

A BIOPSYCHOSOCIAL APPROACH TO THE INTERRELATION BETWEEN REPRODUCTION AND EXCESSIVE WEIGHT IN WOMEN

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Ao abrigo do Art.º 8º do Decreto-Lei n.º 388/70, fazem parte desta dissertação as seguintes publicações:

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Ao longo desta dissertação, colaborei ativamente na definição e operacionalização das hipóteses em todos os artigos, bem como na análise e interpretação dos dados que estes reportam. Participei na recolha dos dados de todos os artigos relativos às reavaliações da Geração XXI. Fui responsável pela redação da versão inicial de todos os manuscritos e participei ativamente na preparação das suas versões finais.

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"A woman is the full circle. Within her is the power to create, nurture, and transform."

Diane Mariechild

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Abstract	3
Resumo	9
Introduction	17
1. The epidemiology of excessive weight	19
1.1. Overweight and obesity: impact on health	19
1.2. Measures of excessive weight	21
1.3. Time trends in global and portuguese prevalences: focus on women	22
1.4. Weight evolution throughout women's adult life	24
1.5. Psychosocial determinants	25
1.5.1. Psychological factors	25
Depression and anxiety	25
Body image	26
1.5.2. Social factors	28
Socioeconomic position	28
Lifestyles	29
2. Women's reproductive health	31
2.1. The interrelation between reproductive health and women's weight	31
2.2. Motherhood as an opportunity for prevention	34
2.3. Body image before, during and after pregnancy	36
2.4. Impact of social conditions on women's reproductive health	37
2.5. Metabolic features: healthy obesity after pregnancy	39
Aims	43
Research Methods	47
Papers	55
I. Weight change and its determinants in Portuguese adult women: a longitudinal analysis in the Epiporto cohort	57
II. Weight change and its determinants in childbearing women: a longitudinal analysis in mothers of a Portuguese birth cohort	79
III. Women's satisfaction with body image before pregnancy and body mass index 4 years after delivery in the mothers of Generation XXI	101
IV. Social trajectory and body image satisfaction in childbearing women	111

V. Healthy excessive weight in Portuguese women 4 years after delivery of a liveborn	121
General discussion	131
References	139

ABSTRACT

Portugal is characterized by a high prevalence of overweight and obesity among women, whose weight increases most rapidly in early adulthood. Individual genetic features and behaviours, along with social, cultural and environmental factors interact and produce complex relationships with body weight and with its variation throughout time.

Motherhood may trigger obesity and it remains unclear how this and other reproductive health factors can influence the associations between excessive weight and several other determinants.

With this thesis, we aimed to assess how pregnancy and other reproductive factors influence the association between body weight and biological, psychological and social factors in Portuguese women. To accomplish this objective, five studies were performed using different data sources and several methodologies. The next paragraphs briefly describe the specific objective pursued in each study, as well as the methods used and the main results.

1. To characterize weight differences between women and weight change over time in adult women from the general population and to assess the association of sociodemographic, reproductive and lifestyle characteristics with such variation (Paper I).

This study comprised 1040 women from a population-based cohort of adults from Porto, Portugal, assembled in 1999-2003 and re-evaluated in 2005-2008 (median follow-up 5 years). We fitted a mixed-effects model for longitudinal analysis of body weight on time, with random intercepts and random slopes. Multivariate-adjusted coefficients with 95% confidence intervals (95% CI) were computed for the determinants of weight at baseline and weight change between visits.

There was an average crude increase of 0.11 kg of measured weight per calendar year. Years of fertile life were associated with a larger annual weight gain: - 0.36 kg per year for women until 21 years of fertile life, whereas after that, weight increased progressively more with increasing fertile time up to 0.45 kg per year above 41 years. Height, age, education, marital status, residential neighbourhood deprivation, number of children delivered and use of oral contraceptives influenced interindividual weight variation at baseline, but not weight change from baseline to follow-up.

For the following objectives, we used data from mothers of the Portuguese birth cohort Generation XXI that comprises 8647 infants, corresponding to 8495 mothers. Families were evaluated at baseline (2005-2006) and follow-up visits 4 (2009-2011) and 7 (2012-2014) years after delivery and, of the total sample of mothers, 5729 (67.4%) and 5616 (66.1%) attended a face-to-face evaluation at 4 and 7 years, respectively. In the face-to-face interviews at baseline and follow-up evaluations, information was collected by interviewers, using structured questionnaires concerning the child's and mother's health. Also, an anthropometric evaluation of both family members was performed during the follow-ups by the interviewers.

2. To characterize weight differences between women and weight change over time in fertile women within seven years after the delivery of a liveborn, and to assess the effects of sociodemographic, reproductive and lifestyles characteristics with such variation (Paper II).

This study comprised 4475 mothers of Generation XXI evaluated in 2009-2011 (Visit 1) and 2012-2014 (Visit 2) (median follow-up: 2.8 years). We fitted a mixed-effects model for longitudinal analysis of body weight on time, and computed multivariate-adjusted coefficients with 95% CI for the determinants of weight at Visit 1 and weight variation between visits.

Weight increased on average 0.27 kg per year. A model with random intercepts and random slopes to account for different individual trajectories, as well as fixed effects, explained 12.2% of the weight change from Visit 1 to Visit 2 and 12.6% of the between-women weight differences at Visit 1. Independent determinants of higher weight at Visit 1 were higher height, lower education, having a partner, not being employed, higher number of pregnancies, not using hormonal contraceptives, never smoking and higher intake of soft drinks. Not having a partner, never smoking and lower intake of soft drinks remained independent predictors of weight gain between visits.

3. To assess the impact of body image satisfaction before pregnancy, using current and desired body size, on body mass index (BMI) 4 years after delivery (Paper III).

We analyzed 3612 mothers with prepregnancy BMI $>18.5 \text{ kg/m}^2$ reevaluated 4 years after the birth of a child. Body image satisfaction (BIS) was defined as the difference between perceived and ideal body size before pregnancy, assessed by Stunkard Silhouettes after birth. The associations of BIS with BMI change (continuous) and BMI classes at 4 years, based on measured weight and height, were estimated using linear and multinomial regression, respectively. Among women with normal prepregnancy BMI, those who felt too small regarding their ideal, had a 0.25 kg/m^2 smaller increase in BMI within 4 years and a lower likelihood of becoming overweight or obese than those satisfied with body image. Feeling too large was associated with a 0.41 kg/m^2 larger increase in BMI and a higher risk of becoming overweight or obese. A similar, non-significant, trend was observed for overweight women. Obese women who felt too large had a non-significant decrease in BMI.

4. To explore the relation of childhood, adulthood socioeconomic position (SEP) and social trajectory with body image satisfaction immediately before pregnancy in primiparous and multiparous mothers (Paper IV).

We used information from 5470 women assessed at baseline. Women's and their parents' education were used as indicators of adulthood and childhood SEP, respectively. Social trajectory was classified as stable-high, upward, stable-low, downward, according to both education variables. BIS was assessed with Stunkard Silhouettes immediately after birth as the difference between perceived body size before the index pregnancy and ideal body size. Odds ratios (OR) and 95% CI between social trajectory and BIS were computed using multinomial logistic regression (women satisfied with body image were the outcome reference category), adjusting for age and prepregnancy BMI.

In primiparous women, no association was found between childhood SEP, adulthood SEP or social trajectory and BIS. Downward social trajectory was associated with a higher likelihood of dissatisfaction with body image in multiparous women.

5. To characterize a healthy excessive weight in women 4 years after delivery concerning its prevalence, fat characteristics and identification of sociodemographic, genetic, reproductive or lifestyles factors that can be associated with this phenotype (Paper V).

We evaluated 1847 mothers who attended a face-to-face evaluation 4 years after the index pregnancy and provided a fasting blood sample. A healthy metabolic profile was defined as absence of hypertension, diabetes, dyslipidemia, C-reactive protein <3mg/l and being below the second tertile of HOMA-IR (Homeostasis model assessment of insulin resistance). Adjusted OR and 95% CI were computed using multinomial logistic regression for excessive weight (healthy/ not healthy) and obesity (healthy/ not healthy), taking women with normal BMI as the reference category of the outcome.

Four years after delivery, 47% of women had normal BMI, 33% were overweight and 20% obese. In each BMI class, 61%, 33% and 12% presented a healthy metabolic profile, respectively. Family history of CVD/cardiometabolic risk factors was associated with a higher probability of obesity with a not healthy metabolic profile. Women who breastfed the enrolled child for >26 weeks and practiced physical exercise were less likely to be obese and metabolically unhealthy, with no effect on healthy excessive weight.

This thesis emphasizes that different stages of reproductive life have an effect on women's body weight and its variation throughout time and that this relationship is markedly influenced by several biological, psychological and social factors. Moreover, a life course approach for weight management is essential, since factors associated with weight variation are not always the same throughout life. By gaining a better understanding of how biological, psychological and social factors interact with women's weight, findings from this dissertation provide important clues for better weight control recommendations.

RESUMO

Portugal é caracterizado por uma alta prevalência de excesso de peso e obesidade nas mulheres, sendo que o aumento de peso acontece mais abruptamente no início da vida adulta. Comportamentos e características genéticas individuais interagem com fatores sociais, culturais e ambientais, produzindo relações complexas com o peso e com a sua variação ao longo do tempo.

A maternidade pode desencadear ganho de peso excessivo e permanece por esclarecer qual a sua influência na relação entre o excesso de peso e outros determinantes já estabelecidos.

Com esta tese, propusemo-nos a avaliar como é que a gravidez e outros factores reprodutivos influenciam a associação entre o peso corporal e outros fatores biológicos, psicológicos e sociais em mulheres Portuguesas. Para responder a este objetivo, foram elaborados cinco estudos utilizando diferentes fontes de dados e diversas metodologias. Os parágrafos seguintes descrevem sucintamente o objetivo específico de cada um deles, bem como os métodos utilizados e principais resultados.

1. Caracterizar a diferença de peso entre mulheres e a variação de peso ao longo do tempo numa amostra de mulheres adultas da população geral e averiguar quais os seus determinantes sociodemográficos, reprodutivos e estilos de vida associados a essa variação (Artigo I).

Este estudo englobou 1040 mulheres pertencentes a uma coorte de adultos de base populacional residentes no Porto, Portugal, recrutadas no período 1999-2003 e reavaliadas entre 2005 e 2008 (tempo mediano entre avaliações 5 anos). Estimaram-se modelos de efeitos mistos para a análise longitudinal do peso ao longo do tempo, com um intercepto e uma inclinação aleatórios, bem como coeficientes ajustados e intervalos de confiança a 95% (IC a 95%) para os determinantes do peso basal e para a variação do tempo entre ambos os momentos de avaliação.

Houve um aumento bruto de 0,11 kg no peso por cada ano. Um maior número de anos de vida fértil associou-se a maior aumento anual de peso: -0,36 kg por ano para mulheres até 21 anos de vida fértil, sendo que, depois disso, o peso aumentou progressivamente com o aumento do período fértil até 0,45 kg por ano para mulheres com mais de 41 anos de vida fértil. A altura, idade, escolaridade, estado marital, ambiente socioeconómico desfavorecido da área de residência, número de filhos e uso

de contraceptivos orais influenciaram a variabilidade interindividual do peso na avaliação inicial mas não a variação de peso entre ambos os momentos de avaliação.

Para os restantes objetivos, foram utilizados dados sobre as mães de uma coorte de nascimento Portuguesa, a Geração XXI, que engloba 8647 crianças e as respetivas 8495 mães. Estas famílias foram avaliadas imediatamente após a gravidez (2005-2006), aos 4 (2009-2011) e aos 7 (2012-2014) anos após o parto e, do total das mães, 5729 (67,4%) e 5616 (66,1%) compareceram a uma avaliação presencial na primeira e segunda reavaliações, respetivamente. Relativamente às avaliações presenciais, a informação foi recolhida por inquiridores treinados utilizando questionários estruturados acerca da saúde da criança e da respetiva mãe. Da mesma forma, foi realizada pelos inquiridores nos três momentos de avaliação uma avaliação antropométrica a ambos os membros da família.

2. Caracterizar a diferença de peso entre mulheres e a variação de peso ao longo do tempo numa amostra de jovens mães e averiguar quais os seus determinantes sociodemográficos, reprodutivos e estilos de vida associados a essa variação (Artigo II).

Esta análise compreendeu 4475 mães da coorte de nascimento Geração XXI avaliadas em 2009-2011 (Visita 1) e 2012-2014 (Visita 2) (tempo médio entre avaliações: 2,8 anos). Estimaram-se modelos de efeitos mistos para a análise longitudinal do peso ao longo do tempo, com um intercepto e uma inclinação aleatórios, bem como coeficientes ajustados e IC a 95% para os determinantes do peso na Visita 1 e para a variação do tempo entre ambas as avaliações.

Em média, o peso entre avaliações aumentou 0,27 kg por ano. Um modelo com um intercepto e uma inclinação aleatórios para as diferenças nas trajetórias de peso entre mulheres, juntamente com os efeitos fixos, explicou 12,2% da variação de peso da Visita 1 para a Visita 2 e 12,6% das diferenças de peso entre mulheres na Visita 1. Maior altura, menos escolaridade, viver com um companheiro, não ter emprego, maior número de gravidezes, não utilizar contraceptivos hormonais, nunca ter fumado e um maior consumo de refrigerantes associaram-se a um peso mais elevado na Visita 1. Não viver com um companheiro, nunca ter fumado e um menor consumo de refrigerantes foram os preditores de maior ganho de peso entre visitas.

3. Estudar o impacto da satisfação com a imagem corporal antes da gravidez, usando a diferença entre o tamanho corporal real e o ideal, no índice de massa corporal (IMC) 4 anos após o parto (Artigo III).

Foram analisadas 3612 mães com IMC $>18,5 \text{ kg/m}^2$ e reavaliadas 4 anos após o nascimento de uma criança. A satisfação com a imagem corporal corresponde à diferença entre a percepção da imagem corporal e a imagem ideal antes da gravidez, avaliadas pelas Silhuetas de Stunkard e classificada em satisfeita, acima do ideal, e abaixo do ideal. O IMC foi calculado baseado em pesos e estaturas medidas. As associações da satisfação com a imagem corporal com a variação do IMC (variável contínua) e com as categorias de IMC 4 anos após o parto foram estimadas através de regressões linear e múltipla, respetivamente.

