver sausage; Meat soups (bowl) |
| Poultry | Chicken or other poultry, e.g. Turkey |
| **Fish and fish products** | Fried fish in batter, as in fish and chips; Fish fingers, fish cakes; Other white fish, fresh or frozen, e.g. cod, haddock, plaice, sole, halibut; Oily fish, fresh or canned, e.g. mackerel, kippers, tuna, salmon, sardines, herring; Shellfish, e.g. crab, prawns, mussels; Fish roe, taramasalata |

Table 1. Cont. Food groups

| **Food groups** | Products |
|---|---|
| **Eggs and egg dishes** | Eggs as boiled, fried, scrambled, etc. (one); Quiche (medium serving) |
| **Cereals and cereal products** | White bread and rolls; Brown bread and rolls; Wholemeal bread and rolls; Cream crackers, cheese biscuits; Crispbread, e.g. Ryvita; Porridge, Readybrek; Breakfast cereal such as cornflakes, muesli, etc.; White rice; Brown rice; White or green pasta, e.g. spaghetti, macaroni, noodles; Wholemeal pasta; Lasagne, moussaka; Pizza |
| Refined grain products | White bread and rolls; Cream crackers, cheese biscuits; Crispbread, e.g. Ryvita; Breakfast cereal such as cornflakes, muesli, etc; White rice; White or green pasta, e.g. spaghetti, macaroni, noodles; Lasagne, moussaka; Pizza |
| Whole-grain products | Brown bread and rolls; Wholemeal bread and rolls; Porridge, Readybrek; Brown rice; Wholemeal pasta |
| **Milk and milk products** | Single or sour cream (1 tbs); Double or clotted cream (1 tbs); Low fat yoghurt, fromage frais (125g carton); Full fat or Greek yoghurt (125g carton); Dairy desserts (125g carton); Cheese, e.g. cheddar, Brie, Edam (medium serving); Cottage cheese, low fat soft cheese (medium serving); Low calorie, low fat salad cream (1 tbs) |
| Low-fat dairy | Single or sour cream (1 tbs); Low fat yoghurt, fromage frais (125g carton); Dairy desserts (125g carton); Cottage cheese, low fat soft cheese (medium serving); Low calorie, low fat salad cream (1 tbs) |
| Whole-fat dairy | Double or clotted cream (1 tbs); Full fat or Greek yoghurt (125g carton); Cheese, e.g. cheddar, Brie, Edam (medium serving) |
| **Fats and oils** | Salad cream, mayonnaise (1 tbs); French dressing (1 tbs); Other salad dressing (1 tbs); Butter (1 ts); Block margarine, e.g. Stork, Krona (1 ts); Polyunsaturated margarine, e.g. Flora, Sunflower (1 ts); Other soft margarine, dairy spread, e.g. Blue Band, Clover (1 ts); Low fat spread, e.g. Outline, Gold (ts); Very low fat spread (1 ts); Sauces, e.g. white sauce, cheese sauce, gravy (1 tbs) |

Table 1. Cont. Food groups

| **Food groups** | Products |
|---|---|
| Oils and sauces | French dressing (tbs); Other salad dressing (tbs) ; Block margarine, e.g. Stork, Krona (ts); Polyunsaturated margarine, e.g. Flora, Sunflower (1 ts); Other soft margarine, dairy spread, e.g. Blue Band, Clover (1 ts); Low fat spread, e.g. Outline, Gold (1 ts); Very low fat spread (1 ts) |
| Animal fat | Salad cream, mayonnaise (1 tbs); Butter (1 ts); Sauces, e.g. white sauce, cheese sauce, gravy (tbs) |
| **Sweets, snacks and preserves** | Sweet biscuits, chocolate, e.g. digestive (one); Sweet biscuits, plain, e.g. Nice, ginger (one); Cakes, e.g. fruit, sponge, home-baked; Cakes, e.g. fruit, sponge, ready-made; Buns, pastries, e.g. scones, flapjacks, home-baked; Buns, pastries, e.g. croissants, doughnuts, ready-made; Fruit pies, tarts, crumbles, home-baked; Fruit pies, tarts, crumbles, ready-made; Sponge puddings, home-baked; Sponge puddings, ready-made; Milk puddings, e.g. rice, custard, trifle; Ice cream, choc ices; Chocolates, single or squares; Chocolate snack bars e.g. Mars, Crunchie; Sweets, toffees, mints; |
| **Sweets, snacks and preserves** | Sugar added to tea, coffee, cereal (1 ts); Crisps or other packet snacks; Jam, marmalade, honey (1 ts) |
| **Fruit** | Apple (one fruit); Pears (one fruit); Orange, satsuma, mandarin (one fruit); Grapefruit (half); Banana (one fruit); Grapes (medium serving); Melon (one slice); *Peach, plum, apricot (one fruit); *Strawberries, raspberries, kiwi fruit (medium serving); Tinned fruit (medium serving); Dried fruit, e.g. raisins, prunes (medium serving) |
| **Vegetables** | Vegetable soups (bowl); Carrots; Spinach; Broccoli, spring greens, kale; Brussels sprouts; Cabbage; Peas; Green beans, broad beans, runner beans; Marrow, courgettes; Cauliflower; Parsnips, turnips, swedes; Leeks; Onions; Garlic; Mushrooms; Sweet peppers; Beansprouts; Green salad, lettuce, cucumber, celery; Watercress; Tomatoes; Sweetcorn; Beetroot; Coleslaw; Avocado; Baked beans; Dried lentils, beans, peas, Tofu, soya meat, TVP, Vegeburger; Marmite, Bovril (1 ts); Tomato ketchup (1 tbs); Pickles, chutney (1 tbs) |

Table 1. Cont. Food groups

| | |
|---|---|
| Vegetables (without legumes) | Vegetable soups (bowl); Carrots; Spinach; Broccoli, spring greens, kale; Brussels sprouts; Cabbage; Marrow, courgettes; Cauliflower; Parsnips, turnips, swedes; Leeks; Onions; Garlic; Mushrooms; Sweet peppers; Beansprouts; Green salad, lettuce, cucumber, celery; Watercress; Tomatoes; Sweetcorn; Beetroot; Coleslaw; Avocado; Tomato ketchup (1 tbs); Pickles, chutney (1 tbs) |
| Legumes | Peas; Green beans, broad beans, runner beans; Baked beans Dried lentils, beans, peas; Tofu, soya meat, TVP, Vegeburger; Marmite, Bovril (1 ts) |
| **Potatoes** | Boiled, mashed, instant or jacket potatoes; Chips; Roast potatoes; Potato salad |
| **Nuts and seeds** | Peanuts or other nuts; Peanut butter (1 ts) |
| **Non-alcoholic beverages** | Tea (cup); Coffee, instant or ground (cup); Coffee, decaffeinated (cup); Coffee whitener, e.g. Coffee-mate (1 ts); Cocoa, hot chocolate (cup); Horlicks, Ovaltine (cup); Low calorie or diet fizzy soft drinks (glass); Fizzy soft drinks, e.g. Coca cola, lemonade (glass); Pure fruit juice (100%), e.g. Orange, apple juice (glass); Fruit squash or cordial (glass) |
| **Alcoholic beverages** | Wine (glass); Beer, lager or cider (half pint); Port, sherry, vermouth, liqueurs (glass); Spirits, e.g. gin, brandy, whisky, vodka (single) |

**Dietary pattern**

Maternal dietary habits were described by the degree of adherence to the alternate Mediterranean diet (aMED) score constructed by Fung et al. (2005). The aMED score is composed of eight food items ([1] vegetables [excluding potatoes], [2] fruits, [3] nuts, [4] legumes, [5] fish, [6] whole grains, [7] red and processed meat and [8] alcohol) and the MUFA:SFA ratio. One point was awarded when the daily consumption of vegetables, fruits, nuts, legumes, fish, whole grains and the MUFA:SFA ratio was greater than or equal to the median, and when the daily consumption of red and processed meat was less than the median and alcohol intake ranged from 5 to 15 g per day. Adherence to the aMED score was based on the overall sum of the scored components and ranged from 0 to 9.

**The feeding methods of newborns and children during the first year of life**

The data about the newborn's feeding methods during the first 48 hours were classified according to the hospital records: bottle, breast only and breast and complement.

### 6.7.3. Maternal anthropometric measurements

Maternal anthropometric measurements were obtained by health professionals following the standard techniques of the NICE Clinical Guideline [CG62] for uncomplicated pregnancy (2019) and the NICE Quality Standard [QS22] (2016). Detailed information regarding the medical equipment used to obtain the anthropometric measurements was not made available to the author.

**The pre-pregnancy anthropometric measurements of mothers**

Pre-pregnancy weight and height measurements were collected from the self-completed SDQ and were used to calculate the body mass index (BMI) before pregnancy.

**Pre-pregnancy BMI**

The BMI – a ratio of weight to squared height (kg/m2) of a person – is the most widely used and accepted method of estimating body fat percentage, which stratifies individuals into categories and defines obesity (Nuttall, 2015). Based on the BMI, individuals are classified into five categories (Table 2).

Table 2. Adult population categories based on the BMI

| Category | BMI |
|---|---|
| **Underweight** | Below 18.5 |
| **Normal** | 18.5 to 24.9 |
| **Pre-Obesity** | 25.0 to 29.9 |
| **Class I Obesity** | 30.0 to 34.9 |
| **Class II Obesity** | 35.0 to 39.9 |
| **Class III Obesity** | Above 40 |

BMI – Body Mass Index. From the WHO Regional Office for Europe (WHO, 2014). Retrieved on May 3, 2020.

**Maternal anthropometric measurements and BMI 'at booking'**

The weight and height measurements 'at booking' for pregnant women were obtained between week 8 and week 12 of pregnancy based on medical advice following the NICE [CG62] (2019) guidelines for an uncomplicated pregnancy. The collected measurements were kept in hospital records. These data enabled the calculation of the BMI 'at booking' and were used to make sure

the pre-pregnancy self-reported weight could be cross-checked against the weight recorded by health professionals at 8–12 weeks of pregnancy. The BMI 'at booking' was calculated in the same manner as the pre-pregnancy BMI.

**Gestational weight gain (GWG)**

The NICE guidelines [CG62] (2019) do not provide national recommendations for monitoring GWG and do not support the routine weight measurement of pregnant women unless this is clinically advised. In Jersey, for women with an uncomplicated pregnancy, besides the weight measurements obtained 'at booking', no routine weight measurements are taken as part of antenatal care unless this is advised by consultants, and this follows the above-mentioned practice.

During this research, through an agreement with the Ethics Committee in Jersey and the Antenatal Clinic Manager, two additional weight measurements during pregnancy were planned for this study cohort. To avoid the need for additional appointments for those on a routine antenatal care schedule, these two weight measurements were taken during the second trimester (28th week) and third trimester (34th week) by community midwives during a routine appointment. Stickers to remind the midwives to take these measurements were designed for this study and were added to participants' personal records. The data on weight gain during pregnancy were essential to calculate the GWG for this study population. The community midwives' collection of pregnancy weight data for this study cohort followed the community midwives and GP-led model of shared antenatal care for pregnant women who were deemed to be a low risk according to the NICE [CG62] (2019). It was logistically not possible for the author to be present for each weight measurement as they were obtained at various times and multiple GP surgeries. Only the community midwives could help with pregnancy weight data collection. Detailed information about the medical equipment used to obtain the weights was not made available to the author.

GWG is calculated as the difference between the pre-pregnancy weight and the weight during the second and third trimesters. GWG is classified according to the guidelines of the IOM(a) (IOM, 2009) which are presented in Table 3. These guidelines are used worldwide to predict adverse pregnancy outcomes (Santos et al., 2018).

Table 3. The IOM(a) guidelines for cumulative weight gain and the rate of weight gain in singleton pregnancies

| BMI category before pregnancy | Total GWG (lbs) | Rate of weight gain, 2nd and 3rd trimesters (lb/wk) |
|---|---|---|
| **Underweight (Less than 18.5 kg/m2)** | 28–40 | 1.0 (1.0–1.3) |
| **Normal weight (18.5 to 24.9 kg/m2)** | 25–35 | 1.0 (0.8–1.0) |
| **Overweight (25.0 to 29.9 kg/m2)** | 15–25 | 0.6 (0.5–0.7) |
| **Obese (≥ 30.0 kg/m2)** | 11–20 | 0.5 (0.4–0.6) |

BMI – Body Mass Index. From IOM (2009). Retrieved on May 4, 2020

### 6.7.4. Anthropometric measurements of newborns

The anthropometric measurements of the newborns at the Maternity Unit followed the standard methods of the NICE [CG62] Clinical Guideline (2019) and the Healthy Child Programme: Pregnancy and the first five years of life (DH, 2009). Information regarding the medical equipment that was used to obtain the anthropometric measurements was not made available to the author.

The following anthropometric measurements of newborns were collected for this study:

- Baby's weight FGA [g],
- Baby's birth length FGA [cm],
- Baby's head circumference FGA [cm].

**Percentile measurements for gestational age**

Growth charts are a useful tool for tracking a child's physical growth and development. The WHO 0–2 Years Baby Infant Growth Chart (UK-WHO, 2013) and Calculator for Boys and Girls, available at https://www.infantchart.com, was used to calculate:

- The birth weight percentile measurements FGA (%),
- The birth weight percentile measurements FGA z-score,

- The birth length percentile measurements FGA (%),
- The birth length percentile measurements FGA z-score,
- The growth percentile (%) FGA (for each child was collected from hospital records and was based on weight and length FGA).

**The health status of newborns after birth**

*Ponderal Index (PI)*

Rohrer's Ponderal Index (PI) provides an indication of a person's weight relative to their height and, similar to the BMI, is used as a proxy measure of adiposity. The PI is calculated as weight (kg) divided by cubed height ($m^3$) (Khoury, Berg & Calle, 1990).

$PI = Weight\ (kg) / [Height\ (m)]^3$

*The Apgar Score of newborns*

The Apgar score contains five easily recognisable parameters taken at 1 and 10 minutes after birth (and 5-minute intervals until the 20th minute for a child who has an initial score of less than 7): the child's activity or muscle tone, pulse rate, grimace or reflex irritability, appearance or skin colour and respiration, and each parameter has a score of 0, 1 or 2 (ACOG. The Apgar Score, 2015). The 1-minute score determines how well the baby tolerated the birthing process. The 5-minute score indicates to the healthcare provider how well the baby is doing outside the mother's womb.

### 6.7.5. Anthropometric measurements at 9-12 months after birth (follow-up)

For each child from the study population, during the routine 9–12-month follow-up (known as the screening and routine review or developmental assessment), the FNHC health visitor collected information regarding the baby's development, such as the baby's age (months), weight (kg) and length (cm). The process of taking the anthropometric measurements followed the standard techniques of the Healthy Child Programme (DH, 2009). Information regarding the medical equipment used to obtain the anthropometric measurements was not made available to the author.

The information concerning the 9- to 12-month developmental assessment was obtained from the Egton Management Information System (EMIS), an electronic clinical record system. In the EMIS, the data is captured using a template, which is completed by the HVs.

The administration process of the FNHC for the scheduling of appointments for parents regarding screening and routine review is as follows:

- Parents are telephoned to make an appointment for a screening.
- Parents are sent a letter with the details of the appointment.
- Parents receive a reminder text message three days prior to the appointment and they are asked to reschedule if unable to attend.
- If the parent(s) does not attend, a new appointment is scheduled and the details are sent to them.
- If the parent(s) does not attend the second appointment, a letter is sent to enquire if they still want an appointment.
- The GP is advised that the child was not brought to the appointment, but no further action is taken.

**Percentile measurements**

The WHO 0–2 Years Baby Infant Growth Chart Calculator (WHO. Child Growth Standards, 2016), available at https://www.infantchart.com, was used to calculate the weight and length percentiles (%) for 9- to 12-month-old children.

### 6.7.6. Other delivery outcomes and pregnancy history

The time of delivery was classified according to hospital records and the NICE guidelines ( 2019) as preterm (37 weeks or less), term (between weeks 38 and 41) or post-term (after week 42).

The type of delivery was classified as normal delivery, assisted delivery, elective caesarean section or emergency caesarean section.

### 6.7.7. Research area – Jersey, Channel Islands

**Geographical location of Jersey**

As stated previously, Jersey is a remote island located close to the coast of Normandy in France, but it is a British Crown dependency. The Public Health Statistics Unit (Statistics Jersey,

2016) reported that, on the 119.5 km2 area of Jersey at high tide, the population density in 2015 was 859 people per square kilometre, and this was greater than twice that of England. The region has a diverse multicultural environment and individuals from various ethnic origins inhabit the island (States of Jersey Statistics Unit, 2012). Jersey is significantly affected by the constant movement of migrants in and out of the area. For example, in 2011, it was determined that 50% of people were born in the area, 31% were born in other places in the British Isles, 7% were born in Portugal and 3% were born in Poland, Figure 8 (States of Jersey Statistics Unit, 2014).

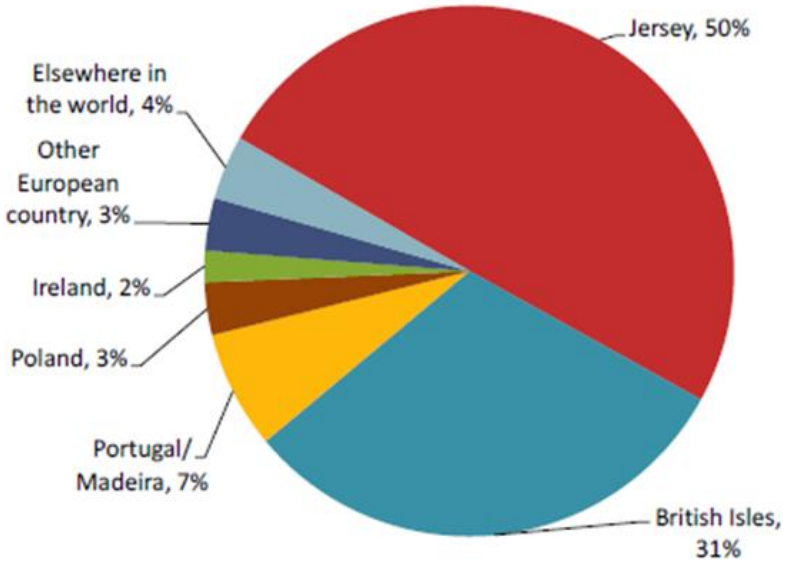
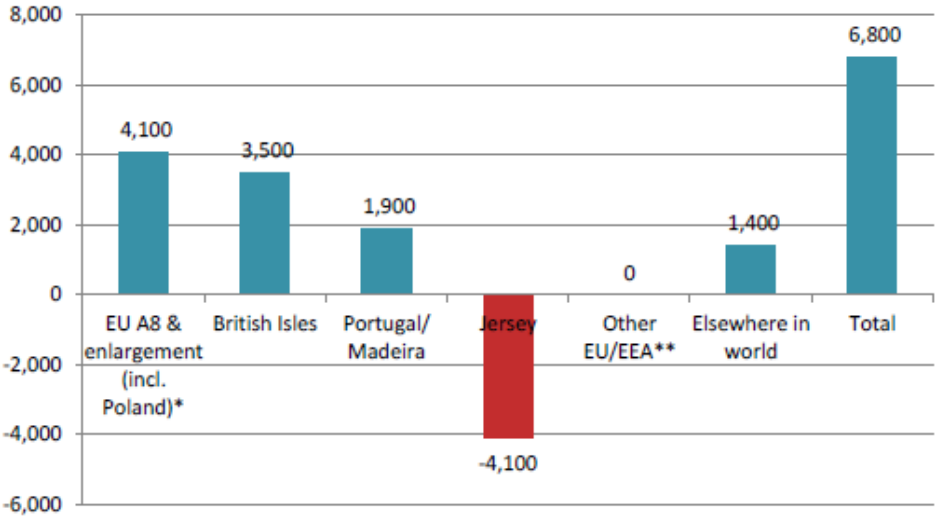



Figure 8. Population by place of birth, 2011.
Retrieved from'Jersey in Figures 2013' the States of Jersey Statistics Unit (2014) on May 27, 2020.

In terms of ethnicity, less than 46% of the participants in the 2011 Census stated they were Jersey, 33% considered themselves British and 8% stated they were Portuguese. The largest ethnicity in context was Whites, followed by Asians, Blacks, and mixed races (States of Jersey Statistics Unit, 2014). Figure 9 demonstrates that the largest number of immigrants from 2001 to 2011 were born in countries that joined the European Union in 2004. Of these 4,100 migrants were from new EU countries and 3,100 were born in Poland. As Jersey witnesses the constant movement of migrants in and out of the island the 2021 Census will present more accurate data on the inhabitants of

Jersey by place of birth. In recent years, there has been an increased movement of people from countries such as Romania and Bulgaria.