Em mulheres com IMC normal antes da gravidez, comparativamente com as mulheres satisfeitas com a sua imagem corporal, aquelas que se perceberam abaixo da sua imagem corporal ideal antes da gravidez apresentaram um aumento de menos $0,25 \text{ kg/m}^2$ no seu IMC ao longo de 4 anos, bem como uma menor probabilidade de apresentarem excesso de peso ou obesidade 4 anos após o parto. Mulheres que se perceberam acima do seu ideal apresentaram um aumento de mais $0,41 \text{ kg/m}^2$ no seu IMC do que as mulheres que se sentiam satisfeitas com a sua imagem e uma maior probabilidade de terem excesso de peso ou obesidade 4 anos depois. Foram encontradas associações semelhantes para as mulheres com excesso de peso antes da gravidez, ainda que não significativas. As mulheres obesas antes de engravidar apresentaram um decréscimo não significativo no seu IMC em 4 anos.

4. Avaliar a associação entre posição socioeconómica da infância, da vida adulta e da respetiva trajetória social com a satisfação com a imagem corporal imediatamente antes da gravidez, em mulheres primíparas e múltíparas (Artigo IV).

Foi utilizada informação acerca de 5470 mulheres recrutadas após o parto. O nível de escolaridade das mulheres e dos seus pais foi indicador da posição socioeconómica no momento da avaliação e na infância, respetivamente. A trajetória social foi definida tendo em conta a posição socioeconómica na infância e idade adulta: estacionária-alta, ascendente, estacionária-baixa, descendente. A satisfação com a imagem corporal corresponde à diferença entre a percepção da imagem corporal e a imagem ideal antes da gravidez, avaliadas pelas Silhuetas de Stunkard e classificada em satisfeita, acima do ideal e abaixo do ideal. Por regressão logística

multinomial, estimámos *odds ratios* (OR) e IC a 95% para a associação da trajetória social com a satisfação com a imagem corporal, ajustando para a idade e IMC antes da gravidez.

Em mulheres primíparas, não foi encontrado qualquer efeito da trajetória social na satisfação com a imagem corporal. Nas múltiparas, a insatisfação com a imagem corporal aumentou gradualmente ao longo das categorias da trajetória social, observando-se o dobro da insatisfação em direção a ambos os extremos nas mulheres com trajetória descendente.

5. Caracterizar o excesso de peso saudável em mulheres 4 anos após um parto, tendo em conta a sua prevalência, características da gordura e identificação de fatores sociodemográficos, genéticos, reprodutivos e estilos de vida que possam estar associados a este fenótipo (Artigo V).

Foram avaliadas 1847 mães que participaram numa avaliação presencial 4 anos após a gravidez índice e que realizaram uma colheita de sangue em jejum. Definimos perfil metabólico saudável pela ausência de hipertensão, diabetes, dislipidemia, proteína C-reativa <3mg/l e HOMA-IR (Modelo de avaliação da Homeostase) abaixo do segundo tercil. Por regressão logística multinomial, estimámos OR e IC a 95% para o excesso de peso (saudável e não saudável) e obesidade (saudável e não saudável) em comparação com mulheres com IMC normal.

Quatro anos após o parto, 47% das mulheres tinham IMC normal, 33% excesso de peso e 20% obesidade, das quais 61%, 33% e 12% apresentavam perfil metabólico saudável, respetivamente. A história familiar de doença cardiovascular/fatores de risco cardiometabólico associou-se a maior probabilidade de ter obesidade não saudável mas não à obesidade saudável. Mulheres que amamentaram a criança Geração XXI >26 semanas apresentaram menor probabilidade de serem obesas não saudáveis 4 anos depois e a mesma associação inversa com um perfil metabólico adverso verificou-se para a prática de exercício físico. Nenhuma destas variáveis se associou significativamente a excesso de peso/obesidade saudável.

Esta tese salienta que diferentes fases da vida reprodutiva da mulher influenciam o peso da mulher e a sua variação ao longo do tempo, sendo que esta associação é influenciada por diversos fatores biológicos, psicológicos e sociais. Além disso, deverá ser considerada uma abordagem ao longo da vida no que diz respeito ao

controlo de peso, uma vez que os fatores associados à variação de peso num determinado momento da vida adulta poderão não ser os mesmos uns anos mais tarde. Os resultados desta dissertação permitiram-nos adquirir um conhecimento mais aprofundado sobre a forma como os fatores biológicos, psicológicos e sociais interagem com o peso da mulher, o que poderá fornecer pistas importantes para a elaboração de medidas de controlo de peso mais eficazes.

INTRODUCTION

1. The epidemiology of excessive weight

1.1 OVERWEIGHT AND OBESITY: IMPACT ON HEALTH

Overweight and obesity are defined as abnormal or excessive fat accumulation that may impair health. This medical disorder leads to several comorbidities, affecting the health of individuals and the economy of societies (1).

Excessive weight is a major public health challenge, and tracking this important risk to health with increased precision and disaggregation in both developing and developed countries is a key global health priority (2). In 2010, overweight and obesity were estimated to cause 3.4 million deaths, 4% of years of life lost, and 4% of disability-adjusted life-years (DALYs) worldwide (3). Increasing public and government awareness of the extent of the problem is imperative and, in 2014, Member States of the World Health Organization (WHO) stated that one of the nine global targets for prevention and control of noncommunicable diseases to be attained by 2025 is to halt the rise in obesity (4).

Several anthropometric measures have been used to assess the association with morbidity and mortality. Body mass index (BMI), waist circumference (WC) and waist-to-height ratio (WHR) showed J-shaped associations with all-cause mortality, whereas waist-to-hip ratio demonstrated positive linear relationships (5). Obesity is related to the onset of cardiovascular diseases (CVD), type 2 diabetes, musculoskeletal disorders, work disability, sleep apnea and several cancers (6, 7). Kannel has stated that no risk factor has as strong an impact on CVD risk profile as obesity (8) and the high prevalence of excessive weight obesity led the American Heart Association to call for action to curb the consequences of this epidemic (9). Obesity is a risk factor for increased blood pressure (10), unfavourable lipid profile, decreased high-density lipoprotein (HDL) cholesterol level and increased low-density lipoprotein (LDL) cholesterol and triglyceride levels (11). Moreover, cardiac complications such as stroke, coronary heart disease, congestive heart failure, and sudden death occur with disproportionately high frequency in obese individuals and may cause or contribute to alterations in cardiac structure and function (12). Thus, the association between obesity and different forms of CVD is complex, involving a large number of interacting factors in diverse physiopathological mechanisms. Mediating roles have been described for subclinical inflammation, neurohormonal activation with increased sympathetic tone,

elevated leptin and insulin concentrations, obstructive sleep apnea, increased free fatty acid turnover and intramyocardial and subepicardial fat deposition (13) (Figure 1).

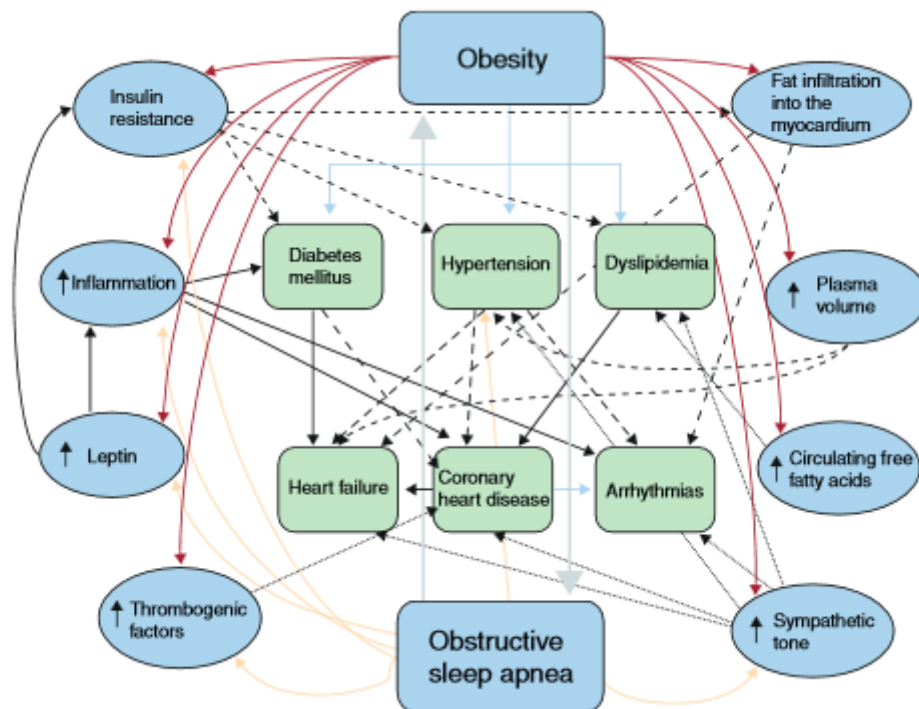


Figure 1. Pathophysiology of obesity and cardiovascular disease (13).

Besides being the major risk factor for CVD, obesity, in particular abdominal obesity, is the most important risk factor for the onset of type 2 diabetes. There is a 7-fold greater risk of diabetes in obese people compared to those of healthy weight, with a 3-fold increase in risk for overweight people (14). Whilst it is known that body fat distribution is an important determinant of increased risk of diabetes, the precise mechanisms underlying the association remain unclear. It is also uncertain why not all people who are obese develop type 2 diabetes and why not all people with type 2 diabetes are obese (15). The existence of individuals with a normal body weight defined by BMI with some metabolic obesity-related abnormalities and obese subjects with a favourable metabolic profile (16) illustrates how heterogeneous the relation between BMI and metabolic features can be.

Also, it is estimated that 20% of all cancer cases are caused by obesity (17). More specifically, adiposity contributes to the increased incidence and/or death from cancers of the colon, breast (in postmenopausal women), endometrium, kidney (renal cell), esophagus (adenocarcinoma), gastric cardia, pancreas, gallbladder and liver (18).

1.2 MEASURES OF EXCESSIVE WEIGHT

There are various ways to measure different aspects of obesity, from basic body measurements to high-tech body scans and all of them have strengths and limitations. They include BMI, WC, WHR, skinfold thickness, bioelectric impedance, densitometry, air-displacement plethysmography, hydrometry, and dual Energy X-ray Absorptiometry (DEXA) (19). In this introduction section, we will only describe in detail the ones used in this thesis.

Adiposity is a continuous trait not marked by a clear division into normal and abnormal, resulting in several definitions of overweight and obesity in adults. BMI is a simple index of weight-for-height that is commonly used as a surrogate measure of fatness. It is calculated as the weight in kilograms divided by the square of the height in meters (kg/m^2). The current definition of obesity in adults as proposed by the WHO is derived from associations of BMI with health outcomes and a BMI below 18.5 kg/m^2 is defined as underweight; a BMI between 18.5 and 24.9 is normal weight; BMI greater than or equal to 25 is overweight; and a BMI greater than or equal to 30 is obesity (20). Similar definitions were recommended by a National Heart, Lung, and Blood Institute (NHLBI) expert committee in the NHLBI Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults (21).

WC is a measure of the accumulation of body fat around the waist (central or abdominal adiposity) and may represent a greater risk to health than fat deposited in other parts of the body. High levels of central adiposity in adults are known to be associated with increased risk of obesity-related conditions including cardiovascular and metabolic disorders. Although measures of central adiposity are strongly correlated with BMI, they have been shown to predict future ill health independently of BMI (22). Current WC thresholds for increased risk of obesity-related health problems among white populations are more than 102 cm in men, and more than 88 cm in women (21). The most accurate measurements of visceral adiposity – magnetic resonance imaging, computed tomography and ultrasound – are seldom available for most clinicians, since the imaging techniques involved are expensive, may involve exposure to radiation, or require intensive training (23). Hence, imaging techniques are frequently substituted by surrogate indexes of visceral adiposity, such as WC and WHR. A recent study that compared several surrogate indexes of visceral adiposity with ultrasound assessment of subcutaneous and visceral adipose tissue depots showed that WC and BMI not only

are the simplest measures to obtain, but are also the most accurate surrogate markers of visceral adiposity in young adults, and are good indicators of insulin resistance (24).

In a considerable number of studies, self-reported height and weight have been used, since it is a simple, efficient, inexpensive and non-invasive method of collecting data from large numbers of people (25). Ascertainment of the agreement between objective (measured) and subjective (reported) data shows trends for under-reporting of weight and BMI and over-reporting of height in men and women, although the degree of the error varies according to the characteristics of the population being examined (26, 27). Studies demonstrate that demographic characteristics have an influence on the degree of reporting error. For instance, research has shown that self-reports from older populations are less reliable (28), that unemployed, retired or disabled women are more likely to under-report their BMIs than employed women (29), and that men are more likely to over-report their height than women (30). In Portugal, studies have demonstrated that overestimation of height increases with age and is greater among men than women and underestimation of weight is greater among women than men (31, 32). However, based on adult women from the 1999-2004 National Health and Nutrition Examination Survey (NHANES), BMI categories using self-reported height and weight had substantial agreement with measured categories among non-pregnant women. Agreement was greatest among white, non-Hispanic women, age 26-35, and decreased significantly among racial minorities and women older than 66 years of age. Socioeconomic position (SEP) was unrelated to strength of agreement and pregnancy significantly decreased the strength of agreement (33). However, change in BMI categories may be less subjective to bias from reporting errors. Self-reported prepregnancy body weights correlate very well with current measured body weights in women of reproductive age, since the reporting error (1–2 Kg) is a small percentage of total body weight (34).

1.3 TIME TRENDS IN GLOBAL AND PORTUGUESE PREVALENCES: FOCUS ON WOMEN

Recent estimates of BMI trends from 1980 to 2013 suggest widespread increases in overweight and obesity (2, 35). Rates of obesity seem to be increasing in both developed and developing countries and, in 2013, the overall prevalence of obesity in women was higher than in men throughout adulthood (Figure 2).

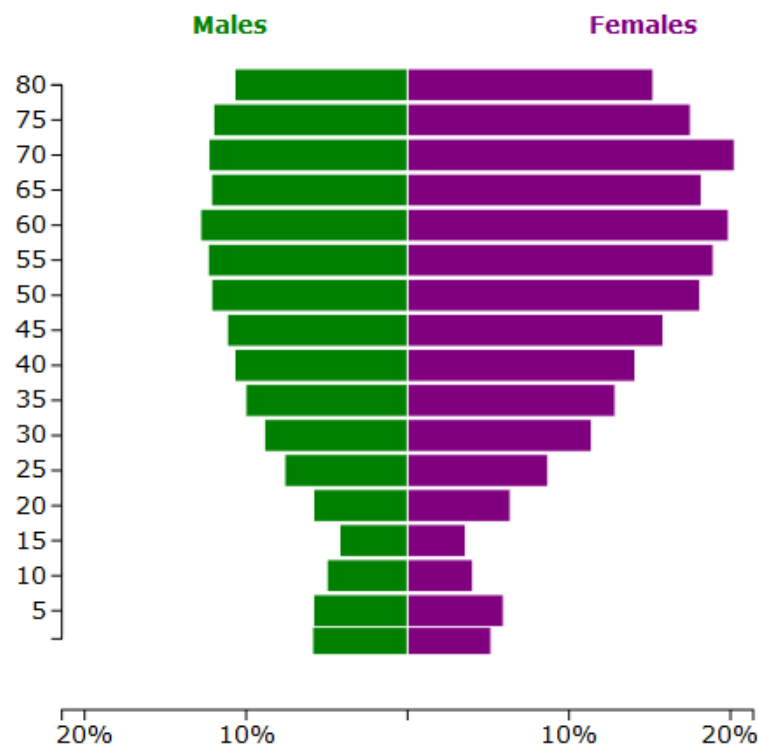


Figure 2. Prevalence of obesity by sex and age, 2013 (36).

Source: Global Burden of Disease Study 2013 - Institute for Health Metrics and Evaluation (available at <http://vizhub.healthdata.org/obesity/>)

In developed countries, increases in obesity that began in the 1980s have attenuated since about 2005; however, the same data draw attention to countries where most adult women are obese and show that no countries had significant decreases in obesity since 1980 (2). Particularly, in the United States of America (USA), 63% of non-Hispanic White adult women were overweight or obese (37). Moreover, even in countries like China and Brazil, where the prevalence of overweight and obesity was relatively low, overweight and obesity has increased rapidly during the past decades reaching prevalences higher than 50% (38, 39). In Europe, prevalences range between 26% and 68% (25).

Particularly in Portugal, self-reported data from The Portuguese National Health Survey already showed an increase in obesity prevalence among adult women from 1995 to 2005 (12.6% to 16.0%), while overweight prevalence remained stable (32.3% to 31.7%) (40). Overall, considering measured and self-reported data, studies conducted after 2000 are unanimous in the idea that Portugal is characterized by a high prevalence of overweight (32.4% to 54.6%) and obesity (13.4% to 26%) (2, 41-44). These numbers reinforce the fact that weight gain prevention programs at a

population level should have high priority in the scientific and political agendas and more deepened investigation is needed in order to develop more efficient strategies to tackle this epidemic.

1.4 WEIGHT EVOLUTION THROUGHOUT WOMEN'S ADULT LIFE

Weight and BMI trajectories change across the lifespan and, although childhood may be pointed as one of the critical periods to the development of obesity, some suspected factors are almost exclusive of adulthood, including marriage, pregnancy and menopause, highlighting the importance of this life stage (45). Concerning this period, weight increases most rapidly in early adulthood. A Canadian study that used self-reported prepregnancy body weight of all women giving birth in Nova Scotia between 1988 and 2006 found that the critical age for weight gain was between 20 and 24 years, as demonstrated in Figure 3, which is not a typical group targeted for intervention. This younger group of women corresponds to the “transition age group” from adolescence into adulthood, women who recently became independent, gained responsibility for food choices and experienced food insecurity (46).

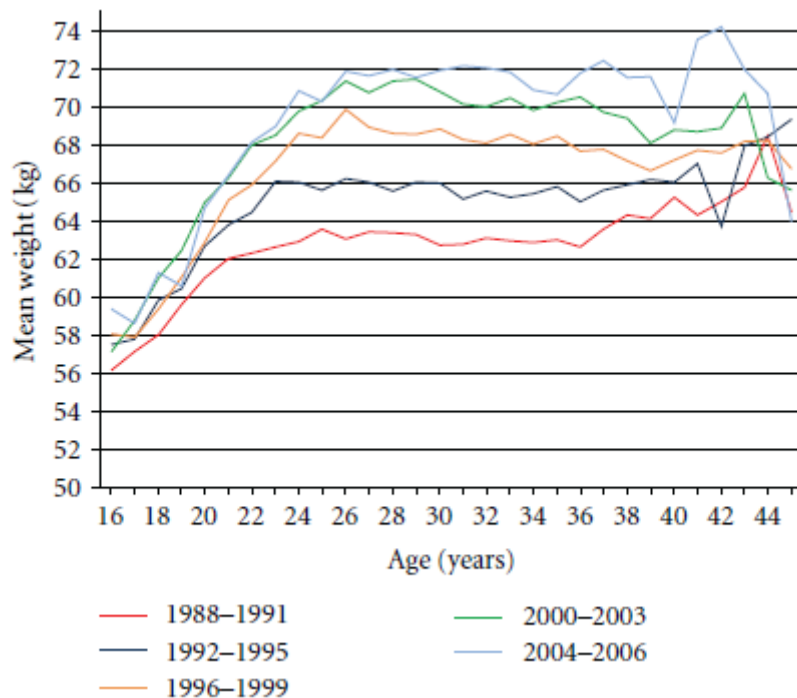


Figure 3. Change in maternal prepregnancy weight by year of age and time period, age 16 to 45 years (46).

After that age, a weight increase is still observed among adult women, although it starts to level off between 48-60 years and then declines in the oldest age groups (45, 47, 48). Nevertheless, weight change over time is affected by baseline BMI: results suggest a trend toward slower rates with increasing BMI categories, with no significant growth among obese women (48).

In their midlife, women undergo a biologic transition into menopause. The association between the menopause transition and weight gain is not fully understood, mainly due to the lack of longitudinal studies. The menopausal transition is associated with weight gain in women partially attributed to the reduction in energy expenditure (49) and this variation in weight has been examined as a potentially contributor factor to midlife body weight (50). A recent review assumes that whereas weight gain *per se* cannot be attributed to the menopause transition, the change in the hormonal milieu at menopause is associated with an increase in total body fat and an increase in abdominal fat (51).

Factors associated with an increase in BMI in midlife were not associated with an increase in BMI after the age of 65 years, suggesting that causes and consequences of changes in BMI differ across the lifespan and health recommendations need to be adjusted accordingly (52).

1.5 PSYCHOSOCIAL DETERMINANTS

While the causes of the obesity epidemic are simple in principle – an imbalance between energy consumption (diet) and energy expenditure (physical activity) – in reality, the problem is complex and the result of multiple interactions between genetic, reproductive, environmental, psychological and lifestyles factors (53). In this section, we emphasize the psychosocial determinants that were relevant for all the works comprising this thesis. A deeper understanding of the implications of women's reproductive health on weight is provided in the following section.

1.5.1 PSYCHOLOGICAL FACTORS

Depression and Anxiety

Throughout the reproductive years, women are roughly twice as likely to experience clinically significant depression and anxiety disorders as men although

reasons for this increased vulnerability are not well understood (54). This fact can be due to the complex array of factors – biological, psychological and social - that are known to contribute to the risk of depressive and anxiety disorders. Understanding how they combine, their relative influence at different stages of life course, and why women are at such markedly increased risk constitute significant challenges for research (54-56). Although anxiety may also be associated with obesity (57, 58), most studies on the association between psychiatric disorders and obesity have exclusively studied depression (59, 60). Depression may be seen as both a cause and a consequence of obesity. A meta-analysis found bidirectional associations between depression and obesity: obese persons had a 55% increased risk of developing depression over time, whereas depressed persons had a 58% increased risk of becoming obese. Moreover, the association between depression and obesity was stronger than the association between depression and overweight, reflecting a dose-response gradient (61).

Body image

How a person perceives his/her own body also affects weight outcomes. Studies conducted among a range of populations have found that perceptions affect weight-control behaviours regardless of age, ethnicity and other social characteristics (62, 63). Furthermore, weight perceptions do not remain stable throughout life. Burke and colleagues described differences in the self-perception of weight status in 1988-1994 and 1999-2004 and that the probability of self-classifying as overweight was significantly lower on average in the more recent survey, reflecting a generational shift in social norms related to body weight. As a result, people may be less likely to desire weight loss than before, limiting the effectiveness of public health campaigns aimed at weight reduction. On the other hand, there may be health benefits associated with improved self-perception such as higher self-esteem and, potentially, a decline in the incidence of eating disorders (64). The widespread secular increase in BMI also influences body weight ideals. Taken together, these changes are of concern since acceptance of a higher body weight could impede recognition of obesity as a risk factor (65).

Body image is a complex and multidimensional construct that relates to a person's perceptions, feelings and thoughts about his or her body. Most contemporary research on body image derives directly or implicitly from cognitive and/or behavioural paradigms in psychology that distinguish historical (past events that influence how people think, feel and act in relation to their body) from proximal or concurrent factors

(current live events, internal dialogues, body image emotions). Through various types of social learning, historical factors instil fundamental body image schemas and attitudes, including two sub-dimensions: dispositional body image evaluation and degrees of body image investment. Body image evaluation pertains to cognitive appraisals and associated emotions about one's appearance, including self-ideal discrepancies and body satisfaction-dissatisfaction evaluations. Body image investment refers to cognitive, behavioural and emotional importance of the body for self-evaluation (66).

Selection of body image measures for use in clinical and research settings is a complicated endeavour because of the multidimensionality of the construct and the availability of an extraordinary number of assessment tools. For some purposes, a broad multidimensional assessment is indicated and, in other cases, a fine-grained analysis of cognitive bias or affective response is more adequate. Care should be taken in the selection of the measure for the intended purpose and researchers should be specific in labelling the dimension of body image they wish to investigate and choose a measure that assesses that specific dimension (67).

Although body image is conceptualized as a multidimensional construct, most research in this area has focused on the narrower construct of dissatisfaction with weight, particularly the desire to be thinner. There is clear evidence that obesity is linked with poor body image (68, 69), particularly in women (70-72) but this does not mean that all obese persons have negative feelings toward their bodies. Certain characteristics and experiences of obese individuals appear to be associated with lower body image satisfaction (BIS) in adulthood such as childhood onset of obesity, an experience of weight-related stigmatization, binge eating disorder and a history of weight cycling (73-75). Women can also feel themselves too small regarding their ideal silhouette (76), however, research considering this extreme of dissatisfaction is still lacking. Although in both cases we are dealing with dissatisfaction, we hypothesize that characteristics that are associated with feeling too large might be distinct from those that are associated with feeling too small, therefore, further research should study both groups separately.

It has been hypothesized that BIS could play a role in motivating people to lose weight. Individuals with a moderate degree of dissatisfaction might be motivated to lose weight and, in contrast, those with a low level of dissatisfaction might not be inclined to change their behaviours in order to lose weight. Accordingly, the highly body dissatisfied obese individuals, due to their perceived inability to lose weight, might give up and not even attempt to change their dietary habits or exercise behaviours (77). At

the same time, weight reduction itself may have the ability to improve body image (78). Exploring psychological determinants of health behaviour such as reasons, goals, expectations, values, beliefs, or self-perceptions and getting individuals more (and better) motivated in self-managing their health, remain important aspects to address in fighting obesity (79). Thus, it has been suggested that weight loss interventions can benefit from proactively addressing body image-related issues as part of their protocols (80).

1.5.2 SOCIAL FACTORS

Socioeconomic position

SEP is an aggregate term that includes resource-based (income, wealth, educational credentials) and prestige-based measures (ranked in a social hierarchy evaluated with reference to people's access to goods, services and knowledge), linked to both childhood and adulthood social class (81). Body size is often associated with SEP, however, the magnitude and direction of association tend to differ by level of economic development, sex, and race/ethnicity (82-84). Weight appears to vary considerably more by SEP in women than in men, suggesting that body weight may be associated more closely with social and cultural roles among women. For adult women in developing countries, a direct relationship between SEP and excessive weight exists, while in western societies, women from a higher SEP are thinner than women from lower SEP (84, 85). Part of the protection against weight gain in this group could result from a higher frequency of weight monitoring, a lower threshold for defining themselves as overweight, and a greater likelihood of deliberate efforts at weight control (86). This pattern illustrates the concept of "embodiment" that is often used in social epidemiology. This construct recognizes the human being as simultaneously a social being and a biologic organism, and that society affects how people inhabit their bodies in everyday lives producing population patterns of health (81, 87).

Moreover, this association depends on the measure of SEP that is used. Results for the methodologically strongest studies showed that among non-black samples, there were relatively consistent inverse associations between occupation and weight gain, slightly less consistent using education and inconsistent when using income, although fewer studies were available (84).

SEP early in life is also related to adult BMI (88), arguing for early childhood being an important life stage in determining obesity risk over the lifetime.

Lifestyles

Adult behaviours such as smoking, diet and physical exercise are sources of risk for many chronic diseases and obesity is no exception. The need to change unhealthy behaviours remains a key aspect of health promotion policies. The difficulty of changing adult behaviours requires a deeper understanding of the origins and development of individual actions and healthy lifestyles.

Despite the decline in women's smoking rates in some developed countries, the same trend is not yet apparent in Portugal (89). Cigarette smoking is associated with lower body weight while smoking cessation is associated with weight gain (90-92). Smoking cessation is associated with a mean increase of 4-5 kg in body weight after 12 months of abstinence, and most weight gain occurs within three months of quitting. Variation in weight change is large, with about 16% of quitters losing weight and 13% gaining more than 10 kg (93). Additionally, dissatisfaction with one's weight or body shape has also been shown to be associated with initiation of smoking (94). Although obese smokers are more likely to be concerned about gaining weight when quitting than are normal-weight or overweight smokers, few studies have explored obese smokers' attitudes, beliefs, and experiences related to smoking cessation efforts and cessation-related weight gain, information that can be useful in understanding potential barriers to treatment success (95). Female smokers generally have greater weight concerns in relation to quitting than men (96), possibly reflecting women's belief that smoking is an effective method for weight control (97).