**EU A8 (2004): Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia, Cyprus and Malta; and Enlargement (2007): Bulgaria, Romania.*
***EU/EEA (2001 definition): Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Liechtenstein, Luxembourg, Netherlands, Norway, Spain, Sweden, Switzerland.*

Figure 9. Net migration from 2001 to 2011 by place of birth
Retrieved from 'Jersey in Figures 2013' the States of Jersey Statistic Unit (2014) on May 27, 2020

**Health profile**

The birth statistics in Jersey demonstrate that women aged 30 to 34 had the highest birth rates in 2019 (Statistics Jersey, 2020b). Moreover, Jersey witnessed 890 live births in 2019, which was the lowest rate since 2012 (Statistics Jersey, 2020b). Additionally, the rate of caesarean section births in Jersey between 2017 and 2019 was 34% compared to 27% in England (Statistics Jersey, 2020b) and over 26% in Europe (WHO, 2021c). The statistics for breastfeeding show that in 2019, 75% of newborn babies were breastfed when discharged from a care facility. This decreased to 58% by 6 to 8 weeks (39% breastfeeding exclusively and a further 19% partially) and to 23% by one year (19% were fed exclusively with breastmilk and 4% received breast milk and formula) (Statistics Jersey, 2020b). The Jersey Census from 2011 outlined a high rate (77%) of working females aged 16–59 years (States of Jersey Statistics Unit, 2012) and this percentage was even

higher (83%) in the Jersey Opinions and Lifestyle Survey (JOLS) published in 2017 (States of Jersey Statistics Unit, 2017).

In the 2008 Annual Report (States of Jersey, 2008), the Medical Officer of Health presented the main barriers towards improved health among women and children in Jersey: no consumption of healthy foods (42%), healthy foods were expensive (30%) and a lack of willpower (28%). In the same report, it was highlighted that reducing obesity among pregnant women is crucial due to the observed high percentage of women who had excess weight at the first antenatal appointment (32% overweight and 10% obese). Furthermore, the 2019 JOLS report presented that greater than half (52%) of women self-reported a waist measurement in excess of 80 cm (31.5 inches), which has been associated with an increased risk of CVD (Statistics Jersey, 2019c).

From 2009–2011 and 2018–2019, the proportion of Reception children defined as having excess weight was approximately 20% and 21%, respectively. The most recent percentage of Year 6 children of unhealthy weight is approximately 30%, which is lower than in England (34%), however, the 2018–2019 data are comparable to the 2011–2013 period, during which the proportion of children classified as overweight or obese in Year 6 was 31% (Statistics Jersey, 2019a). In Jersey, for both Reception and Year 6 children, public schools have a higher number of children identified as overweight or obese than fee-paying schools. Furthermore, regarding the parish of residence of the group of children in Year 6, a higher percentage of those living in built-up areas have excess weight than those living outside towns (Statistics Jersey, 2019a). In 2019, 79% of children received a 9- to 12-month developmental assessment by 15 months of age and 76% of children had their 2–2½ year health check by 32 months of age (FNHC, 2019). There is no report that shows the anthropometric measurement profile of younger children based on their developmental assessment before they enter Reception at school.

Concerning lifestyle, in the 2019 JOLS report, 80% of respondents regarded themselves as reasonably fit, but in reality, only 51% of adults met the NHS requirements for moderate exercise (Statistics Jersey, 2019c). According to this report, in the group of physically inactive residents, a lack of time was the main reason for the inactivity (Statistics Jersey, 2019c). From 2013 to 2019, only 33% of males and 38% of females consumed adequate portions of fruits and vegetables (Statistics Jersey, 2019c). Nonetheless, smoking decreased among adults in Jersey, from 19% in 2005 to 11% in 2019 (Health and Community Services, 2019). One in six babies is exposed to a

smoking household (Statistics Jersey, 2016). The CO testing is available for all women at the antenatal booking appointment to identify smokers or those exposed to tobacco smoke and the cessation rate amongst pregnant women who are supported by the Help2Quit stop smoking service is 36% (Statistics Jersey, 2020a).

The local disease projections report states that the total percentage of the Jersey population defined as having excess weight may increase between 2016 and 2036 by more than 25% (State of Jersey, 2017b). Jersey has identified the need to improve the health of the community, particularly children, through plans and strategies such as the Common Strategic Policy (CSP) 2018–2022 (Government of Jersey, 2019a), the Government Plan 2020–23 (Government of Jersey, 2019b), the organisation of public finance (Public Finances [Jersey] Law, 2019), the Children and Young People's Plan (Government of Jersey, 2019c) and the Food and Nutrition Strategy for 2017–2022 (Strategic Public Health Unit, 2017). These initiatives have significant potential to improve the health of women and children by addressing the negative impacts of obesity through prevention. The public health context is highlighted in the aims and objectives of the Reducing Preventable Disease (RPD) 2020–2023 work that is planned for the island. Under the health docket, the RPD portfolio provides financial support to help reduce smoking and increase the consumption of healthy foods among the population. It also funds other programmes that aim to improve the efficiency of the public health team concerning the weight management of the citizens (Government of Jersey, 2020b).

Regarding the youngest members of the population, the local government has previously implemented several measures, including the Health, Exercise, and Nutrition for the Really Young (HENRY) programme that was launched in 2018 (States of Jersey, 2019). It is an evidence-based child obesity prevention programme that provides aid for parents and carers of 0 to 5-year-olds and targets families with children who have obesity or those who are more likely to develop excess weight (GOV.UK, 2017b). In Jersey, this programme was adopted to equip early years professionals with nutritional knowledge. Additionally, Jersey partly adopted the UK Healthy Start programme, which provides aid for low-income pregnant women and children up to 4 years old (NHS, 2020a). The programme aims to provide support for the period between the health visitors' care during the initial years and when a child begins primary school. This programme offers vouchers for basic food such as fruits, vegetables and milk (NHS, 2020a). The Healthy Start

programme in Jersey provides vouchers to low-income mothers of 0 to 1-year-olds, and the RPD portfolio hopes to expand this programme to older age groups so that vouchers could be offered to 0 to 4-year-olds (Government of Jersey, 2020b). Thus, the programme aims to provide support until children reach an age when they can avail of other health initiatives at school that will promote a heathy lifestyle and address poor nutrition.

The Food and Nutrition Strategy that was launched in 2017 applies a life course approach, encourages people to maintain a healthy lifestyle, promotes a healthy environment and utilises a multi-sector alliance for its implementation (Strategic Public Health Unit, 2017). Three pilot schemes were launched in 2019 for several primary schools to promote healthy eating among children in Jersey. These include nutritionally balanced lunches managed by the Caring Cooks charity, where either the cost of meals for parents is significantly reduced or the meals are free for certain eligible children; the 'Food Dudes' behaviour change programme, which aims to increase the consumption of fruits and vegetables and the eight-week Family Healthy Lifestyle programme, which is based on weekly sessions with a registered dietitian and physical activities provided by Jersey Sport (Government of Jersey, 2020c). These schemes were continued in 2020 (Gov.je, 2020c). Initiatives designed to address unhealthy body weight and habits have been well researched and locally tested by Coppins et al. (2011) via a multi-disciplinary family-based programme for treating childhood obesity.

Further work is expected in line with the Jersey 'Putting Children First' strategy (Gov.je, 2019b) to improve the health of children. Moreover, local authorities plan to dedicate funds to support the integration of the Cooking and Skills programme into the primary school curriculum (States of Jersey, 2019) and intend to extend it to a school-wide Cooking and Growing programme in 2021 (Government of Jersey, 2020b). There is also a plan to allocate funding to expand school meals to additional primary schools, support breakfast clubs at schools and offer the Family Weight Management initiative for additional children and families across the island (Government of Jersey, 2020b).

Jersey aims to achieve a high rate of breastfeeding through the UNICEF Baby Friendly accreditation (Gov.je, 2019a; UNICEF United Kingdom, 2020). In 2019, 199 mothers participated in the perinatal education programme offered by FNHC known as Baby Steps (FNHC, 2019). Moreover, in 2020, the local authority formulated family-friendly employment legislation that

provides breastfeeding rights for new mothers and protects the parents of newborns by giving them 52 weeks of leave (including 6 weeks of paid leave) and increased pay for the second parent (the partner of the birth mother) for up to 6 weeks (Gov.je, 2020d). Furthermore, if a mother returns to work within the 52 weeks beginning with the birth of the child and wishes to breastfeed (which includes expressing breast milk), she is entitled to reasonable paid breaks from work for breastfeeding. The new law covers the period of up to 52 weeks and after that, the time off work needed for breastfeeding is unpaid. Since January 2021, the new Parental Allowance (maximum 32 weeks) is paid weekly, where 6 weeks is dedicated for mother, 6 weeks for the second parent and 20 weeks can be shared between parents. This financial support allows for parents to take time off work (Gov.je, 2020b).

In addition to the large investment administered throughout the island to improve the activity level of the inhabitants (State of Jersey, 2017a), and prevent obesity and modify unhealthy dietary patterns amongst younger children (Strategic Public Health Unit, 2017), the weight management of adult citizens in Jersey has also been highlighted as part of the future plan (Government of Jersey, 2020b) and is directly associated with the new Jersey Care Model. This proposed care model intends to reorganise primary and secondary care and focus on prevention and self-care to enable individuals to look after their health through the Health and Care system or by working on their lifestyle independently (Government of Jersey, 2019d). It is anticipated that this change will have a positive impact on the health status of the inhabitants in the short and long term. In terms of workforce capacity regarding the Major Projects and Service Improvements planned for 2020–2023, the government also intends to increase the number of health professionals to improve the delivery and quality of services for children and pregnant women (Government of Jersey, 2020b). Moreover, through the Closer to Home initiative, the communities and existing health services are connected and can deliver support for children and parents, e.g. a mother and toddler group, an after-school club or a nursery (Government of Jersey, 2020b).

### 6.7.8. Statistical analyses

Several variables were generated: habitual diet, socioeconomic and demographic factors, selected anthropometric measurements for pregnant women and their babies, breastfeeding and complementary feeding. The normality of the variables was examined using the Shapiro-Wilk test.

For all the continuous variables, the data are presented as the median and interquartile range (IQR). For the continuous variables with a normal distribution, a one-way analysis of variance (ANOVA) with Tukey's posthoc test was used. For the continuous variables with a non-normal distribution, the Kruskal-Wallis test was applied. The variables are presented as a number and percentage, and the chi-square test or Fisher's exact test were also used. Longitudinal changes in the maternal weight and the weight and length of a child were evaluated using linear mixed models, and the participants were used as a random intercept. Changes in maternal weight were measured or modelled at four time points: before pregnancy, at booking (8–12 weeks of pregnancy), at 28 weeks and at 34 weeks. Changes in a child's weight and length were measured or modelled at two time points: at birth and after one year. The P-values for the changes were approximated using Satterthwaite's method. The level of statistical significance was set to $P < 0.05$ for all tests. All statistical analyses were performed using STATISTICA (version 13.1 PL, StatSoft Inc, Kraków, Poland) and R software (version 3.5.2, R Foundation for Statistical Computing, Vienna, Austria).

# VII. RESULTS

## 7.1. Characteristics of pregnant women at the Maternity Unit at Jersey General Hospital in 2017

### 7.1.1. Ethnic origin of all women at the Maternity Unit at Jersey General Hospital in 2017

Table 4 summarises the ethnicities of the women who had antenatal appointments at the Maternity Unit at Jersey General Hospital in 2017. The ethnicity with the highest number of women was White Jersey (297; 30.8%). White British women constituted 25.2% of the total and the ethnicities with the lowest number of women were Asian or Asian British (any other background, Pakistani), Black or Black British (Caribbean) and Chinese (only 0.2% of the total number of women). Two per cent of the women did not state their ethnicity, while 11.2% were of unknown ethnicity.

Table 4. Summary of pregnant women by ethnic origin

| **Ethnicity** | **Total** |
|---|---|
| Asian / Asian British – Any other background | 2 |
| Asian / Asian British – Bangladeshi | 4 |
| Asian / Asian British – Indian | 9 |
| Asian / Asian British – Pakistani | 2 |
| Asian / Asian British – Thai | 4 |
| Black / Black British – African | 9 |
| Black / Black British – Caribbean | 2 |
| Chinese | 2 |
| Mixed White / Black Caribbean | 1 |
| Not Stated | 19 |
| Other Mixed Background | 1 |
| **Other White Background** | **78** |
| Other ethnic groups | 2 |
| Unknown | 108 |
| **White British** | **243** |
| White French | 9 |
| **White Irish** | **21** |
| **White Jersey** | **297** |
| **White Polish** | **56** |
| **White Portuguese** | **96** |

Author's elaboration based on the TrakCare reports MAT00023A and MAT00017C, accessed February 24, 2020

### 7.1.2. BMI classification off all women at the Maternity Unit at Jersey General Hospital in 2017

Figure 10 illustrates the distribution of women in relation to their BMI classification. The data collected revealed that 46% of the women had a normal or healthy body weight and had a BMI of between 20kg/m$^2$ and 25kg/m$^2$. A significant proportion of women were underweight (9%), overweight (27%), or obese (11%). There was also a significant proportion of women who were morbidly obese (6%) and had a BMI of greater than 35kg/m$^2$. The overall percentage of pregnant women who were overweight or obese was 44%.

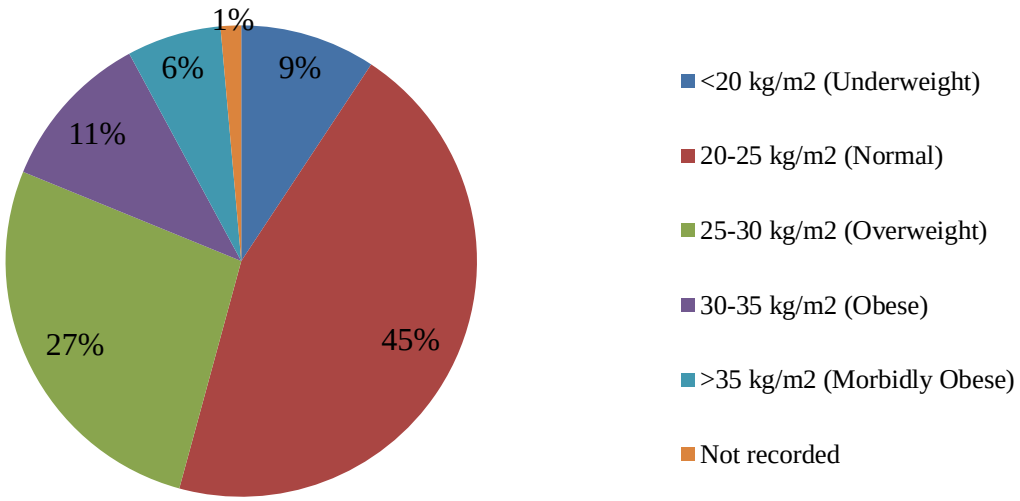



Figure 10. BMI classification 'at booking' for all pregnant women at the Maternity Unit at Jersey General Hospital in 2017. 'At booking' = at 8–12 weeks of pregnancy.
(Source: TrakCare reports MAT00023A and MAT00017C, accessed February 24, 2020)

## 7.2. Characteristics of women identified as potential participants and invited to participate in the study during 2017

### 7.2.1. Ethnicities of the women who were invited to participate in the study

The ethnicities of the women identified as potential participants and invited to participate in the study between January and December 2017 are shown in Figure 11. The largest proportion of women (30%) who were invited to participate in the study were natives of Jersey Island. A significant number of women who were invited to participate were of Portuguese (20%) and

British (29%) origin. The smallest group of women who participated in the study were Irish (3%). Polish and mixed-ethnicity women were also involved in the research.

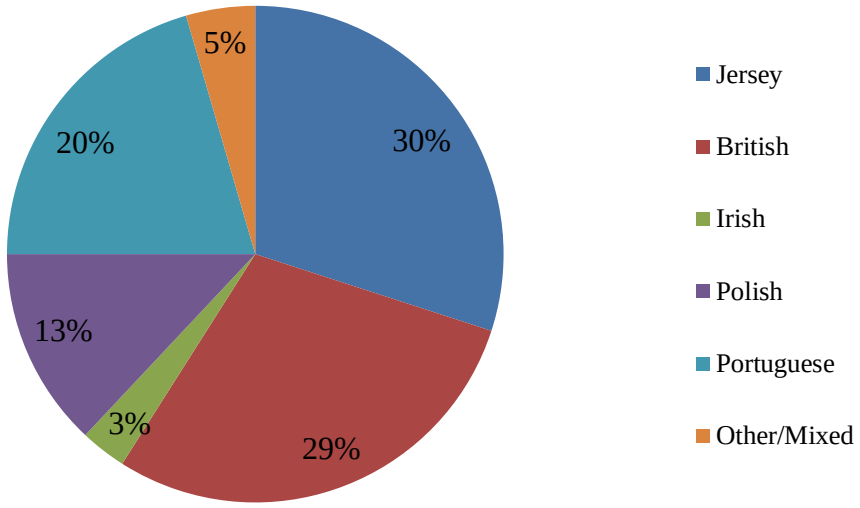



Figure 11. Ethnicities of the 200 women who were invited to participate in the study.
Other/Mixed – Romanian, French, Bulgarian, Slovakian.

### 7.2.2. Research completion rates among women from different ethnicities who were invited to participate in the study

Figure 12 shows the research completion rates among the 200 women from different ethnicities who were invited to participate in the study. This includes the rates of women who completed all stages of the study and the number of women who did not want to participate or did not complete the study. The willingness of the women to participate in or complete the study varied among the ethnicities. The rates of completion of the research or exit before the study was completed were recorded. The largest proportion of women who completed all the stages of the research were Polish and Jersey natives (58% and 57%, respectively). In contrast, the smallest proportion of women (17%) who completed all the stages of the research were Irish and Portuguese.

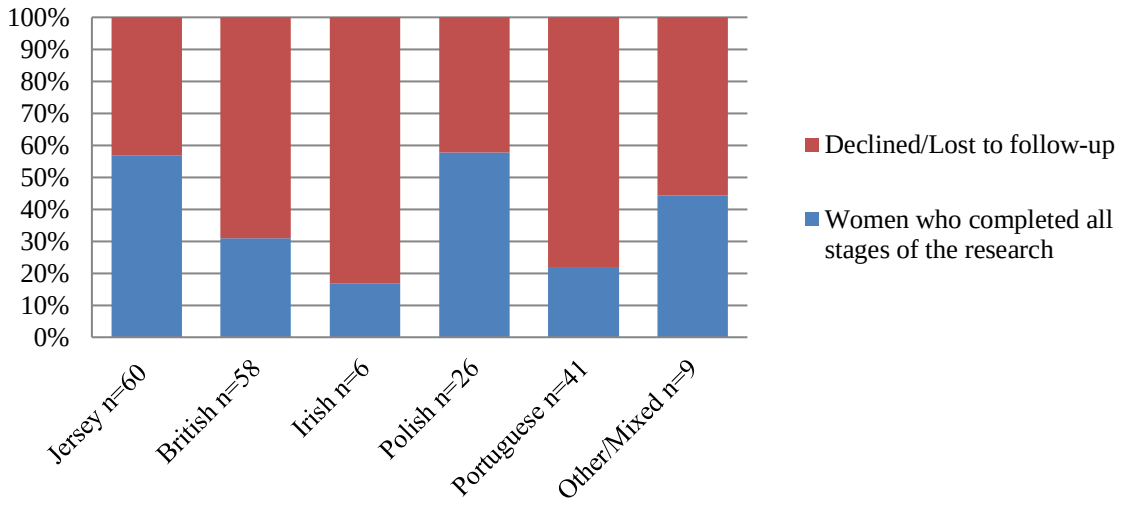



Figure 12. Participation outcomes for women of various ethnicities who were invited to participate in the study (n=200) and declined or were lost to follow-up (n=119).
Other/Mixed – Romanian, French, Bulgarian, Slovakian.

## 7.3. Basic characteristics of mothers and fathers who completed the study

### 7.3.1. Basic characteristics of mothers

Table 5 summarises the socioeconomic and demographic results obtained from the women who participated in the study. The socioeconomic and demographic information collected included age, ethnicity, years of parenting, academic level, household income, level of physical activity and smoking behaviour. A total of 81 women participated in the study, and the mean age was 33 years. The highest proportion (42.0%) of mothers who participated in the study were Jersey natives, while the smallest proportion (1.2%) were Irish. Other ethnicities that were represented included British, Polish, Portuguese and Mixed. A total of 70.4% of the women had completed higher education, while 3.7% lacked formal education. Similarly, most of the women (87.7%) who participated in the study were in regular employment, while 8.6% were housewives. The household income of the women ranged from less than £200.00 per week (1.3%) to greater than £550.00 per week (64.7%). A total of 3.8% of the women led a sedentary lifestyle, while the majority (36.3%) exercised two to three times per week. A total of 8.6% of the women smoked during their pregnancy. Significant variations were observed regarding the socioeconomic and demographic data collected and these were based on the time the women had spent on the island.