On the basis of dramatic increases over recent decades in time spent watching television and car ownership, it is argued that physical activity (PA) is a primary factor underlying the current rates of obesity (98, 99). Most longitudinal studies about individual weight variation show that higher rates of PA lead to better weight control over time in adult women (100-102).

It is important to distinguish PA and physical exercise, in order to better interpret and compare studies. PA is defined as any bodily movement produced by skeletal muscles that results in energy expenditure and can be categorized into occupational, sports, conditioning, household, or other activities. Physical exercise is a subset of PA that is planned, structured, and repetitive and has as a final or an intermediate objective the improvement or maintenance of physical fitness (103).

In order to understand if total volume of leisure-time PA had a dose-response effect on obesity, the National Health and Nutrition Examination Survey (NHANES)

provided data from 12,227 non-institutionalized individuals, aged 20-64 years, and reported a crude inverse dose-response relationship between total volume of leisure-time PA and obesity in US adult women, but not in men (104). PA also has impact on lipoprotein-cholesterol in obese women. Increased PA duration, independent of fat mass loss and change in diet, reduced the concentration of LDL and very low density lipoprotein particle concentrations, whereas increased PA intensity was associated with adverse changes in some lipoprotein particle subclasses, suggesting that an intervention for this population should focus not only on weight loss but mostly on ways of gaining an active lifestyle to improve metabolic health (105).

The dietary changes that characterize the “nutrition transition” include both quantitative and qualitative changes in diet. The adverse dietary changes include shifts in the structure of the diet towards a higher energy density diet with a greater role for fat and added sugars in foods, greater saturated fat intake (mostly from animal sources), reduced intakes of complex carbohydrates and dietary fibre, and reduced fruit and vegetable intakes (106). Paradoxically, dietary surveys show lower energy intakes to be associated with higher BMI in western countries. These results can be confounded by energy expenditure and under-reporting, which is known to be common in obese individuals (107). Energy, fat, protein and carbohydrate intakes have all been positively related to weight gain in women, though generally associations are weak and inconsistent (108). However, in young and middle-aged women, several aspects of dietary intake were associated with increased weight gain over time, such as high intake of sweet beverages, high salt consumption (109) and total caloric intake (100).

Measurement of dietary exposure is one of the most challenging problems in nutrition, making it difficult to detect correlations between dietary exposure and disease risk. There is a multiple self-reported and biomarker measures of diet and accurate quantification of nutritional exposure is critical. Even moderate flaws in measurement can lead to sizeable distortions in estimations of the effects of exposure (110).

Given that diet and adiposity are difficult to measure and relationships with excessive weight may be weak, the influence of diet on excessive weight may only become apparent when comparing distinct groups, or when diet is acting in combination with other factors (45). All the inconsistencies and uncertainty about the relation between diet and obesity are based in data predominantly from cross-sectional studies. Further investigation is needed in order to analyse this association longitudinally.

2. Women's reproductive health

2.1 THE INTERRELATION BETWEEN REPRODUCTIVE HEALTH AND WOMEN'S WEIGHT

According to the WHO, reproductive health implies that people are able to have a responsible, satisfying and safe sex life and that they have the capability to reproduce and the freedom to decide if, when and how often to do so. Implicit in this are the right of men and women to be informed of and to have access to safe, effective, affordable and acceptable methods of fertility regulation of their choice, and the right of access to appropriate health care services that will enable women to go safely through pregnancy and childbirth and provide couples with the best chance of having a healthy infant (111).

Among the most important indicators of vitality and health in women's life are patterns of menstruation, fertility and pregnancy. Early menarche is a strong predictor of abdominal and general obesity, presenting a dose-response relationship (112, 113), with the risk of overweight and obesity decreasing with increasing age at menarche (112). Also, after menopause, general obesity increased by 52%, compared with premenopause status (113). Moreover, evidence demonstrates that obese women are at an increased risk of sub-fecundity and infertility (114) and also have poorer outcomes following fertility treatment (115-117).

Motherhood is one of the most challenging experiences that can occur in women's life and it can be concomitantly distressing and meaningful to them. These ambivalent feelings are not necessarily a problem, but more research is needed to understand their specificities and how they can interact with weight management in this period of life. The growing number of obese women worldwide has many implications not only on mother's health outcomes but also for their children, as demonstrated by the association between prepregnancy obesity and certain major birth defects (118) and a higher likelihood of having macrosomic infants (119). Also, caesarean delivery risk is increased by 50% in overweight women and is more than double for obese women compared with women with normal BMI (120).

The postpartum period can be critical for the development of obesity in midlife. Evidence consistently shows that excessive gestational weight gain (GWG) contributes to higher postpartum body weight (121-123) and that overweight and obese women

have more than double chances to exceed the weight gain recommendations during pregnancy than other BMI groups (119, 124). Moreover, excessive GWG is associated with abdominal adiposity 8 years after delivery, which may increase a woman's risk of cardiovascular and metabolic diseases (125).

Several pregnancy cohort studies from developed countries have reported independent direct associations between prepregnancy body weight or BMI and postpartum weight retention (126, 127). However, a recent meta-analysis analyzed the association of GWG or prepregnancy BMI with postpartum weight retention and, as illustrated in Figure 4, GWG, rather than pre-pregnancy BMI, determines the shorter- or longer-term postpartum weight retention. When postpartum time spans were stratified into 1-3 months, 3-6 months, 6-12 months, 12-36 months and ≥ 15 years, the association between inadequate GWG and postpartum weight retention faded over time and became insignificant after 15 years (128).

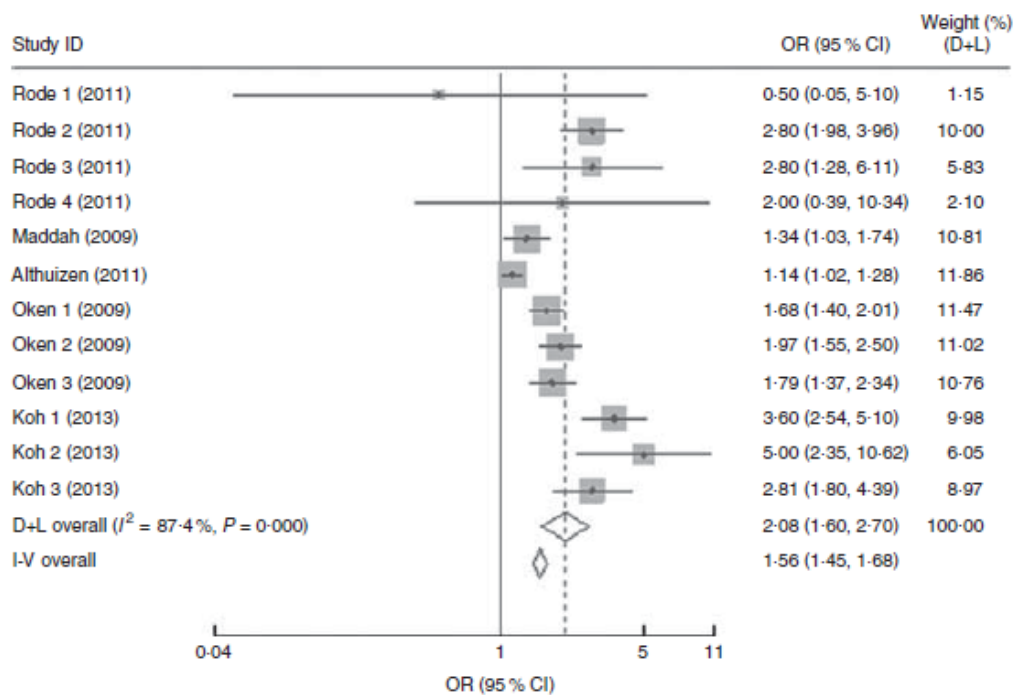


Figure 4. Forest plot of the studies on the risk of postpartum weight retention of ≥ 5 kg for the women with excessive gestational weight gain (GWG) vs. the women with adequate GWG. The study-specific OR and 95% CI are represented by the grey square and horizontal line, respectively; the size of the data marker (grey square) is proportional to the weight of the study in the meta-analysis (note: weights are from random-effects analysis). The center of the open diamond presents the pooled OR and its width represents the pooled 95% CI (128).

Most studies conducted so far focus on weight change only until the first year postpartum, and few studies have obtained serial measurements for longer periods to assess patterns of weight change. Characterization of the interrelationships between

prepregnancy body weight, GWG and postpartum weight retention is essential to a deeper knowledge of weight changes after pregnancy and obesity rates in childbearing age. Given the modifiable nature of this risk factor, the preconception, prenatal, and postpartum periods may present critical windows to implement interventions to prevent weight retention and the development of overweight and obesity in women of childbearing age (129).

Increasing parity contributes to the long-term development of obesity in women (130-132) but this relationship differs by maternal BMI in young adulthood, number of births, race-ethnicity and length of follow-up. Findings from a representative cohort from the USA confirmed that white and black primiparous and multiparous women were more likely to gain weight with childbearing 10 years after baseline than nulliparous ones, this association being stronger among women with high BMI before pregnancy. However, 25 years later the same study showed that only black women who were overweight at baseline and delivered more than one child gained significantly more weight than those not giving birth (133). Women often report their obesity to be triggered by pregnancy - as many as 40–50% in one Swedish study. Yet, for 30% of the women in the same study, pregnancy was associated with a weight loss (134). Additionally, place of residence, ethnicity, as well as individual SEP and lifestyle factors can considerably explain this association (135, 136). All these data allude to a complex parity–weight relationship for women with a range of confounding factors that act across the life course, with the possibility for further variations (137). Thus, further research is needed to confirm the links between parity and weight gain, as well as more information regarding confounders of this association framed in social and current economic conditions.

The risk of weight gain is not equal throughout all pregnancies. In large cohort studies, weight gain due to childbearing was greater after the first birth (primiparous versus nulliparous), and weight gain was greater with increasing baseline maternal body weight. Average weight gain associated with having a first child was 3 to 6 kg among women who were overweight before pregnancy, and about 1 kg among women with normal BMI. After the first pregnancy, cumulative increases do not occur with subsequent births and the weight gain is smaller (129, 138, 139). Furthermore, multiparity is positively associated with abdominal girth from preconception to several years after delivery (138, 140).

Despite some disparities, evidence supports that substantial weight gain associated with childbearing is an important risk factor for the development of overweight and obesity in adult women. Future studies should identify women more

susceptible to benefit from interventions to prevent weight gain and which are the most effective critical periods to intervene: before, during or after pregnancy.

2.2 MOTHERHOOD AS AN OPPORTUNITY FOR PREVENTION

Some authors defend that the preconceptional period should be seen as the best time for prediction and prevention of noncommunicable diseases, thus not only improving pregnancy outcomes and maternal health, but also promoting long-term beneficial effects for both the mother and the child (141). Prepregnancy weight loss can reduce obesity-related complications, which can have considerable impact on improving obesity-related perinatal complications - gestational diabetes mellitus, hypertensive disorders, macrosomia, and large for gestational age babies (142).

Women's health in Portugal has experienced a huge overall improvement since the late 70s and the implementation of the National Health System, which ensures all citizens nearly free access to primary care centers and public hospitals (143). Moreover, prenatal care is one of Portugal's health care system most successful areas, with practically 100% coverage and adequate prenatal care in the vast majority of pregnancies (144). However, a study performed in the north of the country showed that, whilst good prenatal surveillance exists, only 27% of the puerperal women had preconceptional care (145). Also, a study performed in mothers of Generation XXI birth cohort showed an adverse cardiovascular risk profile since the preconceptional period (146), supporting the idea that interventions should start earlier in childbearing women.

The label "teachable moment" has been used to characterize life transitions or health events that increase perceptions of personal risk and outcome expectancies, prompt strong affective or emotional responses, and redefine self-concept or social roles. In other words, a cognitive response precedes motivation, skills acquisition and self-efficacy that in turn, increase the likelihood of ceasing adverse lifestyles. Additional key factors to consider are predisposing factors such as age, dispositional and cultural characteristics that may influence an individual's cognitive and emotional response. Pregnancy has been widely referred as a teachable moment because of mothers' strong motivation to protect the well-being of the fetus and strong social pressure to avoid unhealthy habits, such as smoking during pregnancy (147, 148).

Some psychological issues should also be highlighted when discussing pregnancy's impact on women's life. A qualitative study explored beliefs and expectations about motherhood, and the main themes are illustrated in Figure 5. Since a discrepancy between women's expectations and reality was found, a psychological preparation to motherhood should be considered when preparing women to their new role. Such preparation promotes a sensible image of motherhood, the infant, the novelty of the future and the relationships with others and discuss this themes may be particularly relevant to women vulnerable to postnatal psychological adjustment difficulties (149).

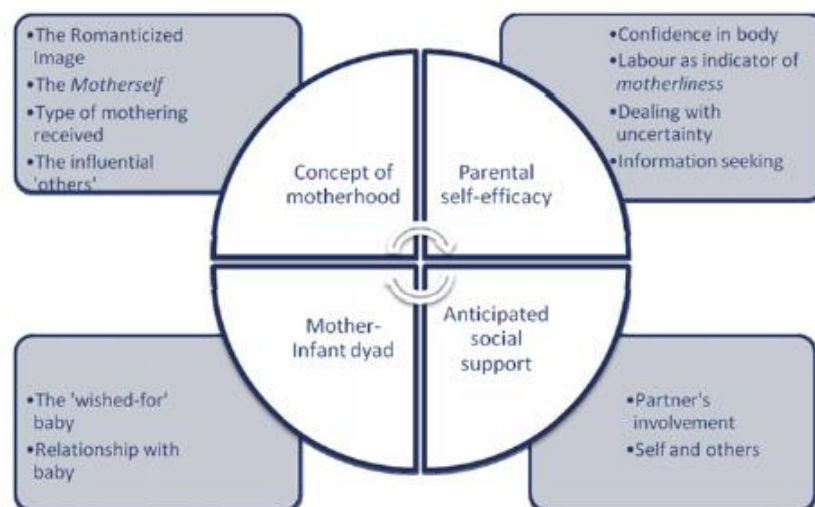


Figure 5. Themes and sub-themes identified within the 'Expectations and beliefs about motherhood views' (149).

According to a study performed in the United Kingdom between 1998 and 2003, there was a significant reduction in smoking, alcohol consumption and intake of caffeinated drinks when women became pregnant, although little change occurred in fruits and vegetables intake (150). In Portuguese mothers, although almost half of smokers ceased tobacco consumption during pregnancy, approximately two thirds resumed smoking within 4 years after delivery (151), leading us to believe that, although pregnancy enhances the perceived need of adopting healthy lifestyles, that does not mean that healthy habits will persist throughout time. Since reproductive-aged women are prone to change healthy habits when they receive health care provider's advices (152), interventions to this segment of population should be restructured, focusing more on women's intrinsic motivations and expectations, which is proved to result in long-lasting behaviour change (153).

In summary, weight management before, during and after a pregnancy have advantages for both mother and child. Monitorization of prepregnancy BMI, GWG, and postpartum weight will allow the identification of women who are more susceptible of having an inadequate weight throughout childbearing years. Preconception is an important period and obese women should be targeted for intervention before they get pregnant for the first time. Likewise, healthcare providers involved in the care of pregnant women, should be trained to provide a most effective approach. Since it has been demonstrated that social and psychological characteristics have impact on maternal excessive weight, the psychosocial context should be acknowledged.

2.3 BODY IMAGE BEFORE, DURING AND AFTER PREGNANCY

Pregnancy, due to its concomitant changes in body size and shape, can have a significant impact on a woman's body image (154). This stage of life is often the first time weight gain is expected and accepted and some women view body changes as transient and unique to the childbearing endeavour so they are able to assimilate these changes without distress (155).

Research results on body image in pregnancy have been contradictory, with some studies highlighting that women are able to assimilate the bodily changes of pregnancy without a negative shift in BIS (156, 157), and other studies finding a decreased BIS during pregnancy (158) and postpartum (159). Also, prepregnancy BMI has impact on BIS during pregnancy, with overweight women reporting an increase in their satisfaction and women with normal BMI reporting a decrease (158). Those who had been overweight before their pregnancy may view their pregnancy as excusing them from unpleasant comments or feeling uncomfortable in activities exposing their body, like swimming (160).

In the postpartum period, despite some variation, body image is generally more negative, when women's constructions of their postpartum body indicate that once the baby was born, they no longer perceived any excuse not to adhere to their perceived socially constructed ideal silhouette (161). Harris and colleagues also found that women who were less satisfied with their bodies postpartum had significantly greater long term weight gains than those women who displayed no increase in dissatisfaction with their bodies after pregnancy (131). One possible reason for this disappointment is

that women (especially primiparous women) tend to expect that their bodies will return to their pre-pregnancy weight and shape shortly after the birth of their child (162).

A recent review work synthesized the existing qualitative literature describing women's experiences of their pregnancy and postpartum body image. Hodgkinson and colleagues (154) highlighted that women's perception of their pregnancy body image is varied and depends on the strategies they use to protect against social constructions of female beauty. Women often perceived the pregnant body to be out of their control and as transgressing the physical manifestation of the socially constructed ideal, against which they tried to protect their BIS. Body dissatisfaction dominated the postpartum period, emphasizing the women's need for additional support at this moment. Moreover, health professionals are reported to feel uncomfortable about discussing weight as an aspect of body image due to lack of knowledge and fear of being considered insensitive (163). However, since during pregnancy women are more receptive to conversations about weight-related aspects of their body image, communication skills training could increase professionals' confidence in exploring women's body image in order to improve their weight management strategies independently of their BMI (154).

If it seems clear that BIS before pregnancy has a considerable impact on postpartum weight changes, further research is needed to assess if this same construct can influence weight over a longer term.

2.4 IMPACT OF SOCIAL CONDITIONS ON WOMEN'S REPRODUCTIVE HEALTH

Female reproductive health is highly sensitive to the physical and social environment throughout life. Women are currently less likely to be married and more likely to be single or cohabiting (164, 165), more women are remaining childless or having fewer children and the proportion of women's lives spent rearing their children has been reduced (166). If social factors change, so their impact on women's reproductive life can also change; therefore, a deepened study of this relation, together with psychological and biological attributes, is still a challenge to be faced.

Maternal SEP is known to be a strong correlate of numerous maternal and child health outcomes. Low individual SEP (e.g. education and income) has been associated with adverse pregnancy and birth outcomes (167, 168) and delayed prenatal care

(169). A recent large population-based study compared the direction and magnitude of individual and neighbourhood social inequalities across multiple maternal and child health outcomes (maternal and infant health status indicators; prenatal care; maternal experience of labour and delivery; neonatal medical care; and postpartum infant care and maternal perceptions of health care services) and revealed that SEP measures had stronger associations with outcomes belonging to the health status of the mother and infant, as opposed to other groups. The magnitude of maternal and child health inequalities was higher when individual-level SEP was used than when we considered neighbourhood SEP. In particular, education showed the greatest gradients compared to household income, neighbourhood SEP, and combined SEP (combination of low and high individual and neighbourhood SEP) (170).

A relation between SEP and obesity has been well established for a long time (171), also in childbearing women (172), with those who have a lower SEP being the ones with a higher risk of being obese. However some specificities of this association considering young adult women remain unclear. In adulthood, reproduction may have an added influence on obesity risk in women, although research is lacking on how adult influences combine, namely social and psychological ones, for the development of excessive weight in this particular period.

Additionally, research on childhood growth has pointed to the possibility that early life may be an important stage in the development of obesity and longitudinal studies consistently show that a lower SEP in childhood increases the risk of fatness in adulthood (88). These associations between childhood SEP and adult health are also observed in the context of motherhood. Figure 6, based on the British 1958 birth cohort study (173), maps how childhood disadvantage links to early motherhood.

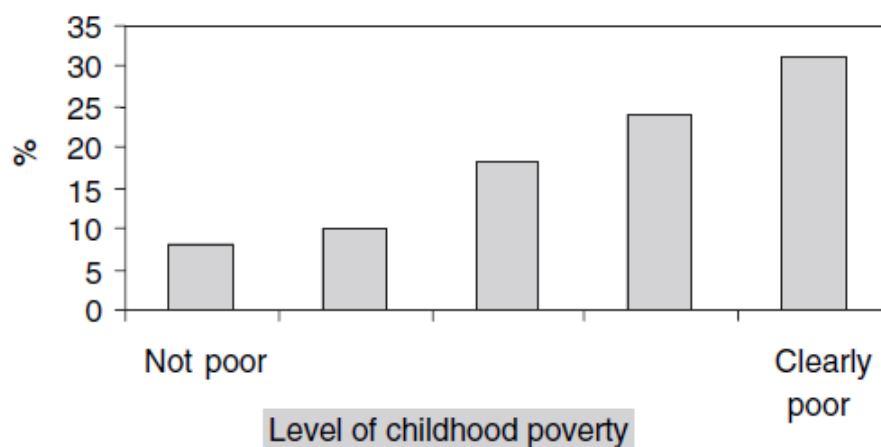


Figure 6. Proportion of women having their first baby by the age of 20 according to level of poverty in childhood (173).

This continuity in disadvantage throughout life is an important part of the link between childhood disadvantage and poor adult health, with SEP across childhood and adulthood emerging as a stronger predictor of adult health than SEP at any one point in time (173).

Social trajectory is a lifelong evolution of the volume and composition of an individual's capital (social, cultural, economic and/or symbolic), combined with his/ her parents' asset volume and structure and can be described as upward, downward or stationary (174).

Most of the findings concerning obesity and socioeconomic characteristics have been based on women's SEP in adulthood but, recently, evidence is emerging about the impact of intergenerational social trajectory taking into account a life course perspective. In order to study the influence of social class in childhood, young adulthood and middle age, and intergenerational mobility, on adult central and total obesity, a study was conducted using a population-based birth cohort. In women at 53 years, father's social class was inversely associated with all measures of obesity, both adult social classes (at ages 26 and 43 years) were inversely associated with all obesity measures at age 53 years and women with an upward intergenerational social mobility had lower levels of central and total obesity compared with those who remained in the same social class as their father (175).

Changes in social circumstances, or intergenerational movement between social classes, might entail a transition in terms of priorities and resources related to weight and appearance, or a shift in experience of social norms regarding the appeal of particular body types (176), particularly when considered in the context of women who have recently given birth. Knowing that society influences women's perception of good or bad appearance, future studies should better assess the social determinants of BIS in childbearing women, considering a life course approach.

2.5 METABOLIC FEATURES: HEALTHY OBESITY AFTER PREGNANCY

The numbers regarding obesity are alarming, largely due to its association with several cardiovascular diseases. However, recently, a healthy obese phenotype has been identified and these individuals appear to be at no increased cardiovascular risk (177, 178). This clinical condition, termed benign obesity or metabolically healthy

obesity, is restricted to a unique subset of the obese population which, despite excessive BMI, are insulin sensitive and have a normal blood pressure, lipid, inflammation and hormonal profile (177-181). The relevance of establishing such phenotype is underlined by data that suggests that weight loss among healthy obese may adversely impact their favourable cardiometabolic profile (182).

The absence of a uniform definition for this subtype of obesity is one of the main limitations of this topic, with prevalences ranging from 6% to 37% (183-185), depending on the criteria to define the phenotype. However, even when unique criteria are used, considerable variability in the prevalence of healthy obesity is found across different European countries (186) and, to the best of our knowledge, there are no estimates for Portugal. Normally, metabolically healthy obese persons have family members with uncomplicated obesity, early onset the obesity, fasting plasma insulin within normal range and normal distribution of the excess fat (187). Additionally, some lifestyles features are associated with this metabolic profile, such as moderate and higher levels of PA and higher dietary quality (185).

Some controversy exists considering the relevance of this phenotype. A recent systematic review and meta-analysis showed that, compared with metabolically healthy normal weight individuals, obese persons are at increased risk of adverse long-term outcomes even in the absence of metabolic abnormalities, suggesting that there is no healthy pattern of increased weight (188). Also, another study that evaluated the 3-year incidence of cardiometabolic risk factors concluded that an increase in BMI during the follow-up period was significantly associated with the occurrence of cardiometabolic alterations (189). More research concerning this subject is still needed and longer longitudinal analyses should be provided in order to clarify if these individuals are protected during the entire life or whether healthy obesity simply represents delayed onset of obesity related cardiometabolic problems. Also, most of the studies that assessed healthy obesity used samples comprising women above 40 years of age (181, 190, 191) and information concerning childbearing women is still lacking.

The increase in deposition of fat in abdominal visceral adipose tissue is favoured after pregnancy, due to increased abdominal compliance, rendering women more susceptible to abdominal obesity after childbirth (130). Abdominal fat distribution, visceral and ectopic fat accumulation are also key characteristics for the development of unhealthy obesity (192). Thus, it is interesting to characterize the obesity phenotype in women who had a child, to assess to which extent their obesity is healthy or is conveying a higher risk of CVD, thus supporting or not the need for preventive action directed at this segment of the population. By examining subtypes of obesity we

attempt to understand obesity's heterogeneous nature that could result in more appropriate weight loss recommendations, even among childbearing women.

Aims

Individual genetic features and behaviours, along with social, cultural and environmental factors interact and produce complex relationships with body weight and with its variation throughout time. Reproductive events can also influence the development of excessive weight in women. Specifically, motherhood may trigger obesity and it remains unclear how this experience can influence any of the associations between excessive weight and several other determinants. Concomitantly, having a child entails not only physical but also psychological changes in a woman and this period can be an interesting window for a detailed study of the interplay of biological, social and psychological factors on weight management.

Excessive weight is a public health problem in women and Portugal is no exception. Since prenatal care is one of Portugal's most successful areas within the health care system, pregnancy and motherhood should be seen as opportunities for prevention, and a deeper knowledge of women's health at this stage of life could be useful to design more effective weight control interventions.

Therefore, with this research project, we aimed to assess how pregnancy and other reproductive factors influence the association between body weight and psychological, social and biological factors in Portuguese women. To answer this main question, five specific objectives were outlined and pursued, resulting in five papers:

- I. To characterize weight differences between women and weight change over time in adult women from the general population and to assess the association of sociodemographic, reproductive and lifestyle characteristics with such variation.
- II. To characterize weight differences between women and weight change over time in fertile women within seven years after the delivery of a liveborn, and to assess the effects of sociodemographic, reproductive and lifestyles characteristics with such variation.
- III. To assess the impact of body image satisfaction before pregnancy, using current and desired body size, on body mass index 4 years after delivery.

- IV. To explore the relation of childhood, adulthood socioeconomic position and social trajectory with body image satisfaction immediately before pregnancy in primiparous and multiparous mothers.
- V. To characterize the healthy excessive weight in women 4 years after delivery concerning its prevalence, fat characteristics and identification of sociodemographic, genetic, reproductive or lifestyles factors that can be associated with this phenotype.

As illustrated in Figure 7, the first objective is based on women from the EPIPorto adult cohort and the last four objectives on mothers of the Generation XXI birth cohort.



Figure 7. Schematic depiction of the specific objectives of the thesis.

RESEARCH METHODS

The objectives of this thesis were accomplished through the analysis of data obtained from two Portuguese population-based cohorts: EPIPorto and Generation XXI. Regarding the EPIPorto adult cohort, information about baseline and the first follow-up was analysed. Concerning Generation XXI, we used data from the baseline and follow-ups at 4 and 7 years after delivery. A general description of the participants and data collection of both cohorts is provided below. The selection of participants eligible for each analysis depends on the specific objectives of the investigations and is described in detail in the methods sections of the individual papers.