Table 5. Socioeconomic and demographic characteristics of the women who participated in the study

| Characteristics | All | Length of time living on the island | | | *p* |
|---|---|---|---|---|---|
| | | Native and British | European ≥ 10y on the island | European < 10y on the island | |
| *N* | 81 | 55 | 12 | 14 | |
| Age, years | 33.0 (30.0, 36.0) | 33.0 (29.0, 36.0) | 35.0 (34.5, 37.5) | 31.5 (28.0, 33.0) | 0.174 |
| Residence in Jersey, years | N/A | N/A | 14.0 (12.0, 16.0) | 5.5 (4.0, 7.0) | <0.001 |
| Ethnicity, *n* (%) | | | | | |
| Jersey | 34 (42.0) | 34 (61.8) | 0 (0.0) | 0 (0.0) | <0.001 |
| British | 18 (22.2) | 18 (32.7) | 0 (0.0) | 0 (0.0) | |
| Irish | 1 (1.2) | 0 (0.0) | 1 (7.1) | 0 (0.0) | |
| Polish | 15 (18.5) | 0 (0.0) | 8 (57.1) | 7 (58.3) | |
| Portuguese | 9 (11.1) | 2 (3.6) | 4 (28.6) | 3 (25.0) | |
| Other/Mixed | 4 (4.9) | 1 (1.8) | 1 (7.1) | 2 (16.7) | |
| Parent of children <5y [yes], *n* (%) | 33 (41.8) | 26 (48.2) | 1 (8.3) | 6 (46.2) | 0.038 |
| Education level, *n* (%) | | | | | |
| Higher | 57 (70.4) | 44 (80.0) | 4 (33.3) | 9 (64.3) | 0.022 |
| Secondary | 18 (22.2) | 7 (12.7) | 7 (58.3) | 4 (28.6) | |
| Other | 3 (3.7) | 2 (3.6) | 1 (8.3) | 0 (0.0) | |
| No formal qualification | 3 (3.7) | 2 (3.6) | 0 (0.0) | 1 (7.1) | |
| Employment status, *n* (%) | | | | | |
| Regular | 71 (87.7) | 47 (85.5) | 11 (91.7) | 13 (92.9) | 0.955 |
| Student | 1 (1.2) | 1 (1.8) | 0 (0.0) | 0 (0.0) | |
| Unemployed | 2 (2.5) | 2 (3.6) | 0 (0.0) | 0 (0.0) | |
| Housewife | 7 (8.6) | 5 (9.1) | 1 (8.3) | 1 (7.1) | |

Data are presented as the median and interquartile range (IQR) or number (%). BMI – body mass index; Other/Mixed – Romanian, French, Bulgarian, **S**lovakian; [a,b] – differences between time on island groups $p<0.05$ (Kruskal-Wallis test or ANOVA with Tukey posthoc test).

Table 5. Cont. Socioeconomic and demographic characteristics of the women who participated in the study

| Characteristics | All | Length of time living on the island | | | *p* |
|---|---|---|---|---|---|
| | | Native and British | European ≥ 10y on the island | European < 10y on the island | |
| *N* | 81 | 55 | 12 | 14 | |
| Household income, *n* (%) | | | | | |
| < £200 | 1 (1.3) | 0 (0.0) | 0 (0.0) | 1 (7.1) | <0.001 |
| £200–400 | 7 (8.9) | 2 (3.7) | 1 (9.1) | 4 (28.6) | |
| £400–550 | 9 (11.4) | 4 (7.4) | 3 (27.3) | 2 (14.3) | |
| >£550 | 51 (64.7) | 44 (81.5) | 4 (36.4) | 3 (21.4) | |
| Declined to answer | 11 (13.9) | 4 (7.4) | 3 (27.3) | 4 (28.6) | |
| Physical activity, *n* (%) | | | | | |
| Daily exercise | 16 (20.0) | 11 (20.0) | 4 (8.3) | 4 (30.8) | 0.563 |
| Exercise 2-3 times/week | 29 (36.3) | 22 (40.0) | 5 (41.7) | 2 (15.4) | |
| Exercise once/week | 17 (21.3) | 11 (20.0) | 2 (16.7) | 4 (30.8) | |
| Occasional | 15 (17.8) | 9 (16.7) | 4 (33.3) | 2 (15.4) | |
| Sedentary | 3 (3.8) | 2 (3.6) | 0 (0.0) | 1 (7.7) | |
| Smoking before pregnancy, *n* (%) | | | | | |
| Non-smoker | 64 (79.0) | 44 (80.0) | 10 (83.3) | 10 (71.4) | 0.849 |
| Ex-smoker | 10 (12.4) | 6 (10.9) | 1 (8.3) | 3 (21.4) | |
| Current smoker | 7 (8.6) | 5 (9.1) | 1 (8.3) | 1 (7.1) | |
| Smoking status at booking, *n* (%) | | | | | |
| Non-smoker | 64 (79.0) | 44 (80.0) | 10 (83.3) | 10 (71.4) | 0.849 |
| Ex-smoker | 10 (12.4) | 6 (10.9) | 1 (8.3) | 3 (21.4) | |
| Current smoker | 7 (8.6) | 5 (9.1) | 1 (8.3) | 1 (7.1) | |
| Mental health problems [yes], *n* (%) | 20 (24.7) | 19 (34.6) | 1 (8.3) | 0 (0.0) | 0.010 |

Data are presented as the median and interquartile range (IQR) or number (%). BMI – body mass index; Other/Mixed – Romanian, French, Bulgarian, **S**lovakian; [a,b] – differences between time on island groups $p<0.05$ (Kruskal-Wallis test or ANOVA with Tukey posthoc test).

### 7.3.2. Basic characteristics of fathers

Table 6 summarises the anthropometric, socioeconomic and demographic data of the fathers ($n=74$) whose partners were involved in the study. Fifty of the fathers were natives, 12 had spent more than 10 years on the island and 12 had spent less than 12 years on the island. Based on

the anthropometric data collected, 12.2% and 37.8% of all the fathers were obese or overweight, respectively. The mean age of the fathers was 34 years. The highest prevalence of obese (16.7%) and overweight (66.7%) fathers was observed among foreigners (Europeans) who had lived on the island for more than 10 years. The most dominant ethnicities were native Jersey and British. The rate of smoking during pregnancy was the highest (42.9%) among the foreigners who had lived on the island for less than 10 years.

Table 6. Characteristics of the fathers

| Characteristics | All | Length of time living on the island | | | *p* |
|---|---|---|---|---|---|
| | | Native and British | European ≥10y on the island | European <10y on the island | |
| *N* | 74 | 50 | 12 | 12 | |
| Age, years | 34.0 (31.0, 38.0) | 34.0 (30.0, 37.0) | 36.5 (33.5, 44.5) | 34.5 (34.0, 39.0) | 0.163 |
| Weight, kg | 79.0 (73.0, 89.0) | 77.0 (72.0, 89.0) | 82.5 (78.5, 87.0) | 79.0 (73.5, 88.5) | 0.279 |
| Height, cm | 178.5 (175.0, 183.0) | 180.0 (175.1, 183.0) | 176.5 (171.5, 179) | 178.4 (174.5, 186.0) | 0.118 |
| BMI, kg/cm$^2$ | 25.0 (23.1, 28.3) | 24.8 (22.5, 27.7) | 26.9 (25.2, 29.6) | 24.4 (23.5, 26.2) | 0.098 |
| BMI, *n* (%) | | | | | |
| Underweight | 2 (2.7) | 2 (4.0) | 0 (0.0) | 0 (0.0) | 0.233 |
| Normal | 35 (47.3) | 25 (50.0) | 2 (16.7) | 8 (66.7) | |
| Overweight | 28 (37.8) | 17 (34.0) | 8 (66.7) | 3 (25.0) | |
| Obese | 9 (12.2) | 6 (12.0) | 2 (16.7) | 1 (8.3) | |
| Ethnicity, *n* (%) [†] | | | | | |
| Jersey | 28 (36.4) | 25 (48.21) | 2 (18.2) | 1 (7.1) | <0.001 |
| British | 27 (35.1) | 21 (40.4) | 3 (27.3) | 3 (21.4) | |
| Irish | 1 (1.3) | 0 (0.0) | 0 (0.0) | 1 (7.1) | |
| Polish | 8 (10.4) | 2 (3.9) | 3 (27.3) | 3 (21.4) | |
| Portuguese | 11 (14.3) | 4 (7.7) | 3 (27.3) | 4 (28.6) | |
| Other/Mixed | 2 (2.6) | 0 (0.0) | 0 (0.0) | 2 (14.2) | |
| Smoking before pregnancy, *n* (%) | | | | | |
| Non-smoker | 45 (56.3) | 30 (55.6) | 7 (58.3) | 8 (57.1) | 0.824 |
| Current smoker | 32 (40.0) | 31 (38.9) | 5 (41.7) | 6 (42.9) | |
| Ex-smoker | 3 (3.7) | 3 (5.6) | 0 (0.0) | 0 (0.0) | |

Data are presented as the median and interquartile range (IQR) or number (%). BMI – body mass index; Other/Mixed – Romanian, French, Bulgarian, **S**lovakian (not provided); [a, b] – differences between time living on island groups $p<0.05$ (Kruskal-Wallis test or ANOVA with Tukey posthoc test); [†]n = 77.

Table 6. Cont. Characteristics of the fathers

| Characteristics | All | Length of time living on the island | | | *p* |
|---|---|---|---|---|---|
| | | Native and British | European ≥10y on the island | European <10y on the island | |
| *N* | 74 | 50 | 12 | 12 | |
| Smoking during pregnancy, *n* (%) | | | | | |
| Non-smoker | 45 (56.3) | 30 (55.6) | 7 (58.3) | 8 (57.1) | 0.160 |
| Current smoker | 21 (26.3) | 11 (20.4) | 5 (41.7) | 5 (35.7) | |
| Ex-smoker | 14 (17.5) | 13 (24.1) | 0 (0.0) | 1 (7.1) | |

Data are presented as the median and interquartile range (IQR) or number (%). BMI – body mass index; Other/Mixed – Romanian, French, Bulgarian, **S**lovakian (not provided); [a, b] – differences between time living on island groups $p<0.05$ (Kruskal-Wallis test or ANOVA with Tukey posthoc test); [†]n = 77.

## 7.4. Basic characteristics of women and the pregnancy outcomes in relation to the period of time living in Jersey

### 7.4.1. Relationship between the period of time living in Jersey for native/British and relocated women and the pregnancy outcomes

Information regarding the type and time of the deliveries and the methods of feeding are summarised in Table 7. No statistically significant correlations were observed. For the entire population, spontaneous vertex delivery was the most common type of delivery (55.0%). This was also true for natives and foreigners who had lived on the island for less than 10 years. For foreigners who had lived on the island for more than 10 years, assisted delivery was the most prevalent type of delivery (50%). The delivery time also varied depending on how long the women had lived on the island. The rates of preterm delivery were highest (14.3%) for those who had lived on the island for less than 10 years, while it was lowest among the natives (1.9%). Similar trends were observed regarding the feeding methods, with breastfeeding during the first 48-hours being the most dominant across all the groups. On average, 61.3% of the women only offered continuous breastfeeding for the first months. The highest rate of breastfeeding for the first six months was observed among the foreigners who had lived on the island for less than 10 years (71.4%), while it was lowest for those who had lived on the island for 10 years or more (63.6%).

Table 7. Types of delivery and feeding methods

| Characteristics | All | Length of time living on the island | | | *p* |
|---|---|---|---|---|---|
| | | Native and British | European ≥ 10y on the island | European < 10y on the island | |
| *N* | 80 | 54 | 12 | 14 | |
| Is this current pregnancy planned? [yes], n (%) | 64 (80.3) | 44 (80.0) | 11 (91.7) | 10 (71.4) | 0.691 |
| Delivery type, n (%) | | | | | |
| Natural (spontaneous vertex) | 44 (55.0) | 31 (57.4) | 3 (25.0) | 10 (71.4) | 0.152 |
| Assisted delivery | 17 (21.3) | 10 (18.5) | 6 (50.0) | 1 (7.1) | |
| Caesarean section | 18 (22.5) | 12 (22.2) | 3 (25.0) | 3 (21.4) | |
| Emergency Caesarean section (breech) | 1 (1.3) | 1 (1.9) | 0 (0.0) | 0 (0.0) | |
| Delivery time, n (%) | | | | | |
| Term | 73 (91.3) | 50 (92.6) | 11 (91.7) | 12 (85.7) | 0.262 |
| Pre-term | 4 (5.0) | 1 (1.9) | 1 (8.3) | 2 (14.3) | |
| Post-term | 3 (3.8) | 3 (5.6) | 0 (0.0) | 0 (0.0) | |
| Feeding method during the first 48-hours, n (%) | | | | | |
| Breast only | 49 (61.3) | 32 (59.3) | 7 (58.3) | 10 (71.4) | 0.669 |
| Formula (Bottle) | 14 (17.5) | 11 (20.4) | 1 (8.3) | 2 (14.3) | |
| Breast and complement | 17(21.3) | 11 (20.4) | 4 (33.3) | 2 (14.3) | |
| Previous pregnancy information | | | | | |
| N | 40 | 29 | 4 | 7 | |
| Any preterm delivery, [yes], n (%) | 1 (2.6) | 0 (0.0) | 0 (0.0) | 1 (14.3) | 0.096 |
| Caesarean section [yes], n (%) | 8 (20.0) | 4 (13.8) | 2 (50.0) | 2 (28.6) | 0.195 |
| Follow-up information | | | | | |
| N | 79 | 54 | 11 | 14 | |
| Feeding method (%) | | | | | |
| Breast only | 50 (63.3) | 33 (66.1) | 7 (63.6) | 10 (71.4) | 0.313 |
| Formula (Bottle) | 12 (15.2) | 11 (20.4) | 0 (0.0) | 1 (7.1) | |
| Breast and complement | 17 (21.5) | 10 (18.5) | 4 (36.4) | 3 (21.4) | |
| Time of breastfeeding (months)* | 7.4 (4.2) | 7.5 (4.0) | 8.4 (4.8) | 6.4 (4.6) | 0.632 |

Data are presented as the median and interquartile range (IQR) or number (%). *n=47 (native and UK = 30, Europe ≥ 10 on the island = 7, Europe < 10 on the island = 10); [a,b] – $p<0.05$ ($chi^2$ test).

### 7.4.2. Anthropometric characteristics of pregnant women

Table 8 summarises the anthropometric characteristics of women who participated in the study. Higher BMIs were recorded among foreigners (Europeans) who had lived on the island for more than 10 years. On average, 9.9% of the women were underweight, while 16.0% and 6.2% of the women were overweight and obese, respectively. None of the foreigners who had lived on the island for less than 10 years was obese. However, none of the analysed parameters revealed statistically significant differences.

Table 8. Anthropometric characteristics of pregnant women

| Characteristics | all | Length of time living on the island | | | *p* |
|---|---|---|---|---|---|
| | | Native and British | European ≥ 10y on the island | European < 10y on the island | |
| *N* | 81 | 55 | 12 | 14 | |
| Height, cm | 165.0 (160.0, 169.0) | 166.0 (160.5, 169.0) | 165.5 (161.0, 169.0) | 164.5 (159.0, 170.0) | 0.960 |
| Weight | | | | | |
| before pregnancy, kg | 59.0 (55.2, 66.0) | 59.0 (55.0, 66.0) | 62.5 (57.5, 72.0) | 59.0 (54.5, 67.0) | 0.491 |
| at 8–12 weeks, kg | 63.0 (57.0, 70.5) | 61.5 (56.0, 70.0) | 60.5 (59.3, 75.3) | 63.3 (57.9, 71.0) | 0.787 |
| at 28 weeks kg[†] | 69.0 (63.0, 74.5) | 68.3 (54.0, 73.3) | 86.5 (72.0, 91.0) | 70.0 (66.0, 73.1) | 0.157 |
| at 34 weeks kg[‡] | 71.5 (65.1, 76.0) | 71.5 (63.3, 75.3) | 75.0 (72.0, 93.8) | 69.3 (65.3, 76.9) | 0.293 |
| BMI | | | | | |
| before pregnancy, kg/cm$^2$ | 22.1 (20.2, 24.6) | 21.5 (20.2, 23.4) | 23.8 (20.5, 26.5) | 22.6 (20.0, 24.2) | 0.440 |
| at 8–12 weeks, kg | 22.7 (20.6, 26.2) | 22.3 (20.4, 25.1) | 23.2 (21.1, 27.9) | 22.8 (21.0, 26.4) | 0.531 |
| BMI before pregnancy | | | | | |
| Underweight | 8 (9.9) | 6 (10.9) | 1 (8.3) | 1 (7.1) | 0.285 |
| Normal | 55 (67.9) | 39 (70.9) | 5 (41.7) | 11 (78.6) | |
| Overweight | 13 (16.0) | 7 (12.7) | 4 (33.3) | 2 (14.3) | |
| Obese | 5 (6.2) | 3 (5.5) | 2 (16.7) | 0 (0.0) | |

Data are presented as the median and interquartile range (IQR) or number (%). BMI – body mass index; [a,b] – differences between time on island groups $p<0.05$ (Kruskal-Wallis test ANOVA with Tukey posthoc test); [†]$n = 29$; [‡]$n = 33$.

### 7.4.3. Correlation between the period of time living in Jersey amongst native/British and relocated women and maternal weight

Table 9 summarises the differences in weight gain at different stages of the gestational period for native and British women and women who had lived on the island for less than or more than 10 years. The weight gained among the groups of women who participated in the research varied significantly based on the length of time living on the island. For all the women, there were significant changes in the weight gained at week 28 compared to weeks 8 and 12 ($p < 0.001$), as well as the period before pregnancy until the 34th week of gestation ($p < 0.001$). The same trend was observed for native and British women. For the women who had lived on the island for less than 10 years, a significant weight gain was only observed at the 34th week of gestation ($p < 0.001$). The changes in weight gain did not vary significantly at any of the stages for the foreign women who had lived on the island for 10 years or more.

Table 9. Weight gain for all the women who participated in the study

| Characteristics | all | Length of time living on the island | | | *p* |
|---|---|---|---|---|---|
| | | Native and British | European ≥ 10y on the island | European < 10y on the island | |
| *N* | 81 | 55 | 12 | 14 | |
| at 8–12 weeks vs. before pregnancy | + 2.7 (0.0; 5.3)* | + 2.8 (0.2; 5.4)* | + 1.7 (-3.9; 7.2) | + 3.4 (-1.7, 8.6) | NS |
| at 28 weeks vs. at 8–12 weeks | + 8.0 (4.0; 12.1)*** | + 8.4 (4.6; 12.3)*** | + 8.9 (1.1; 16.6)* | + 6.9 (-1.6; 15.3) | NS |
| at 34 weeks vs. at 28 weeks | + 1.2 (-5.8; 3.4) | + 1.2 (-3.1; 5.5) | + 1.7 (-7.1; 10.5) | + 3.0 (-6.5; 12.6) | NS |
| at 34 weeks vs. before pregnancy | + 11.9 (8.0; 12.1)*** | + 10.0 (6.4; 13.7)*** | +12.3 (4.5; 20.0)** | +13.3 (5.7; 21.0)*** | NS |

Data are presented as the average estimated disparity and 95% confidence interval (95% CI). NS – not significant. For the differences between the time on the island groups, $p<0.05$ (Kruskal-Wallis test ANOVA with Tukey posthoc test). For the differences between the time of pregnancy, * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

## 7.5. Characteristics of babies at birth and during the developmental assessment at 9–12 months after birth (follow-up)

### 7.5.1. Birth outcomes

Table 10 provides a comparison of the birth outcomes among the three groups.

Data on the birth parameters were also collected to determine the impact of mothers' length of time living on the island on the babies' anthropometry. Overall, the results were statistically significant for weight for gestational age (FGA) in centile, weight FGA in terms of z-score and length FGA in centile. The centiles of weight and length were significantly lighter and shorter for mothers from Europe who had lived on the island for less than 10 years compared to native/British mothers. The same relationship was observed for the z-score weight for native/British mothers and those who had lived on the island for 10 years or more. Although barely significant, the weight, head circumference and growth percentiles were lowest for the foreigners who had lived on the island for less than 10 years, while these parameters showed the highest results among the natives.

Table 10. Babies' birth parameters for gestational age (FGA) and mothers' length of time living on Jersey

| Parameter | All | Mothers' length of time living on the island | | | *p* |
|---|---|---|---|---|---|
| | | Native and British | European ≥ 10y on the island | European < 10y on the island | |
| | 80 | 54 | 12 | 14 | |
| Gestation age, weeks | 40.0 (39.0, 41.0) | 40.0 (39.0, 41.0) | 40.0 (39.0, 41.0) | 39.0 (38.0, 40.0) | 0.154 |
| Apgar score 1 min | 9 (8, 9) | 9 (8, 9) | 9 (8, 9) | 9 (9, 9) | 0.349 |
| Apgar score 5 min | 9 (9, 10) | 9 (9, 9) | 9 (9, 10) | 9 (9, 10) | 0.225 |
| Ponderal Index, g/cm$^3$ | 2.4 (2.2, 2.6) | 2.4 (2.2, 2.7) | 2.4 (2, 2.6) | 2.4 (2.2, 2.5) | 0.860 |
| Weight, g | 3525.0 (3217.5, 3860.0) | 3580.0 (3350.0, 3860.0) | 3412.5 (3027.5, 3800.0) | 3222.5 (3020.0, 3535.0) | 0.055 |
| Weight FGA, centile | 55.5 (31.0, 83.5) | 64.5 (37.0, 85.0) [a] | 43.5 (19.5, 76.0) | 35.0 (15.0, 61.0) [a] | 0.039 |
| Weight FGA [z-score] | 0.2 (-0.5, 1.0) | 0.4 (-0.3, 1.0) [a] | -0.2 (-1.0, 0.7) [b] | -0.4 (-1.1, 0.3) [ab] | 0.009 |
| Length, cm | 52.8 (50.0, 54.5) | 53 (50.5, 54.5) | 53.0 (50.0, 56.0) | 52.0 (50.0, 53.0) | 0.228 |
| Length FGA, centile | 88.5 (51.0, 98.0) | 92.0 (51.0, 98.0) [a] | 90.5 (50.0, 99.6) | 83.0 (60.0, 95.0) [a] | 0.029 |
| Length FGA [z-score] | 1.2 (0.0, 2.2) | 1.4 (0.0, 2.2) | 1.6 (0.0, 2.7) | 1.0 (0.0, 1.6) | 0.175 |
| Head circumference, cm | 34.5 (33.5, 35.5) | 35.0 (34.0, 36.0) | 34.5 (33.0, 36.0) | 34.0. (33.0, 34.0) | 0.068 |
| Growth percentile, % | 56.1 (24.7, 74.5) | 63.2 (30.5, 76.0) | 39.2 (18.9, 68.6) | 29.8 (18.6, 58.0) | 0.052 |

Data are presented as the median and interquartile range (IQR). FGA – for gestational age; [a,b] – differences between the time on the island groups, $p<0.05$ (Kruskal-Wallis test or ANOVA with Tukey posthoc test).

### 7.5.2. The anthropometric parameters of babies during the developmental assessment at 9–12 months after birth (follow-up)

Table 11 summarises the anthropometric parameters of the babies during the follow-up. None of the results obtained was statistically significant. However, the weight and length in centile were the lowest for babies of women who had lived on the island for less than 10 years, while these parameters were the highest for babies of women who had lived on the island for more than 10 years.

Table 11. Babies' anthropometric parameters during follow-up and mothers' length of time living on Jersey

| Characteristics | all | Mothers' length of time living on the island | | | *p* |
|---|---|---|---|---|---|
| | | Native and British | European ≥ 10y on the island | European < 10y on the island | |
| *N* | 67 | 44 | 10 | 13 | |
| Assessment age, months | 12.5 (11.9, 13.2) | 12.4 (11.9, 13.2) | 12.2 (11.9, 13.6) | 12.7 (12.1, 13.2) | 0.793 |
| Weight, kg | 10.0 (9.16, 11.2) | 10.2 (9.5, 11.2) | 10.0 (8.7, 11.5) | 9.4 (8.6, 10.6) | 0.766 |
| Weight, cent. | 67.5 (39.6, 89.9) | 69.3 (44.7, 92.9) | 76.2 (34.6, 95.9) | 54.9 (29.2, 69.3) | 0.257 |
| Length, cm | 76.8 (75.0, 78.8) | 77.0 (75.0, 79.0) | 76.0 (76.0, 78.0) | 75.0 (74.0, 78.0) | 0.770 |
| Length, cent. | 69.6 (44.0, 85.4) | 72.8 (51.4, 85.4) | 77.3 (51.9, 89.2) | 45.1 (19.0, 66.6) | 0.110 |

Data are presented as the median and interquartile range (IQR). Follow-up: Baby's developmental assessment at 9–12 months after birth; [a,b] – differences between the time on the island groups, $p<0.05$ (Kruskal-Wallis test or ANOVA with Tukey posthoc test).

### 7.5.3. Relationship between the weight and length of babies at birth and during the developmental assessment at 9–12 months after birth (follow-up) and the length of time living on the island for native/British and relocated women

Specific differences in weight and length gains up to the follow-up for the various groups are provided in Table 12.

The differences in weight gain at birth and during follow-up were significant between the babies whose mothers were native and British and the babies whose mothers had lived on the island for less than 10 years ($p = 0.03$). Moreover, the babies of the mothers who had lived on the

island less than 10 years gained approximately 0.4 kg less weight than the other babies. In all the groups, no statistically significant differences were observed regarding the changes in the length of babies at birth and during follow-up.

Table 12. Babies' weight and length at birth and during follow-up and mothers' length of time living on Jersey

| Characteristics | Differences in parameters during follow-up vs at birth | | | | *p* |
|---|---|---|---|---|---|
| | all | Mothers' length of time living on the island | | | |
| | | Native and British | European ≥ 10y on the island | European < 10y on the island | |
| *N* | 67 | 44 | 10 | 13 | |
| Weight, kg | + 6.7 (6.3; 7.1) | + 6.8 (6.4; 7.2)[a] | + 6.8 (6.1; 7.6) | + 6.4 (5.7; 7.)[a] | <0.05 |
| Length, cm | + 23.7 (22.5; 25.0) | + 24.3 (23.0; 25.6) | + 22.9 (20.3; 25.5) | + 24.1 (21.7; 26.4) | NS |

Data are presented as the average estimated disparity and 95% confidence interval (95% CI). NS – not significant; Weight at birth: baby's weight at birth for gestational age; Follow-up: baby's developmental assessment at 9–12 months after birth; [a,b] – differences between the time on the island groups, $p<0.05$ (Kruskal-Wallis test or ANOVA with Tukey posthoc test).

### 7.5.4. Pregnancy outcomes at birth and during the follow-up compared to the maternal parameters of age, weight before pregnancy, BMI before pregnancy and total weight gained during pregnancy by week 34

Data on the correlation between the maternal parameters and pregnancy outcomes at birth and during the follow-up are shown in Table 13.

None of the maternal parameters measured showed statistically significant correlations with the outcomes, either at birth or during the follow-up, except for the maternal age, which showed a significant correlation with the 5-minute Apgar score ($r = 0.5886$), PI ($r = 0.6173$) and baby's birth length for the gestational age ($r = 0.5182$). Moderate correlations were observed between the maternal age and the 1-minute Apgar score ($r = 0.4666$) and between the total maternal weight gain and the baby's weight during follow-up ($r = -0.4855$).

Table 13. Pearson's correlation between the pregnancy outcomes at birth and during the follow-up compared to the maternal parameters of age, weight before pregnancy, BMI before pregnancy and total weight gained during pregnancy by week 34

| Outcomes | | Mothers' parameters | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Age | | Weight before pregnancy | | BMI before pregnancy | | Total weight gain | |
| | | r | p | r | p | r | p | r | p |
| At birth | Gestational age at birth [weeks] | 0.0550 | p=.846 | -0.1805 | p=.520 | -0.1892 | p=.499 | -0.2526 | p=.364 |
| | 1-minute Apgar score | 0.4666 | p=.080 | 0.2147 | p=.442 | 0.1594 | p=.570 | 0.4223 | p=.117 |
| | 5-minute Apgar score | 0.5886 | p=.021 | 0.2801 | p=.312 | 0.2229 | p=.425 | 0.3321 | p=.227 |
| | Ponderal Index [ g/cm3] | -0.6173 | p=.014 | 0.1608 | p=.567 | 0.1570 | p=.576 | -0.2942 | p=.287 |
| | Baby's weight for gestational age [g] | -0.0174 | p=.951 | 0.2729 | p=.325 | 0.3225 | p=.241 | -0.1802 | p=.520 |
| | Baby's birth length for gestational age [cm] | 0.5182 | p=.048 | -0.0072 | p=.980 | 0.0475 | p=.867 | 0.1530 | p=.586 |
| During follow-up | Weight | -0.4033 | p=.136 | 0.0437 | p=.877 | -0.0404 | p=.886 | -0.4855 | p=.067 |
| | Weight centile | -0.3151 | p=.253 | 0.0727 | p=.797 | -0.0479 | p=.865 | -0.4201 | p=.119 |
| | Length | 0.0002 | p=1.00 | 0.1157 | p=.681 | 0.0743 | p=.792 | -0.2624 | p=.345 |
| | Length centile | 0.0709 | p=.802 | 0.0266 | p=.925 | -0.0409 | p=.885 | -0.1158 | p=.681 |

Data are presented as Pearson's *r* correlation coefficient. BMI – body mass index. Significant correlation for $p < 0.05$.

### 7.6. Characteristics of the diet of pregnant women before and during pregnancy

#### 7.6.1. Dietary intake of pregnant women and the influence of the length of time living on the island on dietary patterns

Table 14 summarises the dietary intake of women before and during pregnancy, which is separated by the length of time spent living in Jersey.

Statistically significant differences were observed regarding the intake of low-fat dairy, vegetables, whole grain products, potatoes, fruits and alcohol. The intake of low-fat dairy was higher among women who had lived on the island for less than 10 years than among native and British women. Furthermore, the frequency of the intake of low-fat dairy was lower during pregnancy for these latter two groups of women.

A reduced intake of potatoes compared to the period before pregnancy was observed only in women who had lived on the island for less than 10 years. The greatest increase in the consumption of whole grain products was observed in the women who had lived on the island for more than 10 years (an increase from 0.61 times/day to 1.22 times/day). Furthermore, women from Europe who had lived on the island for less than 10 years consumed fruits more frequently than the native and British women. The frequency of fruit intake decreased during pregnancy only for the women who had less than 10 years of residency.

Although the intake of fats and oils increased during pregnancy in the women who had lived on the island for less than 10 years (1.5 times/day) and more than 10 years (1.28 times/day), this rate of consumption was not significantly higher or lower, respectively, than the average fats and oils intake before pregnancy for native and British women (1.43 times/day). The intake of non-alcoholic beverages decreased during pregnancy in all the groups. No alcoholic beverages were consumed during pregnancy in any of the groups except for the women who had lived on the island for more than 10 years, who had an intake of 0.04 times/day.

One interesting insight, albeit a statistically insignificant one, is that the intake of animal proteins including meat and meat products, red and processed meat, poultry, fish and fish products, and eggs and egg dishes decreased or remained the same before and during pregnancy when we look at the whole cohort. For example, the intake of meat and meat products before pregnancy was 1.14 times/day but decreased to 0.99 times/day. However, when we look at different groups this

trend was observed among the native and British women and the women from Europe who had lived on the island for less than 10 years, with exception of the red and processed meat for this second group, where the consumption was actually higher during pregnancy than before. Furthermore, reduced intake of fish and fish products was noticed among women who had lived on the island for less than 10 years, from 0.35 times/day before pregnancy to 0.28 times/day during pregnancy. Unlike the native and British women and the women who had lived on the island for less than 10 years, the consumption of animal proteins among the women who had lived on the island for more than 10 years increased or remained the same before and during pregnancy. This group increased the consumption of red and processed meat, fish and fish products, and eggs and egg dishes during pregnancy. For example, the intake of eggs and egg dishes increased from 0.29 times/day before pregnancy to 0.43 times/day during pregnancy.

Table 14. Frequency of the intake of various food groups in women before and during pregnancy

| **Intake frequencies of food groups (times/ day)** | All | | Length of time living on the island | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Native and British | | European >10y on the island | | European < 10y on the island | |
| | Before pregnancy | During pregnancy | Before pregnancy | During pregnancy | Before pregnancy | During pregnancy | Before pregnancy | During pregnancy |
| *N* | 80 | 60 | 54 | 39 | 12 | 10 | 14 | 11 |
| Meat and meat products | 1.14 (0.63, 1.57) | 0.99 (0.49, 1.21) | 1.20 (0.56, 1.57) | 0.92 (0.42, 1.13) | 0.96 (0.39, 1.61) | 0.96 (0.49, 1.57) | 1.10 (0.78, 1.71) | 1.07 (0.64, 1.34) |
| Red and processed meat | 0.70 (0.42, 1.14) | 0.57 (0.28, 0.85) | 0.71 (0.28, 1.13) | 0.49 (0.28, 0.78) | 0.57 (0.25, 1.18) | 0.67 (0.35, 1.14) | 0.49 (0.49, 1.28) | 0.64 (0.28, 1.20) |
| Poultry | 0.43 (0.14, 0.43) | 0.43 (0.14, 0.43) | 0.43 (0.14, 0.43) | 0.43 (0.14, 0.43) | 0.43 (0.14, 0.43) | 0.43 (0.00, 0.43) | 0.43 (0.14, 0.43) | 0.43 (0.14, 0.43) |
| Fish and fish products | 0.35 (0.14, 0.63) | 0.35 (0.14, 0.49) | 0.35 (0.21, 0.64) | 0.35 (0.14, 0.49) | 0.18 (0.04, 0.32) | 0.35 (0.14, 0.49) | 0.35 (0.14, 0.71) | 0.28 (0.14, 0.42) |
| Eggs and egg dishes | 0.43 (0.14, 0.50) | 0.21 (0.14, 0.43) | 0.43 (0.14, 0.50) | 0.21 (0.14, 0.43) | 0.29 (0.14, 0.47) | 0.43 (0.14, 0.43) | 0.29 (0.14, 0.43) | 0.14 (0.14, 0.79) |
| Cereals and cereal products | 2.42 (1.78, 3.25) | 2.67 (1.90, 3.28) | 2.31 (1.79, 3.21) | 2.57 (1.86, 3.40) | 2.22 (1.57, 2.82) | 2.75 (1.70, 3.21) | 2.82 (1.92, 3.43) | 2.89 (2.06, 3.34) |
| Refined grain products | 1.35 (0.75, 1.89) | 1.35 (0.92, 1.78) | 1.35 (0.85, 1.64) | 1.36 (0.99, 1.78) | 1.21 (0.42, 2.22) | 1.28 (0.70, 1.71) | 1.57 (0.85, 2.00) | 1.21 (0.64, 1.64) |
| Whole-grain products | 0.93 (0.50, 1.50) | 1.22 (0.61, 1.72) | 0.92 (0.42, 1.50) | 1.14 (0.49, 1.47) | 0.61 (0.39, 1.15) | 1.22 (0.57, 2.00) * | 1.36 (1.00, 2.15) | 1.50 (1.14, 1.79) |
| Milk and milk products | 1.14 (0.71, 1.57) | 1.10 (0.71, 1.61) | 1.14 (0.64, 1.50) | 1.07 (0.71, 1.50) | 1.11 (0.93, 1.61) | 0.85 (0.35, 1.21) | 1.50 (1.00, 2.21) | 1.35 (1.07, 2.00) |
| Low-fat dairy | 0.42 (0.14, 0.79) | 0.32 (0.07, 0.82) | 0.28 (0.14, 0.64) [a] | 0.21 (0.07, 0.64) | 0.46 (0.07, 0.79) | 0.25 (0.14, 0.57) | 0.89 (0.28, 1.14) [a] | 0.86 (0.49, 0.93) |
| Whole-fat dairy | 0.64 (0.43, 0.93) | 0.71 (0.43, 0.93) | 0.57 (0.28, 1.00) | 0.79 (0.43, 0.97) | 0.75 (0.57, 0.90) | 0.61 (0.21, 0.71) | 0.64 (0.28, 1.00) | 0.86 (0.28, 1.21) |
| Fats and oils | 1.07 (0.57, 1.85) | 1.21 (0.57, 2.07) | 1.43 (0.57, 1.86) | 1.18 (0.61, 1.90) | 1.00 (0.50, 1.50) | 1.28 (0.57, 1.43) | 0.75 (0.43, 1.14) | 1.50 (0.64, 2.50) |
| Oils and sauces | 0.21 (0.07, 0.64) | 0.21 (0.00, 0.56) | 0.28 (0.00, 0.79) | 0.25 (0.04, 0.57) | 0.43 (0.14, 0.65) | 0.21 (0.07, 0.78) | 0.14 (0.00, 0.28) | 0.07 (0.00, 0.21) |
| Animal fat | 0.79 (0.28, 1.50) | 0.64 (0.42, 1.28) | 0.93 (0.5, 1.500) | 0.64 (0.32, 1.29) | 0.47 (0.14, 0.90) | 0.57 (0.50, 0.86) | 0.54 (0.21, 1.07) | 0.93 (0.50, 2.50) |

Data are presented as the median and interquartile range (IQR). For the differences between the time on the island groups, [a,b] $p<0.05$ (Kruskal-Wallis test); For the differences before vs. during pregnancy, * $p<0.05$, † $p<0.01$, ‡ $p<0.001$ (Wilcoxon signed-rank test)

Table 14. Cont. Frequency of the intake of various food groups in women before and during pregnancy

| **Intake frequencies of food groups (times/ day)** | All | | Length of time living on the island | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Native and British | | European >10y on island | | European <10y on island | |
| | Before pregnancy | During pregnancy | Before pregnancy | During pregnancy | Before pregnancy | During pregnancy | Before pregnancy | During pregnancy |
| *N* | 80 | 60 | 54 | 39 | 12 | 10 | 14 | 11 |
| Sweets, snacks, preserves | 2.19 (1.28, 3.50) | 2.35 (1.43, 3.85) | 2.27 (1.34, 4.07) | 2.57 (1.78, 4.00) | 1.46 (0.84, 3.19) | 1.31 (0.63, 2.56) | 2.20 (1.28, 3.50) | 1.78 (0.99, 3.98) |
| Fruit | 2.64 (1.57, 3.93) | 2.78 (1.92, 4.14) | 2.43 (1.35, 3.36) [a] | 2.50 (1.60, 3.54) [a]* | 2.68 (1.64, 4.40) | 3.80 (2.43, 5.27) | 4.33 (2.14, 6.16) [a] | 3.93 (2.56, 8.28) [a] |
| Vegetables | 6.13 (4.49, 7.78) | 4.57 (3.48, 6.37) † | 5.99 (4.56, 7.91) | 4.70 (3.56, 6.15) | 4.99 (3.21, 6.62) | 3.88 (2.72, 4.37) | 6.35 (4.55, 9.23) | 5.84 (4.06, 8.45) |
| Vegetables (without legumes) | 4.93 (3.70, 6.16) | 4.56 (3.55, 6.20) | 4.65 (3.56, 6.13) | 4.56 (3.49, 5.70) | 4.40 (2.88, 5.69) | 4.27 (3.06, 4.91) | 5.79 (4.27, 8.36) | 6.93 (4.06, 9.46) |
| Legumes | 0.64 (0.28, 1.14) | 0.64 (0.28, 1.18) | 0.78 (0.42, 1.28) | 0.82 (0.35, 1.43) | 0.42 (0.28, 0.89) | 0.56 (0.42, 0.64) | 0.43 (0.21, 1.14) | 0.28 (0.14, 1.22) |
| Potatoes | 0.57 (0.35, 0.71) | 0.57 (0.42, 0.71) | 0.57 (0.35, 0.71) | 0.64 (0.43, 0.78) * | 0.39 (0.28, 0.60) | 0.50 (0.42, 0.64) | 0.68 (0.28, 1.07) | 0.50 (0.28, 0.71) * |
| Nuts and seeds | 0.14 (0.07, 0.57) | 0.14 (0.070, 0.79) | 0.14 (0.07, 0.79) | 0.25 (0.07, 0.86) | 0.14 (0.14, 0.36) | 0.11 (0.07, 0.50) | 0.14 (0.07, 0.43) | 0.14 (0.07, 0.79) |
| Non-alcoholic beverages | 3.78 (1.93, 5.50) | 3.18 (1.29, 4.58) * | 3.86 (2.14, 6.07) | 3.22 (1.32, 4.58) | 2.79 (1.61, 4.11) | 2.22 (1.21, 3.28) | 4.11 (1.28, 5.50) | 3.64 (1.28, 6.07) |
| Alcoholic beverages | 0.28 (0.07, 0.64) | 0.00 (0.00, 0.00) ‡ | 0.42 (0.14, 0.79) | 0.00 (0.00, 0.00) [a]‡ | 0.43 (0.04, 0.68) | 0.04 (0.00, 0.07) [ab]* | 0.14 (0.00, 0.35) | 0.00 (0.00, 0.00) [b]* |

Data are presented as the median and interquartile range (IQR). For the differences between the time on the island groups, [a,b] $p<0.05$ (Kruskal-Wallis test); For the differences before vs. during pregnancy, * $p<0.05$, † $p<0.01$, ‡ $p<0.001$ (Wilcoxon signed-rank test).

### 7.6.2. The Mediterranean diet score and pregnancy outcomes for mothers and babies across Mediterranean diet score levels

Regarding the Mediterranean diet (aMED) score and its distribution among the women who were grouped by length of time spent living on the island, no differences were observed before or during pregnancy. However, diet during pregnancy worsened for native women or those who had lived on the island more than 10 years, whereas the women who had lived on the island for less than 10 years adopted a healthier diet. Since significant changes in aMED score for women before and during pregnancy were not observed, further analysis of the aMED scores obtained before pregnancy was used, as shown in Table 15.

Table 15. Mediterranean diet score distribution for women before and during pregnancy

| Characteristics | all | Length of time living on the island | | | *p* |
|---|---|---|---|---|---|
| | | Native and British | European ≥ 10y on the island | European < 10y on the island | |
| Before pregnancy | | | | | |
| **aMED** score, (-) | 3.0 (2.0; 4.0) | 3.0 (2.0; 4.0) | 3.0 (2.0; 4.5) | 3.0 (3.0; 4.0) | 0.749 |
| Low, *n* (%) | 47 (58.0) | 31 (56.4) | 8 (66.7) | 8 (57.1) | 0.500 |
| Medium, *n* (%) | 28 (34.6) | 18 (32.7) | 4 (33.3) | 6 (42.9) | |
| High, *n* (%) | 6 (7.4) | 6 (10.9) | 0 (0.0) | 0 (0.0) | |
| During pregnancy | | | | | |
| **aMED** score, (-) | 3.0 (2.0; 4.0) | 3.0 (2.0; 4.0) | 2.0 (1.0; 3.5) | 4.0 (3.0; 5.0) | 0.158 |
| Low, *n* (%) | 31 (62.0) | 21 (65.3) | 6 (75.0) | 4 (40.0) | 0.216 |
| Medium, *n* (%) | 16 (32.0) | 9 (28.1) | 1 (12.5) | 6 (60.0) | |
| High, *n* (%) | 3 (6.0) | 2 (6.25) | 1 (12.5) | 0 (0.0) | |

Data are presented as the median and interquartile range or number (%). $p<0.05$ represents a significant difference between the time on the island groups (Kruskal-Wallis test or ANOVA with Tukey posthoc test).