THE EPIPORTO COHORT

The EPIPorto study is a population-based cohort of adult inhabitants of the city of Porto, Portugal with the aim of assessing the determinants of health in the adult population. The recruitment occurred between 1999 and 2003, when non-institutionalized inhabitants were selected using random digit dialing. At the time, 97% of households had a landline telephone, which assured the representativeness of eligible households. After the identification of a household, permanent adult residents were characterized according to age and sex, and one adult was selected by simple random sampling and invited to visit the Department of Clinical Epidemiology, Predictive Medicine and Public Health at the University of Porto Medical School for an interview and a physical examination. If there was a refusal, replacement was not allowed. All participants were Caucasian, had Portuguese citizenship and were aged 18 years or over. The participation rate was 70% and during this period 2485 subjects, of which 1539 women, were recruited.

A follow-up evaluation was conducted between 2005 and 2008 following the same protocol and 1686 (68%) participants (62% women) of the total cohort were reevaluated, the median follow-up period being 5 years. During this period, 122 (4.9%) participants deceased, 253 (10.2%) refused to participate in a new evaluation and 428 (17.2%) were lost to follow-up, the remaining being scheduled for a visit in our Department. Regarding only women, 44 (2.8%) of them deceased, 175 (11.4%) refused to participate in a new evaluation and 273 (17.7%) were lost to follow-up, the remaining 1047 being scheduled for a visit to our premises.

Regarding baseline and follow-up visits, two similar questionnaires and the same physical examination procedures were performed. Trained interviewers conducted a personal interview, using a structured questionnaire comprising self-reported data on sociodemographics (age, gender, marital status, years of formal education, occupation), personal and family medical history, lifestyles (physical activity, smoking and alcohol intake) and psychological characteristics (health-related quality of life, depressive symptoms). Physical examination was performed during the morning, after a 12-hour over-night fasting and included anthropometry measurements (weight, height, waist and hip circumferences), blood pressure, electrocardiogram, lung function and blood sampling. All the instruments were carefully standardized and calibrated regularly. Both the questionnaires and physical examinations were performed by interviewers that were trained by a multidisciplinary team.

THE GENERATION XXI BIRTH COHORT

The Generation XXI is the first prospective Portuguese population-based birth cohort recruited with the purpose of analyzing prenatal growth and development, identifying their modifiable determinants, seeking to better understand health during childhood and later in adolescence and adulthood, thereby contributing to health gains among the population.

This cohort was assembled between 2005 and 2006 at all five public maternity units covering the metropolitan area of Porto, Portugal: Centro Hospitalar de Vila Nova de Gaia (CHVNG), Centro Hospitalar do Porto – Maternidade de Júlio Dinis (MJD), Hospital de São João (HSJ), Centro Hospitalar do Porto - Hospital de Santo António (HSA), and Unidade Local de Saúde de Matosinhos – Hospital Pedro Hispano (HPH). The maternities corresponded to level III units, with differentiated perinatal support, and all except MJD, were included in a general hospital, with a variety of medical and surgical specialties. In 2004, these hospitals were responsible for 91.6% of the deliveries in the whole catchment population, with the remaining occurring in private hospitals/clinics.

All mothers resident in the catchment area who delivered a live-born child (with a gestational age ≥ 24 weeks) in one of the five units, during the cited period were eligible and were invited to join the study, 24 to 72 hours after delivery. Seventy

percent of the eligible mothers were invited to participate and, of these, 91.4% accepted to participate. A total of 8647 infants, corresponding to 8495 mothers, were enrolled in the cohort.

At baseline and during the hospital stay, interviewers at the five hospitals were responsible for the study presentation and subsequent invitation of the mothers after delivery. Data were collected, in a face-to-face interview, conducted by trained interviewers using structured questionnaires. Clinical records were also reviewed at birth by the same interviewers to retrieve data on prenatal care, pregnancy complications, delivery and neonatal characteristics.

Four years after birth, between 2009 and 2011, a follow-up evaluation of the entire cohort was performed. At that time, 5986 (69.2%) of the children were evaluated in a face-to-face interview, 1472 (17.0%) were unable to attend an in person evaluation but families provided data by telephone interview, and 1189 (13.7%) were lost to follow-up. Regarding the mothers, 5729 (67.4%) participated in the face face-to-face interview, 1428 (16.8%) provided self-reported data by telephone interview and 1338 (15.8%) were lost to follow-up. Overall, 86.2% of the children and 84.2% of the mothers were reevaluated.

Between April 2012 and April 2014, an average of 7 years after birth, all families were invited once again to attend the reevaluation of the cohort. In person, 5843 (63.4%) children and 5616 (66.1%) mothers were evaluated. One thousand and forty (12.0%) children and 956 (11.2%) mothers gave information by telephone interview, resulting in a total of 79.6% and 77.4% children and mothers evaluated, respectively.

Similar procedures were adopted throughout all the evaluations. In the face-to-face interviews at baseline and at both follow-ups, information was collected by interviewers, using structured questionnaires concerning the child's health and health of the mother. Data on demographic and socioeconomic characteristics, personal and family medical history, gynaecologic and obstetric history, lifestyles were collected. Additionally at baseline, information on prenatal care and body image before pregnancy were retrieved.

An anthropometric evaluation of the mother and the child was performed at both follow-ups by the interviewers. Infant and adult scales, infantometers, and stadiometers were carefully standardized and calibrated regularly. Specifically for the mother, weight, height, waist and hip circumferences were measured and weight before pregnancy was self-reported. Additionally, blood pressure was measured at both follow-ups, to the mothers and children. At baseline, venous blood samples were taken from the umbilical

cord, the mother and, whenever possible, the father. These samples were processed within two hours and aliquots for metabolic, hormonal and genetic analyses stored at -80°C . A sub-sample of randomly selected children provided a venous blood sample at both follow-ups and a sub-sample of randomly selected mothers collected a blood sample at the follow-up 4 years after delivery. For one of the works presented in this thesis (Paper V), we used information regarding total cholesterol, high-density lipoprotein (HDL), low-density lipoprotein (LDL), triglycerides, fasting plasma glucose concentration, C-reactive protein and fasting serum insulin parameters measured in the serum samples from the mothers.

For all the evaluations, interviewers were trained by a multidisciplinary team and were responsible for the application of the questionnaires to the mothers and for the physical examination of both family members.

STATISTICAL ANALYSES

Throughout this thesis, different statistical methods were explored. Every results section began with a sample description, with data being described as counts and proportions for categorical variables, mean and standard deviation (SD) for normally distributed continuous variables, and median and interquartile range (IQR) for non-normally distributed continuous variables. Then, different analytic approaches were used and are described in detail in the methods sections of each paper.

To pursue our aims, we defined specific outcomes for the preparation of Papers III, IV and V. Concerning Paper III and V, we calculated BMI as the weight in kilograms divided by the square of the height in meters (kg/m^2) and we used this variable as continuous and categorical. For the categorization, the standard WHO definition was used: underweight ($<18.5 \text{ kg}/\text{m}^2$), normal ($18.5\text{--}24.9 \text{ kg}/\text{m}^2$), overweight ($25.0\text{--}29.9 \text{ kg}/\text{m}^2$) and obese ($\geq 30 \text{ kg}/\text{m}^2$) (21). In Paper IV, we used body image satisfaction (BIS) as our outcome calculated as the difference between perceived self body size and ideal body size, both assessed after delivery, by the Stunkard silhouettes (193). This scale consists of nine numbered silhouette figures that increase gradually in size from very thin to very obese (1–9, respectively). Self body size was the number of the figure selected by participants in response to “choose the figure that reflects how you think you looked before you got pregnant” and ideal body size in response to “choose your

ideal figure". BIS was categorized as being satisfied with one's body image (difference between self and ideal body size =0); feeling too small regarding one's ideal (difference between self and ideal <0); and feeling too large regarding one's ideal (difference between self and ideal >0). Finally, for the definition of the main outcome for Paper V, we considered several obesity profiles considering BMI (normal/overweight/obese) and metabolic profile (healthy/not healthy) resulting in five groups: women with normal BMI, overweight women metabolically healthy, overweight women metabolically not healthy, obese women metabolically healthy and obese women metabolically not healthy. A metabolically healthy profile was defined as the absence of hypertension, diabetes, dyslipidemia, a level of C-reactive protein until 3 mg/l and being below the second tertile of HOMA-IR (homeostasis model assessment of insulin resistance).

Briefly, for the purpose of characterizing weight change over time and to ascertain its determinants (Papers I and II), we fitted mixed-effects models for the longitudinal analysis of body weight on time, with random intercepts and random slopes, after documenting with a likelihood ratio test that this model had better fit than simpler ones, with only random intercepts or no random effects at the women's level at all. Since several weight measures within one subject are correlated over time, these multilevel techniques assume that regression coefficients are allowed to differ between subjects. Also, these models allow to test possible interaction terms between each of the predictor variables with time and are able to indicate if the relationship between the predictor variable and the outcome differs along the longitudinal period (194).

In Paper III, to evaluate the association between BIS and BMI change over 4 years (continuous variable), linear regression models were used, and crude and adjusted coefficients were calculated with the respective 95% confidence intervals (95% CI). Multinomial logistic regression models were used to estimate odds ratio (OR) and the respective 95% CI, for the associations between exposures and outcomes in Papers III, IV and V and the respective confounders of each association were taken into account. Multinomial logistic regression is a simple extension of binary logistic regression that allows for more than two categories of the dependent or outcome variable (195): in Papers III and IV, both outcomes have three categories (BMI and BIS, respectively) and in Paper V the outcome has 5 categories.

All statistical analysis was performed using the statistical software Stata 11.0 (College Station, TX, 2009).

ETHICAL CONSIDERATIONS

In both cohorts, similar ethical considerations were taken into account. The study protocols for all the evaluation periods were approved by the Ethics Committee of Hospital de São João and by the Portuguese Authority of Data Protection. Procedures were developed in order to guarantee data confidentiality and protection. All participants received an explanation on the purposes and design of the study, and gave written informed consent at baseline and at follow-up evaluations according the Declaration of Helsinki from the World Medical Association.

Specifically considering the cohort Generation XXI, the children gave consent through their legal representative. For the telephone interviews, verbal consent was explicitly solicited.

PAPERS

PAPER I

Henriques A, Severo M, Alves L, Barros H, Azevedo A.
**Weight change and its determinants in Portuguese adult women: a longitudinal
analysis in the EPIPorto cohort.**
J Epidemiol Community Health [accepted].

Weight change and its determinants in Portuguese adult women: a longitudinal analysis in the EPIPorto cohort

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ABSTRACT

Background: We aimed to characterize between-women and within-woman weight change in adult women and to assess the association of sociodemographic, reproductive and lifestyle characteristics with such variation.

Methods: This study comprised 1040 adult women from a population-based cohort of adults from Porto, Portugal, assembled in 1999–2003 and reevaluated in 2005–2008 (median follow-up 5 years). A mixed-effects model for longitudinal analysis of body weight was fitted, with random intercepts and random slopes. Multivariate-adjusted coefficients with 95% confidence intervals (95% CI) were computed for the determinants of weight at baseline and weight change between visits.

Results: There was an average crude increase of 0.11 kg of measured weight per calendar year (95%CI: 0.05 to 0.17). In a multivariate model, despite not explaining differences in weight between women at baseline, years of fertile life were associated with individual weight change: -0.34 kg per year for women with up to 21 years of fertile life, whereas after that, weight increased progressively more with increasing fertile time (21.1–34.0 years: -0.34 kg+0.42 kg=0.08 kg; 34.1–41.0 years: -0.34 kg+0.46 kg=0.12 kg) up to 0.44 kg per year above 41 years. Height, age, education, marital status, residential neighborhood deprivation, number of children delivered and use of oral contraceptives influenced interindividual weight variation at baseline, but not weight change from baseline to follow-up.

Conclusions: Cross-sectional determinants of weight and those of weight change over time are different. Reproductive factors play important roles in explaining both differences among women and in individual weight change over time.

Keywords: women, reproductive life, weight change.

BACKGROUND

Worldwide, overweight and obesity have reached epidemic proportions and are a serious public health challenge (1, 2). The progressive increase in body weight over adult life is common, especially in Western developed countries (3).

Although not consensual (4-6), a considerable number of studies have reported significantly greater weight gain and body mass index (BMI) change over time among women compared to men (7-10). Despite recent data from the United States of America (USA) showing a trend towards increasing overweight and obesity (11), especially in older women, individual weight gain may be slowing in some countries (5). Additionally, weight variation is not equally observed in all ages and socioeconomic positions and depends on numerous factors encompassing psychosocial and lifestyle characteristics (4, 12, 13).

Fluctuations in female sex hormones throughout women's reproductive life may play a role in regulating weight and body fat distribution over time, but longitudinal studies are scarce (14). Also, pregnancy is associated with weight increase beyond delivery (15), but most studies focus on weight variation in the first years after delivery and data on long-term weight change after motherhood is limited. Moreover, factors that explain weight differences between women and determinants of individual weight variation should be sought complementarily, in order to identify subgroups of women at higher risk of excessive weight.

Our aim is to characterize weight differences between women and weight change over time in adult women and to assess the association of sociodemographic, reproductive and lifestyle characteristics with such variation.

METHODS

Study design and participants

This study is based on the EPIPorto cohort study, previously described elsewhere (16). Briefly, in 1999-2003, 2485 subjects, of whom 1539 were women, were recruited by phone from a random sample of households in Porto, Portugal using random digit dialing. Subsequently, a person aged 18 or over was randomly selected from each household.. Age ≥ 18 years old and being a permanent resident in Porto were the inclusion criteria. Refusals were not replaced from within the same household. Participants were invited for an interview and clinical examination, and the proportion of participation was 70%.

Between 2005 and 2008, 68% of the women were reevaluated, the median follow-up period being 5 years. During this period, 44 participants deceased, 175 refused to participate and 273 were lost to follow-up. The remaining 1047 were scheduled for a visit. We further excluded those with missing information on weight at baseline or follow-up evaluations ($n=7$). The final sample comprised 1040 women.

The local ethics committee approved the study protocol and participants provided written informed consent for both study visits.

Data collection and definition of variables

Apart from neighborhood socioeconomic class and dietary intake, only assessed at baseline, all of the variables were collected during both visits.