No relationships were observed between the maternal pregnancy parameters and the aMED score. Neither weight nor BMI was different among the aMED score levels. Therefore, women with better aMED diet scores did not have healthier BMIs as expected. The aMED score was also not associated with the type of delivery, gestation time or feeding method after birth or at the follow-up, as shown in Table 16.

Table 16. Pregnancy characteristics and aMED score levels

| Characteristics | aMED score before pregnancy | | | *p* |
|---|---|---|---|---|
| | Low | Medium | High | |
| Age, years | 33.0 (30.0, 36.0) | 33.5 (31.0, 36.5) | 31,0 (29.0, 35.0) | 0.924 |
| Weight before pregnancy, kg | 58.0 (54.0, 66.0) | 61.0 (57.6, 69.0) | 59.5 (56.0, 64.0) | 0.219 |
| Weight at 8–12 weeks, kg | 60.0 (56.0, 70.5) | 64.5 (60.5, 71.5) | 57.5 (54.0, 64.0) | 0.149 |
| Weight at 28 weeks [kg]† | 72.0 (56.0, 86.5) | 67.8 (64.0, 73.3) | 66.4 (61.7, 71.0) | 0.765 |
| Weight at 34 weeks [kg]‡ | 72.0 (65.3, 78.0) | 70.2 (64.5, 75.2) | 68.5 (62.9, 74.0) | 0.698 |
| BMI before pregnancy [kg/m$^2$] | 22.5 (19.9, 25.0) | 22.1 (20.5, 24.9) | 21.7 (20.2, 22.9) | 0.756 |
| BMI at 8–12 weeks, kg/m$^2$ | 22.3 (21.0, 26.2) | 23.2 (20.5, 26.7) | 20.7 (19.8, 22.6) | 0.189 |
| BMI at 28 weeks [kg/m$^2$] † | 26.1 (21.9, 31.0) | 23.6 (22.3, 27.2) | 22.9 (20.9, 24.9) | 0.704 |
| BMI at 34 weeks [kg/m$^2$] ‡ | 27.3 (24.7, 31.2) | 24.2 (22.8, 27.3) | 23.6 (21.3, 25.9) | 0.206 |
| Delivery type, *n* (%) | | | | |
| Natural (spontaneous vertex) | 27 (58.7) | 14 (50.0) | 3 (50.0) | 0.837 |
| Assisted delivery | 9 (19.6) | 7 (25.0) | 1 (16.7) | |
| Caesarean section | 10 (21.7) | 6 (21.4) | 2 (33.3) | |
| Emergency caesarean section (breech) | 0 (0.0) | 1 (3.6) | 0 (0.0) | |
| Delivery time, *n* (%) | | | | |
| Term | 41 (89.1) | 26 (92.9) | 6 (100.0) | 0.913 |
| Preterm | 3 (6.5) | 1 (3.6) | 0 (0.0) | |
| Post-term | 2 (4.4) | 1 (3.6) | 0 (0.0) | |
| Feeding method during the first 48 hours, *n* (%) | | | | |
| Breast only Formula (Bottle) | 29 (63.0) | 16 (57.1) | 4 (66.7) | 0.827 |
| Formula (Bottle) | 9 (19.6) | 4 (14.3) | 1 (16.7) | |
| Breast and complement | 8 (17.4) | 8 (28.6) | 1 (16.7) | |
| Feeding method at follow-up, *n* (%) | | | | |
| Breast only | 30 (65.2) | 17 (63.0) | 3 (50.0) | 0.953 |
| Formula (Bottle) | 7 (15.2) | 4 (14.8) | 1 (16.7) | |
| Breast and complement | 9 (19.6) | 6 (22.2) | 2 (33.3) | |
| Length of time of breastfeeding (months) | 6.0 (3.0, 11.9) | 6.0 (4.0, 10.0) | 11.4 (9.0, 11.9) | 0.480 |

Data are presented as the median and interquartile range (IQR) or number (%). $p<0.05$ represents a significant difference between the aMED score groups (Kruskal-Wallis test or ANOVA with Tukey posthoc test); †$n$ = 29; ‡$n$ = 33.

Table 17 summarises the differences in the gestational characteristics of the babies. Growth percentile for women with low aMED scores was higher (61.9) than that of women with high aMED scores before pregnancy (50.4). This suggests that poor dietary habits among the mothers could be associated with the delivery of larger babies. However,

statistically significant differences between the gestational age, weight and length at follow-up and the aMED score levels were not observed.

Table 17. Characteristics of the babies and the aMED score levels of the mothers

| Characteristics | aMED score before pregnancy | | | p |
|---|---|---|---|---|
| | Low | Medium | High | |
| For gestational age | | | | |
| Gestational age, weeks | 40.0 (39.0, 41.0) | 40.0 (39.0, 40.0) | 41.0 (40.0, 41.4) | 0.077 |
| 1-min Apgar score | 9.0 (9.0, 9.0) | 9.0 (8.5, 9.0) | 8.5 (8.0, 9.0) | 0.773 |
| 5-min Apgar score | 9.0 (9.0, 9.0) | 9.0 (9.0, 10.0) | 9.0 (9.0, 10.0) | 0.772 |
| Ponderal Index, g/cm$^3$ | 2.5 (2.2, 2.8) | 2.4 (2.2, 2.5) | 2.3 (2.2, 2.4) | 0.657 |
| Weight, g | 3570.0 (3170.0, 3860.0) | 3467.5 (3257.5, 3842.5) | 3542.5 (3255,0, 3775,0) | 0.989 |
| Weight, centile | 64.5 (31.0, 85.0) | 46.0 (29.0, 78.5) | 55.5 (35.0, 80.0) | 0.835 |
| Weight [z-score] | 0.4 (-0.4, 1.0) | -0.11 (-0.56, 0.8) | 0.1 (-0.4, 0.8) | 0.937 |
| Length, cm | 52.0 (50.0, 54.5) | 52.8 (51.3, 54.5) | 53.0 (53.0, 54.0) | 0.334 |
| Length, centile | 86.0 (50.0, 98.0) | 91.5 (55.5, 97.5) | 95.0 (95.0, 95.0) | 0.579 |
| Length [z-score] | 1.1 (0.0, 2.2) | 1.4 (0.0, 2.0) | 1.6 (1.6, 1.6) | 0.521 |
| Head circumference, cm | 34.4 (33.0, 35.0) | 34.0 (33.5, 35.8) | 35.0 (34.5, 35.0) | 0.544 |
| Growth percentile, % | 61.9 (28.0, 76.6) | 45.2 (18.8, 67.1) | 50.4 (18.6, 62.4) | 0.410 |
| At the follow-up | | | | |
| Weight, kg | 10.1 (9.2, 10.9) | 10.1 (9.2, 11.5) | 9.6 (9.0, 10.0) | 0.248 |
| Weight, centile | 67.8 (34.8, 85.1) | 69.3 (43.2, 95.9) | 61.6 (55.4, 67.5) | 0.773 |
| Length, cm | 76.5 (75.0, 78.5) | 77.0 (74.5, 79.0) | 75.5 (72.0, 81.0) | 0.859 |
| Length, centile | 69.6 (45.7, 85.3) | 73.1 (42.9, 87.4) | 51.4 (31.4, 98.2) | 0.904 |

Data are presented as the median and interquartile range (IQR). $p<0.05$ represents a significant difference between the aMED score groups (Kruskal-Wallis test or ANOVA with Tukey posthoc test).

# VIII. DISCUSSION

In this observational study, the author provides an analysis of a cross-cultural group of women in Jersey in the Channel Islands and evaluate the relationship between the dietary patterns and selected anthropometric measurements of the women and the pregnancy outcomes for the mothers and their children. To the best of the author's knowledge, this is a unique and novel study that focused on ethnic differences that have implications concerning the reproductive and general health outcomes of mothers and children. This section discusses the major findings of this research and presents information that confirms or disproves the hypotheses outlined in the proposal for this study. This section also discusses the implications of the results and recommendations for future actions and research. Moreover, various limitations are highlighted in the respective sections to guide the interpretation of the findings of this study. Finally, the discussion section highlights the various strengths of the study.

## 8.1. Basic characteristics of study participants

### 8.1.1. Characteristics of the women who attended the Maternity Unit at JGH in 2017 and the resulting children, potential participants and participants who completed the study

In this study, we observed that the majority of actual participants of the study were Jersey Island natives. This finding was expected since the source population of patients who attended JGH was mostly comprised of Jersey natives. According to data from the Jersey 2011 population census, as many as 46% of the residents of Jersey identified themselves as Jersey natives, while 33% considered themselves to be British (States of Jersey Statistics Unit, 2012). Although the ethnic distribution of the participants in the study reflected the general ethnic population characteristics of Jersey, the use of self-reported ethnicity in this study may have provided a different perspective. For example, a woman born outside of Jersey but who has lived on the island for many years may consider herself a 'Jersey native.' Conversely, a woman born in Jersey but whose parents originated from outside the island may have considered the ethnicity of her parents when providing information for the study. Since sociodemographic information, particularly ethnicity, was a key variable in this study, inaccuracies regarding the reporting of the

ethnicity of the participants may have implications for the reporting and interpretation of the findings.

Significant differences in the sociodemographic characteristics of the women were observed, depending on the period of stay on the island of Jersey. For example, the level of education among the natives and British women was significantly higher than that of the European immigrants on the island. Moreover, native and British women tended to have a higher household income. As highlighted previously in this thesis, migration and ethnicity are critical predisposing factors that influence the access and utilisation of healthcare services, both independently and alongside confounding factors such as occupation, education and social relationships (Babitsch et al., 2012). Previous studies have demonstrated that such inequalities regarding the access and utilisation of healthcare services are associated with an increased risk of health implications such as hypertension and preeclampsia (Wang & Geng, 2019). Similarly, differences in care practices for newborns and children, such as breastfeeding, may be attributable to differences in the sociodemographic characteristics between the groups. For example, a low level of maternal education, low SES and being a member of a black and minority ethnic group have been associated with low rates of breastfeeding initiation and maintenance (Simpson et al., 2019). Although insufficient data exists to demonstrate the differences in sociodemographic characteristics among various ethnic groups in Jersey, the results of this study suggest such population characteristics should be considered when implementing health-related policies.

In this study, we observed that the prevalence of cigarette smoking among women before and during pregnancy was higher among migrant women compared to native and British women. Although the differences in smoking prevalence were not statistically significant, the data contradicts the 'healthy migrant effect' (Hao & Kim, 2009). However, the findings were in line with most of the studies conducted in Europe, in which the natives tended to have healthier lifestyles and were less likely to smoke cigarettes than the migrants (Gadd et al., 2005). As highlighted previously in the literature review, drugs of abuse are prevalent reproductive and developmental toxicants of concern to maternal and child health (Perry et al., 2019). Therefore, there is the need for aggressive health promotion activities against drug and substance abuse, particularly among women of reproductive age. For example, Jersey has a comprehensive 'Help2Quit stop smoking service' that focuses on pregnant women (Statistics Jersey, 2020a). During the

development of such programme, it is important to tailor the service to the characteristics of the population, such as targeting migrant women who appear to have a higher tendency to smoke compared to the natives. Moreover, health promotion programmes could target all individuals of childbearing age, with greater emphasis on the information produced in different languages. As demonstrated in the research conducted by Craveiro (2001), this could be achieved through the employment of doctors and health professionals of various backgrounds, as well as close cooperation with key community players who may have a large influence on the sharing of culture-specific health information throughout each community rather than general health information.

### 8.1.2. The occurrence of overweight and obese individuals

The results of this study also indicated that there was a high prevalence of overweight and obese women who attended the maternity unit of JGH in 2017 (44%). This is in line with findings of surveys conducted in Jersey, including the Jersey Opinions and Lifestyle Survey (Statistics Jersey, 2019c). Moreover, approximately one-quarter of the pregnant women who participated in the study were overweight or obese. Considering the association between maternal pre-pregnancy obesity and foetal excessive weight gain, childhood obesity and long-term cognitive and behavioural developmental consequences for the offspring, the pre-pregnancy period is an important window of opportunity for intervention (Leng et al., 2015).

No significant differences were observed regarding the BMI before pregnancy, at 8–12 weeks, 28 weeks and 34 weeks gestation among the three groups of women. Moreover, we report no significant differences regarding gestational weight gain among the three categories of women. These findings contradict the results of most population studies, which have demonstrated significant racial-ethnic differences concerning gestational weight gain as well as women who were overweight or obese (Headen et al., 2012). However, most of these studies were conducted in regions such as the US, where there are clear-cut racial-ethnic differences (Blacks vs. Whites). Regarding the island of Jersey, the length of stay on the island may not correlate with the racial-ethnic differences among the groups. Nevertheless, significantly greater weight gain was recorded among Europeans who had lived on the Island for greater than 10 years compared to the other groups of women. Both inadequate and excessive weight gain during pregnancy may negatively affect the foetal environment during important developmental windows of

metabolic and epigenetic plasticity and may contribute to chronic diseases in the offspring in later life (Headen et al., 2012) and as the authors stated the in-depth understanding of pregnancy and weight related issues in context of the social characteristics beyond the individual may be a crucial matter.

Furthermore, a significantly high level of literacy was observed among the mothers who completed the study, with only 3.7% lacking a formal education. The majority of participants (87.7%) had regular employment. The level of education, employment, income and SES may significantly impact maternal pregnancy outcomes, and this group of women were healthier and had better weight management compared to the group of women who were less educated and unemployed. Therefore, to facilitate a comprehensive decision-making plan for this latter group, future studies should focus on a larger population of women who have a lower level of education and SES.

The interpretation of the findings from this study may be limited because there was a potential bias regarding the procurement of information on the pre-pregnancy weight of the participants. Although we endeavoured to obtain comprehensive and reliable anthropometric measurements for the participants, we did not access maternal weight records for all of the women who participated. Moreover, the pattern of weight gain is highly dependent on the accurate determination of the pre-pregnancy weight. Since we relied on the pre-recorded figures regarding the pre-pregnancy weight, this is a potential source of bias that could significantly influence the outcome and interpretation of the study findings. This study only included women who had low-risk pregnancies. Thus, women who had high-risk pregnancies were automatically excluded, resulting in a potential source of bias concerning the anthropometric measurements and the unhealthy weight.

Since obesity is a recognised global pandemic, it must be addressed in the pre-pregnancy and pregnancy periods. Therefore, there is a requirement for an appropriate public health surveillance and monitoring system to record the anthropometric parameters of pregnant women and women of reproductive age. With such a system in place, it would be easy to obtain data and monitor and evaluate the weight status of women to facilitate and guide public health intervention measures. Furthermore, more ethnic-specific health data would facilitate the identification of high-risk groups through public health interventions and health promotion programmes and create more individualised support, particularly for harder to reach groups.

### 8.1.3. Comparison with recent trends

While the proportion of pregnant women in Jersey who have a healthy weight has declined over the years, the prevalence of overweight and obese pregnant women has increased. Figure 13 shows the trends in the BMIs of women who attended JGH at 8–12 weeks gestation between 2008 and 2019. Notably, there was a general decline in the proportion of women who had a normal or healthy weight from approximately 64% in 2008 to 45% in 2019. The proportion of overweight, obese and morbidly obese women showed a general upward trend from 2008 to 2018. In comparison with this study findings, there was only a subtle increase in the proportion of underweight women, with the proportion of overweight, obese and morbidly obese women corresponding to the figures recorded in the previous year (2018). Moreover, the trend in women who were overweight or obese in Jersey corresponded to the trends observed in other geographical regions and the global trends. For example, the trends in the maternal pre-pregnancy BMI in California between 2007 and 2016 mirrored the trends in Jersey. Although the proportion of women who had a normal weight showed a downward trend over the years, the proportion of overweight and obese women increased gradually (Ratnasiri et al., 2019).

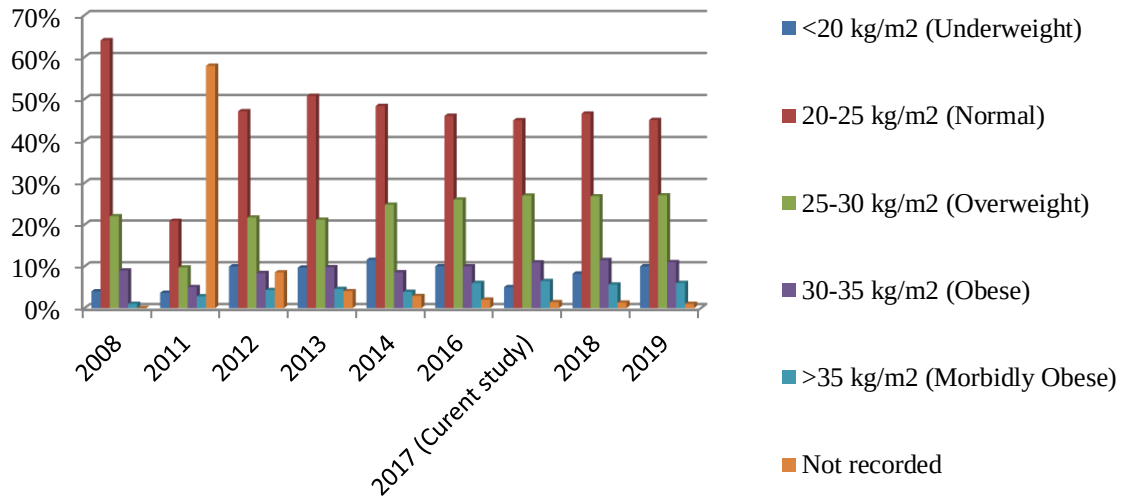



Figure 13. BMI classification among pregnant women in Jersey in 2008 and 2017.

Source: Data for 2008 – The State of Jersey, 2008; data for 2011 to 2019 – TrakCare reports MAT00023A and MAT00017C. Accessed February 24, 2020.

### 8.2. Pregnancy outcomes

#### 8.2.1. Type and time of delivery

Researcher reports no statistically significant differences regarding the type and time of delivery among the three groups of participants. However, the proportion of women who underwent a caesarean delivery was higher among both migrant groups compared with the native and UK women. The results of recent studies corroborate the findings of this research regarding the rates of caesarean deliveries among migrant groups of women. In a systematic review of the literature, the rates of caesarean deliveries between migrants and non-migrants differed in 69% of studies, with higher rates observed among groups of migrant women compared with natives (Merry et al., 2013). The literature review section of this paper provides a theoretical explanation to validate the differences in caesarean section rates observed between migrants and natives. The most frequently postulated risk factors include low SES, poor maternal health, gestational diabetes or high BMI, feto-pelvic disproportion, lack of prenatal care and previous traumatic birth. Additionally, health services may differ among various countries consequently, upon moving to different country, certain migrant women may develop a mistrust of the new system of health service. According to Abraído-Lanza et al., (2006) for example prolonged and stressful experiences related to immigration may lead to poor health outcomes. This has been observed frequently, particularly among women who have a low level of literacy, as demonstrated in a local study by Craveiro (2001).

In this study, higher rates of caesarean deliveries were observed among migrant women who had stayed in Jersey for greater than 10 years compared to those who had a shorter period of stay on the island. This finding is in line with the existing body of research. For example, in a Swedish population-based register study, it was established that a longer duration of residence among immigrants was associated with an increased risk of planned and unplanned caesarean sections (Juárez et al., 2018). Similar findings were obtained in UK- and Norway-based population studies (Essex et al., 2013; Sørbye et al., 2015).

In Jersey the rate of caesarean section births is higher than in England (Statistics Jersey, 2020b) or generally in Europe (WHO, 2021c) what could indicate a need for a more individualised approach to improve this pregnancy outcome. Moreover this finding could be particularly important perhaps due to a lack of understanding around the new

system of health care in different country as this rate is even higher among both migrant groups.

We could argue that obstetric risks and a poor health status increased with the period of residence among immigrants, as suggested by studies conducted in other national contexts (Urquia et al., 2012), thereby, contributing to the increased rates of caesarean deliveries for the island of Jersey. On the other hand, in this study the largest proportion of breastfeeding women were from both European immigrant groups so the period of residence have not influenced this particular pregnancy outcome.

### 8.2.2. Offspring birth outcomes

The results of this study revealed no statistically significant birth outcomes that could indicate any concerns around the growth and developmental pattern of the newborns. Nevertheless, significant differences were noted concerning the weight for gestational age (centiles and z-scores), with natives and British individuals having the greatest weight for gestational age among the three groups of participants. The lowest weight for gestational age was recorded among the European immigrants who had stayed on the island for less than 10 years. These findings can suggest that the risk of small-for-gestational-age babies was highest among the immigrants who had stayed on the island for less than 10 years, while the risk of large-for-gestational-age offspring was highest among the native and British participants. Therefore, the weight for gestational age increased as the period of stay increased. Previous studies established a significantly higher occurrence of small-for-gestational-age offspring among immigrants compared to natives (Bartsch et al., 2017; Pedersen et al., 2012). These differences may be explained by variations in the utilisation of healthcare services as well as lifestyles among the pregnant women, as illustrated in the literature review section of this paper. Furthermore, a correlation was observed between the gestation age in weeks and the weight for gestational age of the offspring, with immigrants who spent less than 10 years on the island having a lower gestational age. The lower gestational age may have contributed to the lower weights of the offspring among the immigrants. These findings also highlight the need to tailor interventions to the migration history and the period of stay in Jersey to control GWG.

This study focused on maternal ethnic origin and migration status when comparing various birth outcomes. Limited research exists regarding the contribution of paternal race and ethnicity to birth outcomes. Due to the increasing prevalence of mixed-race couples

in Jersey, it is important to understand whether and how paternal race or ethnicity contributes to the birth outcomes, above and beyond maternal race and ethnicity (States of Jersey Statistics Unit, 2012) and conducted in 2021 Census could be an additional opportunity to outline the local data for the island of Jersey important for the public health matters. There is increasing evidence from studies conducted in the US to suggest that mixed-race couples tend to have poor birth outcomes compared to couples from the same race, particularly non-Hispanic white couples (Y.Li et al., 2018). Although similar studies could be conducted to try to demonstrate the paternal effects and consequences of mixed-race couples on the birth outcomes, it may be that if the ethnic groups are all from Europe and all culturally and geographically similar, a significant differences for those selected pregnancy outcomes will not be captured.

### 8.2.3. The anthropometric parameters of the offspring during the developmental assessment at 9–12 months after birth (follow-up)

This study did not observe significant differences regarding the basic anthropometric measurements of the offspring at 9–12 months after birth. However, we noted that the weights and heights of the offspring were lowest among the European immigrants who had spent less than 10 years on the island. This trend was similar to what we observed during the analysis of the anthropometric measurements of the offspring at birth. Furthermore, we demonstrated significant differences in weight gain among the offspring from the three categories of women, with women who had stayed on the island for less than 10 years having the lowest weight gain. Therefore, the results suggest a relationship between the anthropometric measurements at birth and 9–12 months of life. A positive linear relationship between the birth weight and childhood obesity was established in previous studies (Baran et al., 2019). Such relationships and differences should be taken into account when designing interventions aimed at reducing overweight and obese children.

The analysis of the anthropometric measurements of children at 9–12 months after birth was significantly limited. Access to comprehensive records of the anthropometric measurements of these children at 2–2.5 years of age and at the time of entering Reception (age 4–5 years) would facilitate a comparison with the findings of this study and locally available data. At present, monitoring the growth and development of children before they enter Reception is optional. Moreover, the present study has shown that several

parents did not present their children for assessment and monitoring at 9–12 months of age. Given the urgency that childhood obesity presents, the monitoring of the body composition of all children, particularly those who have already developed excess weight, would facilitate early recognition and lifestyle intervention for the treatment of childhood obesity (Coppins et al., 2011). This locally conducted study demonstrated that weight control could be achieved among children on the island using economically friendly interventions delivered by well-trained individuals who do not have a clinical background rather than those delivered solely by clinicians.

### 8.2.4. Pregnancy outcomes at birth and during the follow-up compared to the maternal parameters of age, weight before pregnancy, BMI before pregnancy and total weight gain during pregnancy by week 34

Author reports a significant positive correlation between the maternal age and the 5-minute Apgar score of the child. This indicates that a younger maternal age was associated with a poorer Apgar score. As previously mentioned in the literature review section of this study, the Apgar score at 5 minutes is an important predictor of neonatal outcomes, including mortality and neurological sequelae (e.g. cerebral palsy) (Li et al., 2013). Although a young maternal age has been associated with poor outcomes of the offspring, this has only been reported in developing and middle-income countries where adolescent childbearing is common (Gibbs et al., 2012). The findings of this study contradict the results of previous studies conducted in developed countries, which revealed a positive correlation between advanced maternal age and a low Apgar score at 5 minutes (Sydsjö et al., 2019). This contradictory finding may have been due to confounders, such as maternal obesity, which were not controlled for when reporting the results of the study. Therefore, a more detailed analysis that compares the actual Apgar scores and specific age groups of women while controlling for the confounders is required to obtain a conclusive outcome.

We also report an inverse association between maternal age and the PI of the offspring. A high PI has been associated with a high BMI later in childhood (Lande et al., 2005). The findings of this study suggest that increasing maternal age was associated with a decrease in the risk of intrauterine growth restriction, as determined by the PI at birth. We are not aware of any studies that directly compared the maternal age and the PI of the offspring. However, the results of this study suggest the need for close monitoring and

appropriate pregnancy care for younger mothers who are at risk of having offspring with a lower PI. Given the association between a high PI and the risk of childhood obesity, the study findings imply the need for the close monitoring of dietary habits and anthropometric measurements in children born of older mothers in Jersey to prevent childhood obesity.

Unlike the results of previous studies (Godoy et al., 2015), the author did not observe a statistically significant correlation between the maternal pre-pregnancy BMI and the weight of the offspring during follow-up. Moreover, we did not observe a statistically significant correlation between the maternal total weight gain in pregnancy and the weight or weight centile of the offspring during follow-up. Prior studies also established a correlation between maternal gestational weight gain and a poor Apgar score of the offspring (Yeşilçiçek Çalik et al., 2018). However, the results of this study did not demonstrate a significant association between these two parameters. Although this could be the true scenario in the Jersey population, further studies that include larger sample sizes should be conducted to establish a conclusive association between these maternal and offspring parameters.

### 8.3. The dietary intake of pregnant women and infant feeding

#### 8.3.1. The dietary intake of pregnant women and the influence of the length of time living on the island on the dietary patterns

The author observed statistically significant differences regarding the intake of low-fat dairy before pregnancy, with immigrants who had stayed on the island for less than 10 years having a higher intake compared to the other groups of women. This finding may have been due to the 'healthy migrant effect', whereby migrants retain several of their lifestyle habits from their countries of origin (Hao & Kim, 2009). Low-fat milk is recommended as part of a balanced diet during pregnancy in all the Nordic countries (Brantsæter et al., 2012). Considering that most of the immigrants who participated in this study were from Europe, they could have moved to Jersey and maintained their traditional lifestyle habits. In Western population milk and dairy products contribute considerably to the saturated fat input, hence the recommendation is to use those products with reduced amount of fat. Furthermore, an increased risk of large weight FGA can be linked with a high milk consumption (Brantsæter et al., 2012). The results of this study also revealed a decline in the intake of dairy products among the participants, specifically

low-fat dairy, from the pre-pregnancy period to the pregnancy period. This trend was common across the three categories of women. Data from a systematic review of the literature revealed a beneficial foetal growth increase among women who had a moderate intake of dairy products compared to women who had extremely low or no intake (Brantsæter et al., 2012). Therefore, even though most women among research population reduced their intake of dairy during the pregnancy period, they should maintain a moderate intake to accrue the associated benefits regarding foetal growth.

Besides the immigrants who stayed on the island for more than 10 years (who showed a significant increase in the intake of whole grain products), in general, an increase in the intake of whole grains was observed among the women in Jersey as they entered pregnancy. Moreover, there was an increase in the intake of refined grains among the natives and European immigrants who had stayed for 10 years or more on the island. As mentioned previously in the literature review section of this paper, at least 175g of carbohydrates and 28g of fibre is enough for the growing foetus and pregnant woman (Mustad et al., 2020). The intake of high glycaemic index refined carbohydrates has been associated with increased adiposity, gestational diabetes and predisposition of the offspring to the obese phenotype (Zhu et al., 2017). Conversely, whole grain foods are preferred as they have a lower glycaemic index and provide adequate calories for the mother and the growing foetus (Zhu et al., 2017). Therefore, of the three groups of women who participated in the study, the immigrants who had stayed for less than 10 years on the island had the healthiest carbohydrate intake habits as they entered pregnancy due to a significant reduction in the intake of refined grain products and an increase in the intake of whole grain products. This suggests that they may have had healthier lifestyle habits in their countries of origin, which they tended to lose as their stay on the island increased.

This study revealed that the participants in all three groups tended to increase their intake of fruits and decrease their consumption of vegetables as they entered pregnancy. The NICE *Maternal and child nutrition* recommends at least five portions of fruits and vegetables daily (2014). Studies have demonstrated a negative association between low consumption of fruits and vegetables in pregnancy and the risk of foetal complications, for example the intake of fruits and the occurrence of small for gestational age offspring (Martínez-Galiano et al., 2018). Therefore, there is a need to encourage the intake of vegetables among women in Jersey. A nutritional assessment at the begging of pregnancy would indicate signs of a poor diet may help to empower women to maintain a balanced

diet throughout pregnancy and afterwards. Moreover, a nutritional assessment could elucidate barriers associated with the reduced consumption of healthy foods and facilitate educational health promotion or intervention concerning the level of knowledge, financial limitations, and ethnicity or migration status of the women.

We also report a unique trend regarding the intake of animal proteins among women in Jersey. The results of this study revealed that the intake of animal proteins including meat and meat products, red and processed meat, poultry, fish and fish products, and eggs and egg dishes, decreased or remained the same among whole research group as the participants entered pregnancy. As highlighted in the literature review section of this paper, the protein turnover increases by approximately 15–25% towards the second and final trimesters. Therefore, the total increase in protein intake is recommended to be maintained at 15–25% of the pre-pregnancy intake. The findings of this research suggest the need for improved protein intake among women in Jersey, even as they enter pregnancy.

Regarding the aMED score, the results of this study revealed that the diets of the native women or those who had lived on the island for more than 10 years became worse during pregnancy, whereas the women who had lived on the island for less than 10 years tended to have better dietary scores as they entered pregnancy. This could suggest that the women developed poor nutritional habits after staying on the island for some time. Women with high aMED scores in pregnancy have been shown to have a significantly lower chance of delivering foetal growth-restricted infants (Chatzi et al., 2012). In the present study, we did not observe a significant association between the various maternal pregnancy parameters and the aMED scores before pregnancy. For example, the aMED scores did not significantly influence the type of delivery, the gestation at birth or the method of delivery. However, the interpretation of these findings is significantly limited by the small sample size and the subjective nature of the dietary information used for the analysis. Beyond the nutritional guidelines, the Mediterranean diet represents a balanced and healthy lifestyle that includes physical activity, adequate rest, traditional and simple ways of cooking, and sociability. Therefore, there is a need for large population studies within this remote island community based on one to one nutritional assessments to produce a more comprehensive analysis of the beneficial effects of dietary patterns. Moreover, this would facilitate conclusions regarding the diets among pregnant women and nutritional trends amongst families in Jersey as well as specific subgroups.

An arguable limitation of the dietary assessment used in this study is the arbitrariness regarding the use of the FFQ. Since the study was based in a multicultural community, there was a wide variety of foods and food preparation techniques that reflected the ethnic variations in the population. Due to large within-person variations concerning dietary intake, it was difficult to sufficiently determine the usual dietary intake using a single recall. It was, therefore, appropriate to include multiple recall data. However, the issue of recall bias and inaccuracy in determining the actual dietary characteristics of the foods consumed remained. Moreover, due to the multicultural nature of the participants, it was difficult to establish the exact dietary content in traditional or ethnically defined foods. The immigrants also incorporated foods that were available in the host country when preparing their traditional meals, making the FFQ assessment even more complex, as described by Satia-Abouta (2003).

Alterations in dietary habits during pregnancy, whether due to maternal concerns about foetal health or to physiological changes such as nausea, are important because they impact the health of the foetus. Therefore, during an assessment of the dietary patterns of pregnant women, it is important to utilise an accurate and reliable tool that presents minimal room for bias. Regarding dietary analysis in a cross-cultural community, it is important to identify the appropriate reference groups that will provide critical information to facilitate the development of standard dietary assessment tools that are suitable for the target population (Marino et al., 2011). Moreover, as acculturalisation ensues, changes in the dietary patterns of immigrants after approximately 10–15 years of living in a developed country (Commodore-Mensah et al., 2018) should be assessed over time. This would guide the development of an appropriate nutritional assessment tool that could be used to screen for nutrition-related health risks, even for individuals within the community who have a healthy weight. It would also facilitate the establishment of the various backgrounds and requirements that may exist on an individual level to improve pregnancy outcomes.

### 8.3.2. Comparison of infant feeding methods in relation to the period of stay

For all three groups of women, exclusive breastfeeding was the most prevalent method of feeding practised in the first 48 hours of life. Considering the benefits of the early initiation of breastfeeding and the exclusive breastfeeding of infants, as highlighted in the literature review section of this paper, the findings of this study confirmed

commendable feeding habits among the participants in the first 48 hours of life. However, the largest proportion of women who used formula feeds in the first 48 hours were the native and UK women. Moreover, the results revealed that the native and UK women constituted the highest proportion of women who used formula feeds at the 6-month follow-up. These findings contradict (Simpson et al., 2019) because the level of education among the natives and British women was significantly higher than that of the European immigrants on the island.

These results highlight the challenge regarding the failure of UK mothers to initiate exclusive breastfeeding, as mentioned in the literature review section of this study. The UK IFS states that high prevalence of bottle feeding observed among the natives may be due to issues regarding professional responsibilities, misinformation and perceived breast milk insufficiency, easy access to formula milk, and cultural barriers (NHS, 2012) and successive IFS have revealed increases in the proportion of women who initiate breastfeeding. However, successive surveys have also shown that the proportion of women who discontinued breastfeeding before their infant was 6 weeks old has remained high (Oakley et al., 2013). Improving breastfeeding rates in the UK has been a key focus of successive governments during the past decade, with the recent Public Health Outcomes Framework in England identifying breastfeeding as a key indicator of health improvement. The Scientific Advisory Committee on Nutrition (SACN) encourages exclusive breastfeeding for 6 months and continued breastfeeding for up to 1 year as solid foods are being introduced to infants. Therefore, women in Jersey, particularly the natives, should be adequately educated during the pre-pregnancy period and as they proceed into pregnancy about the requirement for and importance of breastfeeding and the avoidance of bottle feeding.

Thirty-two weeks of parental allowance was introduced in Jersey in 2020 (Gov.je, 2020b) to support breastfeeding rates and allow parents to dedicate time to their newborns. From 32 weeks of gestation, both parents are permitted to take 6 weeks of parental leave each and the remaining 20 weeks can be shared between them. This means that if a woman wishes to breastfeed and if she will be financially protected by the parental allowance, she can utilise a total of 26 weeks of protected leave for breastfeeding. To increase the rates of breastfeeding beyond 26 weeks after birth, the current statutory maternity leave should be extended. This strategy has been shown to improve

breastfeeding rates in other jurisdictions within the UK, where policies allow the protected time for breastfeeding to last for longer (Oakley et al., 2013).

### 8.4. The issue of the completion of the research and the limited sample size

The results of the study revealed a low completion rate among the participants (approximately 41%), with 115 of the 200 potential participants being willing and 81 able to complete the study (although all the information concerning the research was available in various languages). Moreover, data collection during the follow-up of children at 9–12 months after birth was affected by approximately 17% of the children missing out on the developmental assessment. A high non-response rate may also have interfered with the reliability, validity and representativeness of the study findings as named by Fincham (2008) the nonresponse bias. Furthermore given the duration of the study, issues concerning its completion were expected however, the author endeavoured to maintain communication with the participants throughout the entire project. During a long-term research project, it is common that participants become tired or bored, which results in poor responses, missing data or complete withdrawal from a project. Furthermore participation in the diet and lifestyle related projects may be influence by general women's attitude and as Szwajcer et al., (2005) outlined general information-seeking behaviours before and during pregnancy.

The population characteristics of Jersey influenced the completion rates for this study, and the largest proportion of women who completed all stages of the research consisted of Polish and Jersey natives (58% and 57%, respectively). According to Brick and Kalton (1996), weighting the study sample segments to reflect the greater population attributes could significantly reduce the issue of lack of representativeness in a study with low research completion rates. However in the presented study, the sample population was too diverse for this to be a viable option for this research. Therefore, there is the need for future research to include samples that are representative of the greater population to further diminish the effects of a non-completion bias. This could be achieved through a larger study that targets a pregnant women across various hospitals from other remote islands, rather than concentrating on one maternity unit in one facility.

When interpreting the findings of this research, it is important to consider the limited sample size, which influences all the results discussed above. A total of 81 women completed the study. This is a small sample size when interpreting public health clinical

effects such as weight, diet and birth outcomes, particularly considering that Jersey has a population of greater than 107,000 (Statistics Jersey, 2019b). The generalisation of the findings of this study is, therefore, limited. When creating descriptive characteristics of a group of subjects or a population, a large sample size often yields more reliable results (Hackshaw, 2008). This is because the main results should have a 95% confidence interval (CI), and the width of the interval is directly dependent on the sample size: large studies produce narrow intervals and, therefore, more precise results. When comparing the characteristics of two or more groups of subjects, the study size is highly dependent on the magnitude of the expected effect size. In this study, the effect sizes were generally quantified by ascertaining the difference between two means or medians. With a small sample size, there were significantly large standard errors and wide confidence intervals, which led to imprecise estimations of the effects, thereby influencing the conclusions and interpretations of the results. Due to the small size of the dataset, it was not always possible to find significant differences or strong correlations. For example, when analysing the weight at 8–12 weeks gestation for Europeans who had stayed on the island for less than 10 years, we recorded a median weight of 63.3 and a confidence interval of 57.9–71.0. Because this category had a sample size of 14, the true weight of the participants, in general, was anywhere between a low or high value, which is not a useful result. Therefore, to confirm and increase the strength of these findings, a larger study should be conducted that includes other small jurisdictions within the region with cross-cultural communities and a greater number of participants.

### 8.5. Strengths of the study

Although the findings should be interpreted with caution, this study has several strengths. To the best of the author's knowledge this is the first study to investigate maternal lifestyle factors, anthropometric measurements and other characteristics and their correlation with the offspring, particularly concerning ethnicity and migration status in the Jersey community. We included common risk factors and outcomes and evaluated their association with various maternal parameters, including BMI. Therefore, this study provides an important collection of data and evidence that is likely to influence policymaking at the community and national level to facilitate an improvement regarding the provision of care for women and children. Moreover, this would facilitate new directions for health inequality redaction throughout community health development

projects regarding the improvement of all pregnancy outcomes. As outlined previously in the research design section of this paper, the author engaged with several local services and organisations to ensure the reliability of the data obtained. Furthermore, the most recent standard globally accepted WHO criteria for the definition of BMI, pregnancy weight gain and other anthropometric parameter limits that would apply to Jersey and other countries and regions were employed in this study.

### 8.6.Implications of the study and recommendations for further research

The findings and discussion of this study highlight that an improvement in maternal and child health and lifestyles cannot be achieved on an individual level and that it involves multidisciplinary action. The slogan 'every contact counts' should be the basis for maximising contact with women and children during the pre-pregnancy, pregnancy and post-partum period; these periods provide an opportunity to establish a healthy lifestyle and reduce obesity. This study aimed to demonstrate the range of limitations and provide the key information necessary to plan and conduct health promotion in Jersey, particularly regarding nutrition and lifestyle. Numerous studies exist that provide nutritional recommendations for pregnant women, the healthy weight range and guides on the appropriate nourishment for children. Nevertheless, health promotion programmes face a number of challenges in reaching a large part of the vulnerable subgroups. Consequently, recognition of the limitations and factors that shape behaviours may be crucial for the planning of interventions and further education for population in Jersey. In the future, an understanding of these relationships locally may contribute to the development of more effective preventive and intervention programmes tailored to nutritional and health issues so that their effectiveness is reflected in available data and the improvement of the health of multinational populations.

In transforming theory to practice, locally conducted observational research can influence a reduction in the cost of antenatal and postnatal care in the case of preventable lifestyle diseases. It can deliver valuable insight for the development of community health projects and provide focus to empower the community to take responsibility for their health in line with proposed Jersey Care Model and according to PHE guidance *Childhood obesity: applying All Our Health*.

### 8.7. Conclusions

1. This study established a high prevalence of obesity in Jersey, particularly among pregnant women and women of childbearing age, thereby signifying the importance of the implementation of measures to address obesity in the pre-pregnancy period as well as closer monitoring of bodyweight measurements during pregnancy with a focus on health and ethnic-specific data.
2. The study revealed significant differences in the sociodemographic characteristics of pregnant women in Jersey, including the levels of education and significant variations in household incomes, thereby indicating that the characteristics of individuals in a population should be considered when implementing policies.
3. Higher smoking rates were noted among migrant women before and during pregnancy. Therefore, an individual approach may be required to address possible harmful behaviours and lifestyle patterns that can have a strong cultural origin.
4. In contrast to the hypothesis of this study, no statically significant correlations were observed between the period of stay on Jersey and most of the studied pregnancy outcomes. The pregnancy and delivery outcomes that indicated significant variations among the three groups of women include the type of delivery, the Ponderal Index and weight for gestational age.
5. No statistically significant differences in GWG were observed among the three groups of women, although the migrant women who had lived on the island for more than 10 years had a higher average weight gain compared to the other groups of women. Therefore, the period of stay on Jersey may have implications for GWG, thereby providing a potential target and guide for interventions to prevent excessive GWG during pregnancy.
6. Although no statistically significant differences regarding the type and time of delivery were noted among the three groups of participants, a higher rate of caesarean delivery among both migrant groups indicates a need for a more individualised approach to improve pregnancy outcomes, perhaps due to a lack of understanding around the new system of health care in different country.
7. Similarly, no statistically significant variations that could indicate any concerns around the growth and developmental pattern were observed for most of the newborns and children during the period of follow-up. Although there were

notable differences that would influence interventions aimed at monitoring and controlling obesity among children before they reach school age.