Women's age was recorded as a continuous variable. Education was recorded as completed years of schooling and used as a continuous variable. Marital status was grouped as married/living together, single/divorced/separated and widowed. Working condition was defined as employed, retired/disabled and no paid occupation (housewives or unemployed). Socioeconomic characteristics of neighborhoods in Porto were based on aggregated data at the census block level provided by the 2001 National Census, as previously explained (17). Using latent class analysis models, three discrete classes of neighborhoods in terms of socioeconomic characteristics were identified, grouping neighborhoods as 1=least deprived, 2=moderately deprived, 3=most deprived.

Current smokers included daily and occasional smokers, and ex-smokers included those who did not smoke for at least 6 months. Leisure-time physical activity was evaluated by questionnaire, exploring all activities over the past 12 months (18).

Subjects reported the average time spent doing activities like watching TV or reading (very light activities) as well as exercise (light, moderate or heavy). For each group of leisure-time physical activity, a standard metabolic energy equivalent task (MET) value was assigned. An average of 1.5, 2.5, 5.0 and 7.0 MET was attributed to very light, light, moderate and heavy activities, respectively (19). To calculate energy expenditure, the MET value was multiplied by the self-reported time spent doing each activity, in hours per day, and subsequently subjects were classified according to energy expenditure quintiles: first (<2.25); second ($2.25-3.75$); third ($3.76-5.79$); fourth ($5.80-8.43$); fifth (>8.43 MET*hours/day).

Parity, defined as the number of deliveries, was collected as a discrete variable and classified in 5 categories: none, 1, 2, 3, and 4 or more deliveries. Duration of oral contraceptive use was categorized as: never, ≤ 2 years, 2.1-10.0 years and >10.0 years. In order to classify women's reproductive stage, menopause was defined as the complete absence of menstruation for at least 12 months, the remaining women being categorized as premenopausal. For postmenopausal women, we calculated time since menopause by subtracting age at menopause from age at the time of each visit and created a variable with 5 categories: premenopausal, ≤ 5 , 6-10, 11-20, >20 years since menopause. To compute years of fertile life, we subtracted age at menarche from age at menopause; for premenopausal women, we subtracted age at menarche from age at the time of each visit. Then, we categorized this variable in 4 categories based on the 10th, 50th and 90th percentiles: ≤ 21.0 , 21.1-34; 34.1-41.0; >41.0 years of fertile life.

Dietary intake was measured using a validated semiquantitative food frequency questionnaire concerning the previous 12 months (20). Women reported the average frequency of consumption for each food item using nine categories, ranging from "never or less than once a month" to "six or more times a day"; subjects indicated the average portion consumed (lower, equal, or higher than a standard portion size) and the seasonal variation of consumption. Food consumption was converted into total energy and nutrients intake using Food Processor Plus software (version 7.02, 1997, ESHA Research, Salem, OR), adapted to Portuguese foods and dishes.

Anthropometrics were obtained with the participant wearing light clothing and no footwear. Body weight was measured to the nearest 0.1 kg using digital scales, and height was measured to the nearest centimeter in the standing position using a wall stadiometer. We used the same regularly calibrated instruments for the anthropometric evaluation at baseline and follow-up. BMI was calculated as weight (kg) divided by squared height (m^2), and further divided into the categories proposed by the World Health Organization (21). Given the low frequency of underweight participants, (8 at

baseline and 12 at follow-up), underweight and normal weight women were grouped together.

Statistical analysis

Statistical analyses were performed using Stata 11.0 (College Station, TX, 2009) and the significance level was fixed at 0.05. Sample characteristics are presented as counts and proportions for categorical variables, mean and standard deviation (SD) for quantitative variables with approximately symmetrical distributions and median and interquartile range (IQR) for quantitative variables with markedly skewed distributions. Proportions were compared using Cochran's Q test and continuous variables with paired-samples Student's *t* test or Wilcoxon signed-ranks test.

We fitted mixed-effects models for the longitudinal analysis of body weight, with random intercepts and random slopes, after documenting with a likelihood ratio test that this model had better fit than simpler ones. We estimated the intraclass correlation coefficient (ICC), interpreted as the proportion of total variance in weight that could be attributed to differences between women. To choose the variables for the fixed effects part of the model, we started with a list of potentially relevant determinants of weight or weight change presented in Table 1 based on the literature. Independent variables were included as continuous after confirming the linearity of their effect on weight. Regarding age, a quadratic term was added, to account for a non-linear association (increasing with age up to old age and then decreasing). Each of these variables and their interaction with time were initially tested adjusting only for the baseline age, baseline age squared, and their respective interaction terms with time, and height. If the product term for the interaction of each potential predictor with time was not significant, it was removed from the model. Then, if the age-, height- and time-adjusted main effect of the predictor was not significantly associated with weight, the variable was no longer considered. Starting with all variables still being considered at this stage, we used a backward stepwise approach, based on Wald tests, to remove variables one by one. The objective was to achieve the most parsimonious model with the best fit.

Age was modeled and expressed as the difference between each woman's age and the sample mean, thus representing years above or below the sample mean. Therefore, for a woman with an average age, this difference is zero and so the product-term of age with time is also zero, and the coefficient for time's main effect directly expresses the weight variation per calendar year.

Ethics

All the phases of the study complied with the Ethical Principles for Medical Research Involving Human Subjects expressed in the Declaration of Helsinki. The study was approved by the University of Porto Medical School/ Centro Hospitalar de São João ethics committee and a signed informed consent was obtained from participants in every visit.

RESULTS

At baseline, women's mean (SD) age was 52.1 (13.9) years. The median education was 8.0 years, with almost one third having completed high school and 40.9% having ≤ 4 years of education. Between baseline and follow-up evaluations, the proportion of widows increased (14.6% to 19.3%) and the proportion of employed women decreased (51.4% to 31.8%). A quarter were living in the least deprived neighborhoods at baseline and almost a fifth in the most deprived areas. More than 70% of women never smoked. One-tenth of women had at least four deliveries and more than a fifth used oral contraceptives for over 10 years. At follow-up, almost 70% of women had experienced menopause and 12.7% had more than 41 years of fertile life. Other characteristics are shown in Table 1.

The baseline weight ranged from 40.3 to 127.6 kg, with a mean (SD) of 65.9 (12.2) kg. In the follow-up evaluation, the mean (SD) weight was 66.4 (12.6) kg, ranging from a minimum of 36.7 kg to a maximum of 132.5 kg. The weight change from baseline to follow-up ranged from a loss of 30 kg to a gain of 26 kg, the mean (SD) being a gain of 0.53 (5.1) kg.

When considering a model with only random intercepts (Table 2, Model 1), the ICC was 91.6%, demonstrating that the weight differences were mainly between women, with strong individual tracking, that is, those who were heavier at the baseline evaluation were also heavier at the follow-up visit (likewise for the lighter ones). The crude change in weight over time was an average increase of 0.11 kg per year (95%CI: 0.05 to 0.17), varying considerably between women (time slope $SD = \sqrt{0.357} = 0.597$ kg/year). The inclusion of random slopes to account for these different individual trajectories explained almost half of the residual variance, improving the model's fit (Table 2, Model 2). All results reported hereafter are from models with random intercepts and random slopes at the woman's level.

Model 3 was estimated including the significant fixed effects of potential weight determinants. Despite not further explaining weight changes from baseline to follow-up, this model was able to explain more residual variance and 21.1% of the between-women weight differences at baseline (Table 2).

In a multivariate model, independent determinants of a higher weight at baseline were height, older age, lower education, having a partner, living in the most deprived neighborhoods, higher parity and use of hormonal contraceptives. Years of fertile life remained the only predictor of weight change from baseline to follow-up. After adjustment for all of the variables presented in Table 3, the annual weight change

between both evaluations was -0.34 kg for women in the ≤ 21 years of fertile life category, whereas, above 21 years of fertile life, weight increased progressively more with increasing years of fertile life (21.1-34.0 years of fertile life: $-0.34 \text{ kg} + 0.42 \text{ kg} = 0.08 \text{ kg}$; 34.1-41.0 years of fertile life: $-0.34 \text{ kg} + 0.46 \text{ kg} = 0.12 \text{ kg}$,) up to +0.44 kg per year with over 41 years of fertile life (Table 3).

DISCUSSION

Our results show a broad variability in weight, not only between women's initial weights but also in weight change between visits. Height, age, education, marital status, residential neighborhood deprivation, number of children delivered and use of oral contraceptives explained differences in weight between women at baseline, but not weight change over time. Weight gain increased with years of fertile life.

The mixed-effects model for longitudinal analysis allowed the regression coefficients to vary between subjects and to demonstrate that the effect of some variables on weight throughout time is not always the same. This is a statistically rigorous method highly suitable for the analysis of longitudinal data. However, the interpretation of the regression coefficients can be tricky; for example, a coefficient of 1.79 for the association between having 1 previous delivery (compared to none) and weight means that 1) the average difference in baseline weight between women with one previous delivery and those with no previous deliveries is 1.79 kg and; 2) nulliparous women who have a delivery during the follow-up period experience an average weight gain of 1.79 kg during that period. The real interpretation is a combination of both relationships (22).

This study demonstrates an annual weight increase among all women, although not as marked as other European (12) and non-European studies (7, 10). A Scottish study evaluated patterns of measured weight change over 9 years in two age-defined cohorts aged 39 and 59 and showed a large increase in the prevalence of excessive weight between 1991 and 2000. Age was the only variable that significantly predicted weight change over time with younger women gaining more weight than older ones (12). In our study, the age spectrum is larger, ranging from 18 to 93 years, allowing us to draw conclusions for older women. It is established that women gain weight from early adulthood to around 65 years of age, after which the increase levels off (23), coherent with the results observed in our sample.

A study investigating the predictors of weight maintenance in young Australian women emphasized that weight maintainers were more likely to be in managerial or professional occupations, to have never married, and to not be mothers (24). In our study, marital status and parity explained differences in weight between women at baseline but not weight variation between visits. Some differences for this discrepancy between studies could be due to the age range that is considerably narrower in this Australian study (18-23 years at baseline). Nevertheless, we were able to show that

marital status and motherhood have a substantial impact on weight, even among older women.

A review covering longitudinal studies in developed countries highlighted the relatively consistent inverse association between occupation and weight gain among women, whereas the evidence was more inconsistent for education or income (3). A Dutch cohort study showed that whilst socioeconomic position was inversely related to BMI cross-sectionally, it was not associated with BMI change (25). Concerning our study and after multivariate adjustment, education and neighborhood deprivation were inversely associated with weight, which is consistent with the majority of recent literature concerning socioeconomic position (26), although not with weight change over time.

The same justification can be applied to the use of oral contraceptives. A previous study found an association between oral contraceptives and short term weight change regardless of women's initial weight (27), however, this study observed the use of oral contraceptives for a short period of time. We observed that when considering longer periods of oral contraceptives use, an association between this variable and weight change was not detected. Possibly, this effect is evident in the initial period of oral contraceptives use but weight then stabilizes.

Contrasting with other reproductive variables considered, years of fertile life were associated with weight change from baseline to follow-up, with a larger annual weight increase with increasing fertile years of life. Estrogens promote the accumulation of subcutaneous fat (28) and the menopausal loss of estrogen is associated with an increase in central fat (29). Additionally, the type of estrogens produced during reproductive years is not always the same (30). This change in endogenous estrogens exposure throughout life can explain why years of fertile life, number of pregnancies and oral contraceptives, each expected to reflect higher exposure to estrogens, do not all have the same effect on weight. For premenopausal women, the number of years of fertile life is still changing, whereas for post-menopausal years this is a fixed characteristic. The effect of years of fertile life and its interaction with time were similar among both groups of women (data not shown), supporting the consistency in the interpretation of the results in the whole population. Since a gradual and significant association with weight change was found, future studies should take into account laboratory measures of hormones to provide a deeper knowledge of what type of estrogen exposures can impact weight variation.

This is one of the few studies assessing weight changes longitudinally in a large community sample of adult women using a statistically rigorous method and all anthropometrics were measured and not self-reported. Moreover, evidence on the

effect of variables concerning women's reproductive life on weight is controversial and many established ideas both in the population and among health care professionals are not evidence based. Looking into different aspects of women's reproductive life (e.g. parity, menopause, years of fertile life), together with other well-known weight determinants in the same study, helps disentangle their effect.

At the same time, our final model explained only half of the residual variance suggesting that, despite all of the potential determinants being considered, we still lack the identification of major contributors. In order to address this potential limitation, we tested the effect of some of the major diseases and medicines expected to change weight and weight variation (cancer, hyper and hypothyroidism, depression and taking corticosteroids or doing thyroid therapy) but they did not influence weight change during the study period and therefore were not kept in the final model. Also, in a subsample of 609 women, the physical and mental dimensions of health-related quality of life were assessed using the self-administered Portuguese versions of Medical Outcomes Study 36-Item Short Form Survey (SF-36) (31) and depressive symptoms using Beck Depression Inventory (32) but, after adjustment for all of the confounders, no effect was found (data not shown).

In conclusion, the results of this study support that cross-sectional determinants of weight and those of weight change over time are different, and both should be taken into account complementarily when designing interventions for weight control. Reproductive factors such as years of fertile life should be considered in the influence on excessive weight, in addition to previously established weight determinants.

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The authors declare that they have no conflicts of interest.