8. The results of the study suggest that during the first weeks after giving birth exclusive breastfeeding is the preferred feeding option for mothers on Jersey. Since scientific evidence suggests that exclusive breastfeeding is the best option, there is a need for continued support for women on the island to further encourage this type of feeding, at least for the first six months of a child's life.
9. Regarding the maternal diet, the intake of fats and oils increased during pregnancy and the general intake of milk and dairy products decreased for all three groups of women during pregnancy. The intake of animal proteins during pregnancy did not change or decreased from that of the pre-pregnancy period among whole research group. Although the intake of vegetables decreased among the participants in all the groups, the intake of fruit increased among the natives and immigrants who had lived on the island for less than 10 years. Only the immigrants who had stayed on the island for more than 10 years registered alcohol intake during pregnancy. There were also several differences in aMED scores among the three groups of women; however, these differences were not statistically significant. These findings imply that tailored pre-pregnancy dietary advice may be beneficial, not only for specific ethnic groups but for all women.
10. This study had various limitations, including inaccuracies regarding the establishment of the true ethnic origin of the participants, a limited sample size and a potential bias regarding the procurement of anthropometric measurements. This study only included women who had low-risk pregnancies. Thus, women who had high-risk pregnancies were automatically excluded, resulting in a potential source of bias concerning the anthropometric measurements, the unhealthy weight as well as poor diet.
11. Therefore, there is a requirement for comparative studies to be conducted within and outside jurisdictions that are similar to the island of Jersey. Moreover, future studies should include larger sample sizes to facilitate an understanding of the paternal influence on birth outcomes for women and children among cross-cultural communities.

## IX. RESEARCH SUMMARY

The principal objective of this project was to investigate, from a public health perspective, whether there was a significant association between maternal diet and selected anthropometric measurements and pregnancy outcomes for a mother and child. To achieve this goal, the available data from a cross-cultural community in Jersey was analysed in the context of the period the study participants lived on the island.

The study population consisted of pregnant women who attended the Maternity Unit at Jersey General Hospital (JGH) and their offspring. The women were from various ethnic backgrounds and were living in Jersey. The study was conducted over three years – between September 2016 and September 2019. Among the 200 pregnant women who were identified as potential participants for this study, a total of 81 women completed all stages of the research.

The sociodemographic and lifestyle information and anthropometric measurements of the participants were collected. This was performed during the pre-pregnancy period, at 12–20 weeks gestation, at 28-–34 weeks gestation, at birth and 9–12 months after birth. Several statistical analyses were conducted to evaluate the various measurements that were relevant to the study. The results of these analyses revealed that most of the participants were Jersey natives and Polish women, while Irish and Portuguese women constituted the lowest number of participants. During analysis, the participants were classified into three groups: Jersey natives and UK participants (Natives), those who had lived on the island for less than 10 years (immigrants <10yrs), and those who had stayed on the island for greater than 10 years (immigrants ≥ 10yrs).

On average, 9.9% of the women were underweight, while the proportions of obese and overweight women were 16% and 6.2%, respectively. The participants in the immigrants <10yrs group showed the maximum weight gain at 34 weeks, suggesting that migration and a change of environment may influence weight gain. Although no significant differences were observed regarding gestational weight gain or BMI before and during pregnancy among the three categories of women who participated in the study, a comparison with recent local trends for women who attended JGH at 8–12 weeks gestation between 2008 and 2018 showed an overall increased proportion of overweight, obese and morbidly obese women. These findings cannot be extrapolated to all patients as this study included only women with low-risk pregnancies. By including a general

weight classification for all pregnant women in Jersey during the year that this research was conducted, it is most likely that the group of women who had already become overweight or obese and had a high-risk pregnancy were not included.

Since obesity is now recognised as a global pandemic, there is a need to address this important public health issue during the pre-pregnancy and pregnancy periods. Therefore, there is a requirement for appropriate public health surveillance and monitoring systems to record the anthropometric parameters of pregnant women and women of reproductive age.

An analysis of the offspring at birth did not reveal significant differences in the anthropometric measurements, except for the weight for gestational age (FGA) z-score for which the natives had significantly higher scores compared with the other groups. The natives also had the highest average birth weight FGA, length FGA centiles and percentage growth percentile. The children born of native women registered the highest weight and length gain while the participants in the immigrants ≥ 10yrs group registered the lowest weight and length gain. The difference in weight gain between the native group and the immigrants < 10yrs group was statistically significant. This implies that interventions to control GWG and child growth should be tailored to an individual's period of stay on Jersey.

The largest proportion of women in this study who used formula feeds in the first 48 hours, as well at the 6-month follow-up, were the participants in the native and UK women group. The differences in feeding and care practices for newborns and children may be attributable to variations in the sociodemographic characteristics among the groups. Although this research was performed on a small cohort, the results suggest that education concerning the benefits of breastfeeding for a mother and child, together with further work at the policy level, could be beneficial in improving exclusive breastfeeding. This could be achieved in the pre-pregnancy and pregnancy periods.

Although the differences in smoking prevalence were not statistically significant, the results revealed higher rates of smoking among the migrant women compared to the native and British women, both before and during pregnancy. These findings indicate the need for an individual approach to improve the pregnancy outcomes for several of the subgroups, particularly women of reproductive age.

Regarding the maternal diet, the intake of animal proteins during pregnancy did not change compared with the pre-pregnancy period. Moreover, the intake of fats and oils

increased during pregnancy, while the intake of milk and dairy products decreased for all three groups of women. Although the intake of vegetables during pregnancy decreased in all the groups, the intake of fruit increased for the natives and the participants in the immigrants <10yrs group. Furthermore, only the participants in the immigrants ≥ 10yrs group registered significant alcohol intake during pregnancy. This implies that pre-pregnancy dietary advice may be beneficial for specific ethnic groups. In terms of the Mediterranean diet scores, the diet of the participants in the immigrants ≥ 10yrs group became worse during pregnancy, while the participants in the immigrants <10yrs group adopted a healthier diet after becoming pregnant. However, the aMED scores between the groups were not statistically significant. Alterations of dietary habits in pregnancy, whether due to maternal concerns about foetal health or due to physiological changes such as nausea, are important because they impact foetal health. Therefore, during an assessment of the dietary patterns of pregnant women, it is important to utilise an accurate and reliable tool that presents minimal room for bias.

To the best of the author's knowledge, this is the first study to investigate maternal diet, anthropometric measurements and other characteristics and their correlation with the offspring, with a focus on ethnicity and migration status in the Jersey community. Common risk factors and outcomes were included in this study and their association with various maternal parameters, including BMI, were evaluated. Therefore, this study provides an important pool of data and evidence that is likely to influence policymaking at a community and national level. However, when interpreting the findings of this research, it is important to consider the limited sample size and the low research completion rate of approximately 41%. The findings and discussion of this study highlight that an improvement in maternal and child health status cannot be achieved on an individual level and requires multidisciplinary action.

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## XI. APPENDICES

Appendix 1. The project's timeline

**September 2014 - July 2015**

- obtaining essential documentation for this project such as Research Proposal;
- finding the Health and Social Services Department HSSD Sponsor;
- research development and writing the Application For Ethical Approval of Clinical Research;
- creating the Information Sheet for Participants, the Consent Forms well as the Informed Parental Consent Form, the Socio-economic and Demographic Questionnaire and advertising tools like leaflet, poster, the Research Recruitment Notice

**July 2015- May 2016**

- obtaining Jersey Ethics Committee Approval for presented study

**May 2016- September 2016**

- preparing the English, Polish and Portuguese copy of the Information Sheet for Participants, leaflet, poster as well as the Consent Form and the Informed Parental Consent Form, the Research Recruitment Notice, the Socio-economic and Demographic Questionnaire as well as Food Frequency questionnaire FFQ ;
- creating the dedicated for this project website www.pregnancy-study.co.uk available in three languages :English, Polish and Portuguese as well as the Facebook page https://www.facebook.com/DietLifestyleProjectJersey/
- DBS Check
- signing the HSSD Honorary Agreement between author Urszula Śliwka and Women and Children's Services Maternity HSSD with clinical attachment in the General Hospital in Jersey

Con. Appendice 1. The project's timeline

**September 2016 – December 2016**

- further research development and building collaboration between Department of Obstetrics and Gynaecology JGH, the Maternity Unit and The Family Nursing & Home Care (FNHC) in Jersey for the study purpose

**January 2017 –December 2017**

- participants recruitment and data collection

**January 2018-December 2018**

- further data collection from the hospital system TRAK, the personal medical records of each woman and from the Child Health System and FNHC

**January 2019- December 2019**

- becoming a Ph.D. Candidate, 22 March 2019;
- further data collection from FNHC;
- preparing a dietary habits review/individualized nutritional feedback for each participant based on the Food Frequency Questionnaire FFQ;
- writing the Thesis Proposal

**January 2020- July 2021**

- preparing and sending out for each women their personal Certificate of Completion and individualized nutritional feedback;
- agree interpretive model, develop & present preliminary findings and analysis;
- final write up of the Thesis

Appendix 2. The Health and Social Services Jersey Ethics Committee Approval

**Health and Social Services Department**
**Jersey Ethics Committee,**
General Hospital, Gloucester Street
St Helier, Jersey, JE1 3QS

States of Jersey

20th May, 2016

Mrs. Urszula Sliwka,
65 New Street,
ST Helier,
Jersey,
JE2 4LB

Our ref: TF/MT/LC

Dear Urszula,

**Project: An investigation into the correlation between dietary intake and selected anthropometric measurements for a woman and her neonate in Jersey, Channel Islands (native-born Jersey, British, Polish and Portuguese nationals).**

Thank you for presenting your revised research application to the Ethics Committee Meeting on Wednesday 11th May, 2016 and for sending to us your recent amendments.

On behalf of the Ethics Committee, I am pleased to confirm our favourable approval for this excellent piece of research.

I would like to convey the Committee's best wishes for the success of this project and we would be interested in knowing the outcome of this research when it is completed, for our records.

Yours sincerely

Maureen Turner

**Maureen Turner,**
**Secretary of the Jersey Ethics Committee**

direct dial: +44 (0)1534 442377
email: ma.turner@health.gov.je

Appendix 3. A memorandum of understanding between the University of Warmia and Mazury (UWM) in Olsztyn, Poland and the Jersey General Hospital, Jersey, Channel Islands from 16th September 2016

**A Memorandum of Understanding**

BETWEEN

the University of Warmia and Mazury (UWM) in Olsztyn, ul. Oczapowskiego 2, Poland
represented by Vice-Rector for Science - prof. dr hab. Jerzy Jaroszewski
the Jersey General Hospital, The Parade, St. Helier, JE1 3QS, Jersey, Channel Islands

.....16th.....**September 2016, Olsztyn, Poland**

**§ 1**

1. Both parties agree that the subject of this MoU is free collaboration on the research and development studies into the correlation between nutrition and lifestyle and health disorders in humans.
Subject of the research project: "An investigation into the correlation between dietary intake and selected anthropometric measurements for a woman and her neonate in Jersey, Channel Islands (native-born Jersey, British, Polish and Portuguese nationals)".

2. The parties agree that they will not make claims and seek compensation from the other party for the costs incurred during the research.

3. Each party reserves the right to their respective research outcomes and their publication. In case of joint publications, contribution of each party will be clearly stated both descriptively and as a percentage, in line with the scientific research ethical framework.

4. The signed agreement does not preclude other forms of collaboration, which may be the subject of an annexe to this MoU.

**§ 2**

1. Named parties in this Memorandum of Understanding are:
   a. University of Warmia and Mazury (UWM) in Olsztyn - Faculty of Human Nutrition; Centre of Gastronomy and Cooking with Dietetics and Food Bioevaluation at the Faculty of Food Sciences
   b. Women and Children's Services, Maternity, HSSD, Jersey General Hospital

2. Named representatives of the respective party responsible for achieving the objectives of this agreement are:
   a. University of Warmia and Mazury (UWM) in Olsztyn - dr hab. Katarzyna Przybyłowicz, prof. UWM,
   b. Jersey General Hospital - Mr Neil MacLachlan MBBS, DCH, FRSB, FRCOG, Consultant Obstetrician and Gynaecologist, Health & Social Services Department (HSSD)

Con. Appendix 3. A memorandum of understanding between the University of Warmia and Mazury (UWM) in Olsztyn, Poland and the Jersey General Hospital, Jersey, Channel Islands from 16th September 2016

§ 3

This Memorandum of Understanding is valid for the period between .....16th.....2016 to end of September 2019 will come into force upon signing by both parties.

§ 4

This agreement will be deemed null and void unless all the changes to the terms of the MoU or to the arrangements for the individual stages of the collaboration are made in the form of a written addendum with the consent of both parties.

§ 5

Either party may terminate this MoU with a 3-month notice period.

§ 6

All disputes which may arise from this agreement will be settled amicably.

§ 7

This MoU has been drawn up in 4 identical copies in Polish and English, with two copies for the University of Warmia and Mazury in Olsztyn, and two for the Jersey General Hospital.

**University of Warmia and Mazury**
**in Olsztyn, Poland**

Vice-Rector for Science
**prof. dr hab. Jerzy Jaroszewski**
**University of Warmia and Mazury**
**in Olsztyn**

UNIWERSYTET WARMIŃSKO-MAZURSKI
w Olsztynie
10-719 Olsztyn, ul. M. Oczapowskiego 2
tel. 89 523 35 52, fax 89 524 04 08

**Jersey General Hospital**
**in Jersey, Channel Islands**

**Mr Neil MacLachlan**
MBBS, DCH, FRSB, FRCOG, Consultant
Obstetrician and Gynaecologist
**Jersey General Hospital**

Appendix 4. Research Notice for health practitioners

UNIWERSYTET WARMIŃSKO-MAZURSKI W OLSZTYNIE

States of Jersey

**RESEARCH NOTICE**

Dear All,

I would like to make you aware of a research study that may be of interest and ask you to consider referring your patients for possible participation.

For many years the Department of Human Nutrition at the University of Warmia and Mazury in Olsztyn, Poland has conducted research on nutrition and its effects on the health of people of all ages. We are now commencing further studies and we would like to kindly ask you to support our new piece of research entitled:

***"An investigation into the correlation between dietary intake and anthropometric measurements for a woman and her neonate in Jersey, Channel Islands (native-born Jersey, British, Polish and Portuguese nationals).***

The proposed observational study for a cross-cultural population in Jersey, Channel Islands is designed to see if the different cultural groups who live in Jersey have different diets and exercise habits and whether these have an effect on their baby's growth and development. This project may also help demonstrate whether a specific approach is needed for individual nationalities in order to raise awareness about healthy eating and activity amongst women of childbearing age living in Jersey.

This proposed research is part of a course of an academic studies for a PhD degree by Urszula Sliwka, a Master's Engineer Degree holder in Food Technology and Human Nutrition, specialisation in Human Nutrition. A collaboration has been formed with Mr Neil MacLachlan, the lead consultant at the Department of Obstetrics and Gynaecology, Jersey General Hospital. The study has been reviewed and approved by the Health and Social Services Ethics Committee in Jersey. Processing, sharing and publication of the results of the research were planned in accordance with the Data Protection (Jersey) Law 2005.

We look forward to speaking to patients who may be interested in participating in this study. Please feel free to contact us, or have your patients contact our research team themselves, using the contact provided in the Resaerch Leaflet or the Information Sheet for Participants. Please find enclosed documents which should provide brief and clear information on the essential elements of the study. Additionally please visit this website: **www.pregnancy-study.co.uk** created for this study project.

Con. Appendix 4. Research Notice for health practitioners

**Only Midwife or medical consultant who knows patients' health status and the project's inclusion and exclusion criteria can refer pregnant woman for this study. This is to ensure that all participants are fit and healthy at the time of participation and remain well during the course of the research.** According to Good Clinical Practice, a researcher is not allowed to contact any potential patients unless she is certain that they have been informed about the clinical research by a health practitioner in the first place.

Every pregnant woman is priceless for this study project and your kind support would be greatly appreciated.

**The main investigators are:**

**Main Researcher: Mrs Urszula Sliwka**

MSc in Human Nutrition; Research Fellow at Women and Children's Services, Maternity, Health and Social Services Department (HSSD), Jersey

Email: u.sliwka@health.gov.je

'Registered with the Association for Nutrition -www.associationfornutrition.org Protecting the public and promoting high standards in evidence-based science and professional practice of nutrition.' Registration Number: 8664

**Sponsor in Jersey: Mr Neil MacLachlan**

Consultant in Obstetrics and Gynaecology, Jersey General Hospital; Health and Social Services Department (HSSD);

A Fellow of the Royal College of Obstetrics and Gynaecology and a Fellow of the Royal Society of Biology

Email: n.maclachlan@health.gov.je; Telephone number: 01534 442660

**University Supervisor: Dr hab. Katarzyna Przybyłowicz** Professor at the Faculty of Food Sciences, Human Nutrition Department, University of Warmia and Mazury in Olsztyn (UWM), Poland
Email: katarzyna.przybylowicz@uwm.edu.pl;

**Additional contact number for the Community and Antenatal Midwifery Manager Kathy Palmer 01534442519**

Thank you for your time and consideration.

Yours faithfully,

*Urszula Sliwka*

Appendix 5. Research Recruitment Notice for patients

**RESEARCH RECRUITMENT NOTICE**

Dear .....

I am writing to tell you about a study being currently conducted at the General Hospital in Jersey entitled: ***"An investigation into the correlation between dietary intake and selected anthropometric measurements for a woman and her neonate in Jersey, Channel Islands (native-born Jersey, British, Polish and Portuguese nationals)".***

The proposed observational study for a cross-cultural population in Jersey, Channel Islands is designed to see if the different cultural groups who live in Jersey have different diets and exercise habits and whether these have an effect on their baby's growth and development. This project may also help demonstrate whether a specific approach is needed for individual nationalities in order to raise awareness about healthy eating and activity amongst women of childbearing age living in Jersey.

For many years the Department of Human Nutrition at the University of Warmia and Mazury in Olsztyn, Poland has conducted research on nutrition and its effects on the health of people of all ages. We are now starting further studies and we would like to kindly ask you to support it.

The study has been reviewed by the Health and Social Services Ethics Committee in Jersey and the Bioethics Committee at the Faculty of Medical Sciences of the University of Warmia and Mazury in Olsztyn, Poland. The project is part of a course of academic studies for a PhD degree by Urszula Sliwka, a Master's Engineer Degree holder in Food Technology and Human Nutrition, specialisation in Human Nutrition. **A collaboration has been formed with Mr Neil MacLachlan, the lead consultant at the Department of Obstetrics and Gynaecology at the Jersey General Hospital and Maternity Unit as well as with The Family Nursing and Home Care (FNHC).** Processing, sharing and publication of the results of the research were planned in accordance with the Data Protection (Jersey) Law 2005.

**You are eligible to be involved in this project** and if you are interested in learning more about it, please read enclosed Information Sheet for Participants and feel free

to contact directly **Urszula Sliwka**, the main researcher on mobile: 07700700652, via email on: u.sliwka@health.gov.je or
through **the website: www.pregnancy-study.co.uk/** created for this study project.

It is important to know that this letter is not to tell you to join the study. It is your decision. We understand that some individuals may feel anxious about taking part in a research project. Your participation is voluntary. Whether or not you participate will have no effect on your pregnancy care. Nevertheless, every questionnaire is priceless for this study project and your kind support would be greatly appreciated.

**The main investigators are:**

**Main Researcher: Mrs Urszula Sliwka**

MSc in Human Nutrition; Research Fellow at Women and Children's Services, Maternity, Health and Social Services Department (HSSD), Jersey

Email: u.sliwka@health.gov.je

'Registered with the Association for Nutrition -www.associationfornutrition.org Protecting the public and promoting high standards in evidence-based science and professional practice of nutrition.' Registration Number: 8664

**Sponsor in Jersey: Mr Neil MacLachlan**

Consultant in Obstetrics and Gynaecology, Jersey General Hospital; Health and Social Services Department (HSSD);

A Fellow of the Royal College of Obstetrics and Gynaecology and a Fellow of the Royal Society of Biology

Email: n.maclachlan@health.gov.je; Telephone number: 01534 442660

**University Supervisor: Dr hab. Katarzyna Przybyłowicz** Professor at the Faculty of Food Sciences, Human Nutrition Department, University of Warmia and Mazury in Olsztyn (UWM), Poland;
Email: katarzyna.przybylowicz@uwm.edu.pl;

Additional contact number for **the Community and Antenatal Midwifery Manager Kathy Palmer 01534 442519.**

Thank you for your time and consideration.

Yours sincerely,

*Urszula Sliwka*

Appendix 6. Informed Consent Form







**INFORMED CONSENT FORM**

***"An investigation into the correlation between dietary intake and selected anthropometric measurements for a woman and her neonate in Jersey, Channel Islands (native-born Jersey, British, Polish and Portuguese nationals)".***

I ..... declare that I have been informed by researcher, Urszula Sliwka, about the purpose of the above research project, its duration, its research methods, its expected benefits as well as potential risks, dangers or any inconvenience associated with my participation in this study. I have also been made aware of my rights and obligations. I have the right to refuse to sign this consent form.

I have read and understood the contents of the Patient Information Sheet. I have been informed that additional questions about the survey may be addressed directly to the person conducting it and that I will receive satisfactory answers. I give consent for my GP to be informed about my participation in the study.

I declare that all the information I have given is true and I undertake to keep the researcher informed as to any changes to my health throughout the duration of the study.

By signing this form I consent to the researcher accessing my personal and medical records for the purpose of obtaining relevant information for the study, and for this access to be granted for the duration of the researcher's formal contract with the Health and Social Services Department in Jersey. However, I have been made aware that I can change my mind and withdraw my consent at any time and for any reason. I also know that exercising this right will not affect the further course of my treatment. I have received copies of the Patient Information Sheet and the Consent Form.

I am aware that I have the right to review and/or copy records of my protected health information kept by the researcher. I do not have the right to review and/or copy records kept by the researcher associated with the research study.

**I hereby give my full, informed and voluntary consent to participate in this study. I also give permission for the anonymous processing, sharing and publication of the results of the research**, in accordance with the Data Protection (Jersey) Law 2005.

1

Con. Appendix 6. Informed Consent Form

.....

Name of the participant (in capitals)

.....

Signature of the participant Date .....

**Statement from the person collecting the Informed Consent Form from the patient:**

I Urszula Sliwka explained the details of the proposed research to the patient, as described in the Patient Information Sheet. Prior to the study commencing, I discussed its nature with the patient outlining its purpose and the nature of the clinical trial with the benefits and risks arising from their participation in the study. I personally provided them with a copy of the Patient Information Sheet and the Informed Parental Consent Form. I personally provided them with a copy of a Patient Information Sheet and a Consent Form to participate in the study.

URSZULA SLIWKA .....
Name of the investigator (in capitals)

..... Date .....

Signature of the investigator

**This document has been drawn up in 2 identical copies, with one copy for researcher and one for participant.**

**The main investigators are:**

**Main Researcher: Mrs Urszula Sliwka**

MSc in Human Nutrition; ANutr.; Research Fellow at Women and Children's Services, Maternity, Health and Social Services Department (HSSD), Jersey

Email: u.sliwka@health.gov.je

**Sponsor in Jersey: Mr Neil MacLachlan**

Consultant in Obstetrics and Gynaecology, Jersey General Hospital; Health and Social Services Department (HSSD)

Email: n.maclachlan@health.gov.je; Telephone number: 01534 442660

**University Supervisor: Dr hab. Katarzyna Przybyłowicz**

Professor at the Faculty of Food Sciences, Human Nutrition Department, University of Warmia and Mazury in Olsztyn (UWM), Poland

katarzyna.przybylowicz@uwm.edu.pl;

Appendix 7. Informed Parental Consent Form

UNIWERSYTET WARMIŃSKO-MAZURSKI W OLSZTYNIE

States of Jersey

**INFORMED PARENTAL CONSENT FORM**

***"An investigation into the correlation between dietary intake and selected anthropometric measurements for a woman and her neonate in Jersey, Channel Islands (native-born Jersey, British, Polish and Portuguese nationals)".***

I, the parent or legal guardian of .....hereby declare that I have been informed by researcher, Urszula Sliwka, about the purpose of the above research project, its duration, its research methods, its expected benefits as well as potential risks, dangers or any inconvenience associated with my child's participation in this study. I have also been made aware of my own and my child's rights and obligations and my right to refuse to sign this consent form.

I have read and understood the contents of the Patient Information Sheet. I have been informed that additional questions about the survey may be addressed directly to the person conducting it and that I will receive comprehensive answers. I give consent for my GP to be informed about my participation in the study.

I declare that all the information I have given is true and I undertake to keep the researcher informed as to any changes to my child's health throughout the duration of the study.

By signing this form I consent to the researcher accessing my child's personal and medical records for the purpose of obtaining relevant information for the study, and for this access to be granted for the duration of the researcher's formal contract with the Health and Social Services Department in Jersey. However, I have been made aware that I can change my mind and withdraw my consent at any time and for any reason. I also know that exercising this right will not affect the further course of my treatment. I have received copies of the Patient Information Sheet and the Consent Form.

I am aware that I have the right to review and/ or copy records of my child's protected health information kept by the researcher. I do not have the right to review and/or copy records kept by the researcher associated with the research study.

**I hereby give a full, informed and voluntary consent for my child to participate in this study. I also give consent for the anonymous processing, sharing and publication of the results of the research**, in accordance with the Data Protection (Jersey) Law 2005. I aware that information about my baby participating in the research will be shared with the Family Nursing and Home Care (FNHC) who provide developmental assessments for children in Jersey.

1

Con. Appendix 7. Informed Parental Consent Form

| | |
|---|---|
| ..... | ..... |
| Name of the participant (in capitals) | Name of the parent / legal guardian (in capitals) |
| ..... | ..... |
| Signature of the parent / legal guardian | Date |

**Statement from the person collecting the Informed Parental Consent Form:**

I Urszula Sliwka explained the details of the proposed research to the patient, as described in the Patient Information Sheet. Prior to the study commencing, I discussed its nature with the patient outlining its purpose and the nature of the clinical trial with the benefits and risks arising from their participation in the study. I personally provided them with a copy of the Patient Information Sheet and the Informed Parental Consent Form.

URSZULA SLIWKA.....
The name of the investigator (in capitals)

| | |
|---|---|
| ..... | ..... |
| Signature of the investigator | Date |

**This document has been drawn up in 2 identical copies, with one copy for researcher and one for participant.**

<u>The main investigators are:</u>

**Main Researcher: Mrs Urszula Sliwka**

MSc in Human Nutrition; ANutr.; Research Fellow at Women and Children's Services, Maternity, Health and Social Services Department (HSSD), Jersey

Email: u.sliwka@health.gov.je

**Sponsor in Jersey: Mr Neil MacLachlan**

Consultant in Obstetrics and Gynaecology, Jersey General Hospital; Health and Social Services Department (HSSD)

Email: n.maclachlan@health.gov.je; Telephone number: 01534 442660

**University Supervisor: Dr hab. Katarzyna Przybyłowicz**

Professor at the Faculty of Food Sciences, Human Nutrition Department, University of Warmia and Mazury in Olsztyn (UWM), Poland

katarzyna.przybylowicz@uwm.edu.pl;

Appendix 8. Information Sheet for Participants

UNIWERSYTET WARMIŃSKO-MAZURSKI W OLSZTYNIE

States of Jersey

# Jersey Maternity Unit

## *Information Sheet for Participants*

## PARTICIPANTS NEEDED

***An investigation into how diet and lifestyle can affect pregnancy and baby's health.***



**www.pregnancy-study.co.uk**

Con. Appendix 8. Information Sheet for Participants

**The aim of the study:** To try and find out if there are different eating and exercise patterns in the different cultural groups of pregnant women in Jersey and if these patterns have any effect on the baby's growth in the uterus during pregnancy, and afterwards when the baby has been born and is in the first year of its life.

Please take the time to read the following information carefully and ask if you would like some more insight into this research entitled: *"An investigation into the correlation between dietary intake and selected anthropometric measurements for a woman and her neonate in Jersey, Channel Islands (for native-born Jersey, British, Polish and Portuguese nationals)".*

**Researcher:** Urszula Sliwka, MSc in Human Nutrition; Research Fellow at Women and Children's Services, Maternity, Health and Social Services Department (HSSD), Jersey

**The nature of research:** observational, non-invasive.

**Study Design:** Participation in the study is entirely voluntary and free of charge with the participants agreeing to be involved in all its stages. Women with an uncomplicated and singleton pregnancy before 20th week of gestational age will be asked to take part in this study. The study will involve both pregnant women and their children. You will be asked to fill in questionnaire about your diet before and during pregnancy. The collected data will be compared with pregnancy outcomes (measurements of body parts such as body mass, weight, etc.) taken during the pregnancy, at birth and at a 9-12 month follow-up for the baby. All measurements are presented below in the Study Framework on page 4.
The information you provide as well as your personal details will be used for future research, without dissemination to a third party. Processing, sharing and publication of the results of the research will be in accordance with the Data Protection (Jersey) Law 2005. A collaboration has been formed with Mr Neil MacLachlan, the lead consultant at the Department of Obstetrics and Gynaecology at the Jersey General Hospital and Maternity Unit as well as with The Family Nursing & Home Care (FNHC).

**This study has been reviewed and approved:**
The study with the RESOLUTION No. 9/2015 has been approved by the Bioethics Committee at the Faculty of Medical Sciences of the University of Warmia and Mazury in Olsztyn on 12 March 2015. It has also been reviewed and approved by the Health and Social Services Ethics Committee in Jersey.

**Once you have signed the consent form:** You will be offered an interview to obtain information about your diet before and during pregnancy, general lifestyle (level of activity, smoking), socio-economic (your average household income) and demographic status (country of origin, ethnicity, language preferences, etc.,). First folder with a questionnaire about your diet before pregnancy will be provided at the

beginning of pregnancy. You will be asked to fill in this folder and return it to researcher during a routine antenatal appointment at week 20 of pregnancy in the Maternity Unit of Jersey General Hospital (JGH). The second questionnaire about your diet during pregnancy will be sent by post to your home address. You will be asked to fill in this second diet review between 28-34th weeks of pregnancy and to send it back to Antenatal Clinic, by using provided for this purpose an envelope with a stamp. No additional appointments connected with this proposed study will be needed.
The next review will be offered by a health visitor for your baby at the Baby Clinic between 9-12 months after you have given birth. During this visit 'Screening and routine review' a health visitor will collect information taken routinely and related to the baby's development (baby's weight and length measurements) as well as information about breastfeeding and passive smoking risk.

Body measurements for women will be taken twice during routine antenatal appointments at 28th and 34th week of pregnancy. To obtain the newborn's body measurements at birth, we will use their medical records from the General Hospital. All essential measurements and information about the child at the age of 9-12 months will be taken from the Family Nursing and Home Care (FNHC) database after the 9-12 months developmental assessment. **Gathered information about the babies of the mothers participating in the research will be shared with FNHC, who provide developmental assessments for children in Jersey.**

**Potential benefits for participants:** No individual diet advice will be offered during this study other than as part of routine antenatal care. However, if you decide to participate in the project:

- You may learn more about your personal diet (an individualized nutritional feedback nine to twelve months after giving birth based on the Food Frequency Questionnaire FFQ done during pregnancy) and exercise levels during pregnancy.
- You may learn more about your own weight and that of your baby's at the 9-12 month follow-up. We will tell you which percentile your baby was born at and check this again at 9-12 months of age.
- You will be supporting a research project which will hopefully produce information that will help pregnant women in the future to determine what is a good diet and exercise level in pregnancy for both themselves and for the health of the baby.

**Confidentiality:** All documentation will remain confidential. Only one of the researchers (who has the duty of confidentiality to you) will be able to identify you. Confidential paper records will be kept in a locked filing cabinet within secure premises, and access will only be granted to the authorized person.

**Possible disadvantages:** Participation in the survey does not pose any risk to participants. You may find it challenging to talk about private matters such as your diet, weight or health. Study participants will only need to answer questions they feel comfortable with.

**Study Framework:**

**Review – pregnancy week 20:**

- Pre-pregnancy weight;
- Pregnant woman's weight at booking (12th week of pregnancy – from hospital medical records);
- Pre-pregnancy diet review using the Food Frequency Questionnaire;
- Socio-economic and Demographic Questionnaire.

**Data from weeks 28 and 34 of pregnancy** obtained from the hospital medical records completed during your routine appointments:

- Fundal Height Measurement and weight of each woman;
- Any scan data on fetal growth;
- Pregnancy diet review using the Food Frequency Questionnaire;

**After birth** data collection for each woman and baby taken from hospital medical records:

- Gestation age of each baby and type of delivery;
- Birth length, new-born's weight for gestation age; head circumference;
- Birth percentile measurement;
- Infant feeding method for the first 48 hours after birth;

**'Screening and routine review' nine- twelve months after giving birth for infant:**

- Percentile measurement taken by the Health Visitors FNHC at the Baby Clinic based on baby's weight, length measurements;
- Infant feeding method during the first 12 months;
- Passive smoking risk

**Study population and sample size:** The planned number of participants enrolled in the study is 400 women and their babies. The study participants will be women from different ethnical backgrounds living in Jersey. There is a valid reason for ethnicity exclusion of other nationalities living in Jersey. Dietary assessment methods for a multi-cultural population may be problematic because of a considerable variety of food eaten by different nationalities and the researcher's unfamiliarity with multi-cultural food and its processing techniques. Consequently, the study needs to be limited to only the largest ethnic groups living in the Island.
Due to a possible language barrier between the researcher and participant, and in order to ensure effective communication and improve the validity of the research data, each woman must speak and understand English at least at a basic level. To further enhance communication and ensure full understanding of the project, most of its documentation will be made available in three languages: English, Polish and Portuguese.

**Only your Midwife or medical consultant who knows your health status and the project's inclusion and exclusion criteria can refer you for this study. This is to ensure that you are fit and healthy at the time of participation and remain well during the course of the research.**

**Inclusion criteria:**

- women with an uncomplicated (healthy) and singleton pregnancy without gynaecological diseases;
- women before 20$^{th}$ week of gestation age;
- native-born Jersey, British, Polish and Portuguese pregnant women living in Jersey, Channel Islands;
- each woman must speak and understand English at a basic level;
- liveborn neonate.

**Exclusion criteria:**

- any pathology known to alter food intake during pregnancy such as diabetes, heart disease, kidney disease, hypertension or antiphospholipid syndrome APS (increased risk of blood clots) ;
- current depression treated by medication;
- a specific clinical problem (mental health, HIV infection and hepatitis B).
- an impairment limiting communication during an interview, limiting the patient's legal actions or their ability to give full consent;
- insufficient language skills to communicate in English;
- patient's unwillingness to participate in all stages of the research;
- patient's unwillingness to have body measurements taken and used as data for the study.

Con. Appendix 8. Information Sheet for Participants

**Benefits for the public and scientists:** The observational study for a multi-cultural population in Jersey, Channel Islands, is designed to study the impact of diet and exercise in different groups in Jersey on the development of the baby. This project may also show whether a specific approach is needed for individual nationalities in order to raise awareness about healthy eating and activity amongst women of childbearing age living in Jersey.
The results of this project can be used by health professionals to improve communication about eating habits, pregnancy weight gain management and general health of mothers and babies, not only at the time of pregnancy but also in their future life. This is additionally important for multi-cultural communities in order to answer questions from pregnant women of different ethnic backgrounds related to their own diet or the diet of their baby or other family members.

**The results of the research:** The proposed research is part of a course of an academic study for a PhD degree of Urszula Sliwka, Faculty of Food Sciences, Human Nutrition Department, University of Warmia and Mazury in Olsztyn (UWM), Poland and Jersey Channel Island. Urszula Sliwka is a Master's Engineer Degree holder in Food Technology and Human Nutrition, specialisation in Human Nutrition.

The results will be written up for worldwide distribution, publication in scientific journals and presentation at international meetings and conferences. Should you wish to, we would be happy to provide you with a copy of the research abstract after publication. No personal data will be included in the publication of the results of the research. Access to hospital records will only be granted to the researcher named in the Ethics Committee application and if necessary to other authorized individuals such as auditors and inspectors.
The expected duration of the study is 3 years.

**If you don't want to carry on with the study or if there is a problem:** You may withdraw from the study at any time for any reason. This will not affect the care you receive in any way. Any stored data that identifies you will be destroyed. In this case please contact main researcher, Urszula Sliwka.

The researcher is obliged to help solve any issues interfering with conducting the research. If you are unhappy about the way you have been dealt with during the research and wish to complain formally, you must do this by contacting the local research Sponsor in Jersey, Mr Neil MacLachlan, University Supervisor: Dr hab. Katarzyna Przybyłowicz or the Community and Antenatal Midwifery Manager Kathy Palmer.

For information connected with child's check-up at 9-12 months of age, you can contact Michelle Cumming, the Operational Lead for Child & Family Services FNHC.

Con. Appendix 8. Information Sheet for Participants

**The main investigators are:**

**Main Researcher: Mrs Urszula Sliwka**

MSc in Human Nutrition; Research Fellow at Women and Children's Services, Maternity, Health and Social Services Department (HSSD), Jersey

Email: u.sliwka@health.gov.je

**www.pregnancy-study.co.uk**

'Registered with the Association for Nutrition -www.associationfornutrition.org Protecting the public and promoting high standards in evidence-based science and professional practice of nutrition.' Registration Number: 8664

**Sponsor in Jersey: Mr Neil MacLachlan**

Consultant in Obstetrics and Gynaecology, Jersey General Hospital; Health and Social Services Department (HSSD);

A Fellow of the Royal College of Obstetrics and Gynaecology and a Fellow of the Royal Society of Biology

Email: n.maclachlan@health.gov.je; Telephone number: 01534 442660

**University Supervisor: Dr hab. Katarzyna Przybyłowicz** Professor at the Faculty of Food Sciences, Human Nutrition Department, University of Warmia and Mazury in Olsztyn (UWM), Poland; Email: katarzyna.przybylowicz@uwm.edu.pl;

**Additional contact numbers:**

Community and Antenatal Midwifery Manager Kathy Palmer 01534 442519;
the Operational Lead for Child and Family Services FNHC Michelle Cumming 01534 443625, who provide developmental assessments for children in Jersey

Con. Appendix 8. Information Sheet for Participants

**Additional information:**

1. We do not reimburse the cost incurred by the participant related to travel expenses to the place of testing.
2. It is estimated that each diet review will last approximately 30 minutes (time needed to fill in Food Questionnaire in your free time) and 30 minutes during a 9-12 month postpartum follow-up at the Baby Clinic.
3. The planned number of participants enrolled in the study is 400 women and their babies. The study participants will be pregnant women from different ethnic backgrounds (native-born Jersey as well as British, Polish and Portuguese/ Madeiran) living in Jersey, Channel Islands.
4. A copy of the Information Sheet will be given to each woman who shows interest in the project prior to her signing a consent form, to provide sufficient time for her to consider participation in the study and to ask any questions.
5. Each woman who takes part in the study will be asked to sign an Informed Consent Form. Parents/legal guardians will be asked to sign an Informed Parental Consent Form, allowing the researcher access to hospital medical records regarding pregnancy details presented in the Study Framework.
6. All participants will be immediately informed should new data regarding the trial emerge which may have an impact on their willingness to continue with their involvement in the study.
7. **To obtain additional information** on the rights of the participants and to report any harm in connection with your participation, please contact the lead investigator, **Urszula Sliwka on Email: u.sliwka@health.gov.je,**
   Mr Neil MacLachlan 01534 442660, the Community and Antenatal Midwifery Manager Kathy Palmer 01534442519, Michelle Cumming from FNHC 01534 443625.
   **Alternatively please visit this website www.pregnancy-study.co.uk**
8. The researcher will remain sensitive to the expectations and opinions of the participants regarding the research.

***Thank you for taking the time to read this Information Sheet. We hope you feel able to help.***

*Urszula Sliwka*



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Appendix 9. Poster for Participants



Appendix 10. 'Thank you Letter' for participants

UNIWERSYTET WARMIŃSKO-MAZURSKI W OLSZTYNIE

States of Jersey

15.01.2020

Dear .....

Thank you for participating in the Diet and Lifestyle Research Project at the Maternity Unit at the Jersey General Hospital. I hope you and your baby are doing well.

I just am writing to tell you that your participation in this study is completed.

Please find your Certificate of Completion as well as your individualized nutritional feedback based on the Food Frequency Questionnaire FFQ (diet before pregnancy).

Your diet review was compared with the Eat Well Plate Guidance https://www.nhs.uk/live-well/eat-well/the-eatwell-guide/, which shows how much of what we eat overall should come from each food group to achieve a healthy, balanced diet.

More insight into the research will be available once the relevant data has been analysed and released on https://www.researchgate.net/profile/Urszula_Sliwka

In line with the Data Protection Law, all names of the study participants are confidential. You ID Number is ___ and you can keep it for reference.

For any further queries, please do not hesitate to contact me directly via email on: u.sliwka@health.gov.je, through the website: www.pregnancy-study.co.uk created for this study project or FB address

https://www.facebook.com/DietLifestyleProjectJersey/

Thank you once again for your commitment. I wish you all the best in the New Year!

Kind Regards,

*Urszula Sliwka*

Research Fellow at Women and Children's Services,
Maternity, Health and Social Services Department (HSSD),
Antenatal Clinic, Jersey General Hospital
The Parade, JE1 3QS
Jersey

AfN ANutr REGISTERED ASSOCIATE NUTRITIONIST

'Registered with the Association for Nutrition -www.associationfornutrition.org Protecting the public and promoting high standards in evidence-based science and professional practice of nutrition.' Registration Number: 8664

Appendix 11. Certificate of Completion for Participants

# CERTIFICATE OF COMPLETION

## JERSEY
## MATERNITY UNIT




THANK YOU FOR YOUR SUPPORT

Main Researcher: Mrs Urszula Sliwka
MSc in Human Nutrition, Human Nutrition Department, University of Warmia and Mazury in Olsztyn (UWM), Poland; Research Fellow at Women and Children's Services, Maternity, Health and Community Services, Government of Jersey

HSSD Sponsor in Jersey: Mr Neil MacLachlan
Consultant in Obstetrics and Gynaecology, Jersey General Hospital; Health and Community Services, Government of Jersey
A Fellow of the Royal College of Obstetrics and Gynaecology and a Fellow of the Royal Society of Biology

Appendix 12. Confirmation of becoming a Ph.D. Candidate

Olsztyn, 30.01.2020

Dr hab. inż. Katarzyna Eufemia Przybyłowicz, prof. UWM
Scientific supervisor

Department of Human Nutrition
Uniwersity of Warmia and Mazury in Olsztyn
Phone: +48 (89) 524 55 21
e-mail: katarzyna.przybylowicz@uwm.edu.pl

## Certificate

I would like to kindly inform you that on 22/03/2019 Mrs Urszula Śliwka gave a seminar opening the doctoral thesis at the Faculty of Food Science.

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**Competing interests**

The author declare that they have no completing interests.

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