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Table 1. Participants' characteristics at baseline and follow-up evaluations

	Baseline n (%) [*]	Follow-up n (%) [*]	<i>p</i>
Age (years)			
Mean (SD)	52.1 (13.9)	57.7 (14.3)	<0.001
Education (years)			
Median (IQR)	8.0 (4.0-14.0)	8.0 (4.0-13.0)	<0.001
Marital status			
Married/living together	662 (63.6)	612 (58.9)	<0.001
Single/divorced/separated	226 (21.7)	227 (21.8)	
Widowed	152 (14.6)	201 (19.3)	
Working condition			
Employed	534 (51.4)	222 (31.8)	<0.001
Retired/disabled	273 (26.2)	315 (45.1)	
No paid occupation	233 (22.4)	161 (23.1)	
Neighborhood socioeconomic classes			
Class 1 (least deprived)	251 (25.9)	NA	NA
Class 2	554 (57.1)	NA	
Class 3 (most deprived)	165 (17.0)	NA	
Smoking status			
Never	741 (72.5)	746 (71.9)	0.132
Current	170 (16.6)	147 (14.2)	
Former	111 (10.9)	144 (13.9)	
Energy expenditure in leisure-time physical activity (quintiles – MET*hours/day)			
< 2.25	191 (18.7)	204 (21.6)	0.146
2.25-3.75	187 (18.3)	206 (21.8)	
3.76-5.79	182 (17.8)	209 (22.1)	
5.80-8.43	194 (19.0)	199 (21.1)	
> 8.43	267 (26.2)	126 (13.4)	
Parity			
None	213 (20.5)	202 (19.6)	0.001
1	224 (21.6)	231 (22.4)	
2	359 (34.6)	353 (34.2)	
3	137 (13.2)	146 (14.2)	
≥ 4	104 (10.0)	100 (9.7)	
Duration of oral contraceptives use (years)			
Never	380 (36.6)	357 (44.7)	0.317
≤ 2.0	191 (18.4)	123 (15.4)	
2.1-10.0	254 (24.5)	86 (10.8)	
> 10.0	212 (20.4)	233 (29.2)	
Time since menopause (years)			
Premenopausal	456 (44.2)	323 (31.7)	<0.001
≤ 5.0	110 (10.7)	91 (8.9)	
5.1-10.0	120 (11.6)	109 (10.7)	
10.1-20.0	198 (19.2)	217 (21.3)	
> 20.0	148 (14.3)	280 (27.5)	
Years of fertile life			
≤ 21.0	129 (12.8)	82 (8.1)	<0.001
21.1-34.0	465 (46.0)	403 (39.9)	
34.1-41.0	363 (35.9)	398 (39.4)	
> 41.0	54 (5.3)	128 (12.7)	
Fruits and vegetables consumption			
< 5 portions per day	446 (43.7)	NA	NA
≥ 5 portions per day	573 (56.2)	NA	

Total energy intake (calories/day)			
Median (IQR)	1998 (1674-2371)	NA	NA
Carbohydrates (g/day)			
Median (IQR)	250.9 (208.3-302.3)	NA	NA
Total fat (g/day)			
Median (IQR)	66.1 (52.3-80.8)	NA	NA
Saturated fat (g/day)			
Median (IQR)	20.4 (15.6-25.5)	NA	NA
Weight (kg)			
Mean (SD)	65.9 (12.2)	66.4 (12.6)	<0.001
Height (cm)			
Mean (SD)	155.9 (6.0)	155.2 (6.1)	<0.001
Body mass index (kg/m²)			
< 25.0	379 (36.8)	339 (32.6)	
25.0-29.9	382 (37.1)	388 (37.3)	
≥ 30	268 (26.0)	313 (30.1)	<0.001

IQR, interquartile range; MET, metabolic equivalent of task; NA, not applicable; SD, standard deviation.

*except for age, weight and height summarized as mean and standard deviation, education, total energy intake, carbohydrates, total fat and saturated fat, summarized as median and interquartile range

Note: In each variable, the total may not add up to 1040 due to missing data

Table 2. Random effects parameters of the different models considered for weight change over time

	Model 1[*]	Model 2[†]	Model 3[‡]
Time slope variance (SE)	NA	0.357 (0.054)	0.486 (0.087)
Proportion of explained variance [§] (%)	NA	REF	-36.1%
Between-women variance (SE)	140.647 (6.460)	141.192 (6.418)	111.336 (5.479)
Proportion of explained variance (%)	REF	-0.4%	21.1%
Within-woman (residual) variance (SE)	12.894 (0.566)	7.237 (0.686)	6.176 (0.802)

NA, not applicable; REF, reference; SE, standard error.

^{*} Model 1: Crude model with random intercepts for the women;

[†] Model 2: Model 1 plus random slopes for the women;

[‡] Model 3: Model 2 plus adjustment for the fixed effects of height, age at baseline, age at baseline squared, education, marital status, neighborhood socioeconomic classes, number of children, duration of oral contraceptives, years of fertile life and interaction between years of fertile life and time;

[§] Proportion of variance explained (%), compared to Model 2: it corresponds to $1 - (\text{variance [Model 3]} / \text{variance [Model 2]})$;

^{||} Proportion of within-woman variance explained (%), compared to Model 1: for each model (x), it corresponds to $1 - (\text{Within-woman variance [Model x]} / \text{Within-woman variance [Model 1]})$.

Table 3. Age-, height and time-adjusted effects of each sociodemographic, reproductive and lifestyles factors on weight (β)

	β (95%CI)*
Time (per year)	-0.34 (-0.64 to -0.03)
Height (per 1 cm)	0.57 (0.46 to 0.69)
Age at baseline (per year deviation from 52 years of age)	0.10 (0.03 to 0.17)
Age at baseline²	-4×10^{-3} (-8×10^{-3} to -1×10^{-3})
Education	-0.46 (-0.60 to -0.32)
Marital status	
Married/living together	0 (REF)
Single/divorced/separated	-2.14 (-3.56 to -0.93)
Widowed	-1.08 (-2.50 to 0.34)
Neighborhood socioeconomic classes	
Class 1 (least deprived)	0 (REF)
Class 2	1.05 (-0.61 to 2.73)
Class 3 (most deprived)	3.51 (1.27 to 5.75)
Parity	
None	0 (REF)
1	1.79 (-0.11 to 3.70)
2	1.41 (-0.51 to 3.34)
3	2.26 (-0.02 to 4.54)
≥ 4	5.34 (2.80 to 7.87)
Duration of oral contraceptives (years)	
Never	0 (REF)
≤ 2.0	1.38 (0.34 to 2.43)
2.1-10.0	1.04 (0.16 to 2.24)
> 10.0	1.52 (0.30 to 2.74)
Years of fertile life	
≤ 21.0	0 (REF)
21.1-34.0	0.11 (-0.71 to 1.48)
34.1-41.0	0.52 (-1.42 to 2.47)
> 41.0	0.37 (-2.33 to 3.06)
Years of fertile life*time	
≤ 21.0 *time	0 (REF)
21.1-34.0*time	0.42 (0.09 to 0.75)
34.1-41.0*time	0.46 (0.12 to 0.80)
> 41.1 *time	0.78 (0.35 to 1.20)

95% CI, 95% confidence interval; REF, reference.

* Estimated by mixed models with random intercepts and random slopes for women and adjusted for all variables in the table. As an example of interpretation, a woman with less than 21 years of fertile life lost 0.34 kg/year, while a woman with more than 41 years of fertile life had an annual weight gain of 0.44 kg ($-0.34+0.78=0.44$).

PAPER II

Henriques A, Severo M, Alves L, Santos AC, Azevedo A.
**Weight change and its determinants in childbearing women: a longitudinal
analysis in mothers of a Portuguese birth cohort.**
[submitted].

Weight change and its determinants in childbearing women: a longitudinal analysis in mothers of a Portuguese birth cohort

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ABSTRACT

Background: Factors known to be associated with weight change in childbearing women only partly explain the phenomenon. We aimed to characterize between-women and within-woman weight change in childbearing women and assess the effects of sociodemographic, reproductive and lifestyles characteristics.

Methods: This study comprised 4475 mothers of a Portuguese birth cohort evaluated in 2009-2011 (Visit 1) and 2012-2014 (Visit 2) (median follow-up: 2.8 years). We fitted a mixed-effects model for longitudinal analysis of body weight on time, and computed multivariate-adjusted coefficients with 95% confidence intervals (95% CI) for the determinants of weight at Visit 1 and weight variation between visits.

Results: Measured weight increased on average 0.27 kg per year (95%CI: 0.23 to 0.33). A model with random intercepts, random slopes (to account for different individual trajectories) and fixed effects, explained 12.2% of the weight change from Visit 1 to Visit 2 and 12.6% of the between-women differences at Visit 1. Despite a higher number of cross-sectional determinants of weight at Visit 1, marital status, smoking status and soft drinks intake were the only independent predictors of weight change between visits.

Conclusions: The influence of sociodemographic, obstetric and lifestyles factors on weight is not the same throughout time. This work contributed to identify childbearing women at increased risk of an unhealthy weight trajectory.

Keywords: weight change, women, childbearing age, obesity.

BACKGROUND

The prevalence of excessive weight has increased all over the world (1) and remains high despite a slowdown in adult obesity in some developed countries. Portugal is no exception and, in 2013, 54.6% of adult women were overweight or obese (2).

Little is known about the patterns of individual weight change during adulthood but available longitudinal analyses highlight that the greatest risk of weight gain occurs between the ages of 25 and 50 years, and suggest that interventions for weight management targeting this segment of the population would be the most fruitful (3-5). Motherhood is one of the most challenging experiences that occur in women at this time in life and many identify having a baby as the main cause of their weight gain (6). However, available data are not consistent in demonstrating a strong association between childbearing and weight gain (7-9), at least partly because study periods, sample characteristics and control for potential confounders vary considerably.

Several demographic, behavioral, and psychological characteristics have been related to weight gain over time such as younger age, lower levels of physical exercise, higher fat intake, and smoking cessation (10), living with a partner (7) or body image dissatisfaction before pregnancy (11). However, all the predictors studied so far only partly explain weight change and most of the variance remains unexplained.

A better understanding of weight management among childbearing women could result in more effective prevention strategies, benefiting not only women but also their children. Therefore, our aim was to characterize weight differences between women and weight change over time in fertile women within seven years after the delivery of a liveborn, and to assess the effects of sociodemographic, reproductive and lifestyles characteristics.

METHODS

Study design and participants

This study is based on the birth cohort Generation XXI, described elsewhere in detail (12). Briefly, in 2005-2006, 8495 women, who gave birth to 8647 infants, were enrolled into the cohort after the child's birth. They were recruited in the maternity clinics of five public hospitals covering the metropolitan area of Porto, Portugal.

Follow-up evaluations of the Generation XXI children were conducted at 4 years in 2009-2011 (Visit 1) and at 7 years in 2012-2014 (Visit 2), the median time between visits being 2.83 years. Of the total sample of mothers, 5729 (67.4%) and 5616 (66.1%) attended a face-to-face evaluation, comprising questionnaires and physical examination (anthropometrics and blood pressure) at Visit 1 and Visit 2, respectively. Of the 4854 women that attended the face-to-face interviews, we further excluded those who were pregnant at any of the visits (n=240), with missing information on weight at any visit (n=135) or who reported having undergone a bariatric surgery (n=4). Thus, the final sample comprised 4475 women.

Data collection and variables definition

In both visits, a personal interview and a physical examination were conducted.

Apart from soft drinks intake and physical exercise, only assessed at Visit 1, all the variables were collected at both visits.

Women's age was recorded as a continuous variable. Education was recorded as completed years of schooling and used as a continuous variable. Marital status was categorized as partnered (married or living together) and not partnered (separated, divorced, widow or single). Household monthly income was inquired using previously defined categories (less than 500 €, 500 to 1000 €, 1001 to 1500 €, more than 1500 €). Working condition was defined as employed, unemployed, housewife and others (student or retired).

The number of pregnancies was recorded including the enrolled infant. Information about hormonal contraceptives included ever use of hormonal contraceptives (contraceptive pill, patch or ring and subdermal implant), and women were then classified as never/former and current users at the time of each evaluation. Years of fertile life were computed by subtracting menarche age from women's age at the time of each visit, and categorized based on the 10th, 50th and 90th percentiles: ≤ 16, 16.1-24; 24.1-31.0; >31.0 years of fertile life.

Current smokers included both daily and occasional smokers and ex-smokers those that did not smoke for at least 6 months. At Visit 1, a food frequency questionnaire was used to assess the current frequency of soft drinks intake, without considering portion sizes. Taking into account their distribution, soft drinks intake was categorized as: < once a month, ≥once a month/< once a day, ≥once a day. Physical exercise was considered as the practice of any type of exercise (mild, moderate or vigorous), regardless of the intensity or duration.

Weight was measured to the nearest 0.1 kg in light clothing, and height was measured without shoes to the nearest 0.1 cm. BMI was calculated as weight (kg) divided by squared height (m²), and divided into the categories proposed by the World Health Organization (13).

Statistical analysis

All statistical analyses were performed using the statistical software Stata 11.0 (College Station, TX, 2009) and the significance level was fixed at 0.05. Sample characteristics are presented as counts and proportions for categorical variables, mean and standard deviation (SD) for quantitative variables with approximately symmetric distributions, and median and interquartile range (IQR) for quantitative variables with markedly skewed distributions.

We fitted mixed-effects models for the longitudinal analysis of body weight on time, with random intercepts and random slopes, after documenting with a likelihood ratio test that this model had better fit than simpler ones, with only random intercepts or no random effects at the women's level at all. We estimated the intraclass correlation coefficient (ICC) which can be interpreted as the proportion of total variance in weight that could be attributed to differences between women. To choose the variables for the fixed effects part of the model, we departed from a list of potentially relevant determinants of weight or weight change based on previous knowledge. Independent variables were included as continuous after confirming the linearity of their effect on weight. Each of these variables and its interaction with time were initially tested adjusting only for baseline age, age's interaction term with time and height. If the product term for the interaction of each potential predictor with time was not significant, it was removed from the model. Then, if the age-and height-adjusted main effect of the predictor was not significantly associated with weight, the variable was no longer considered. Departing from all variables still being considered at this stage, we used a backward approach, based on Wald tests, to remove variables one by one. The objective was to achieve the most parsimonious model with the best fit.

Ethics

All the phases of the study complied with the Ethical Principles for Medical Research Involving Human Subjects expressed in the Declaration of Helsinki. The study was approved by the University of Porto Medical School/ Centro Hospitalar de São João ethics committee and a signed informed consent was obtained from participants in every visit.

RESULTS

Participants' characteristics are summarized in Table 1. At Visit 1, women's mean (SD) age was 34.4 (5.2) years and median education was 12.0 years. Between visits, the proportion of partnered women decreased (90.9% to 75.3%). At both visits, more than 40% of women had a household monthly income above 1500 euros, more than three quarters were employed and almost a quarter were smokers. At Visit 1, 20.9% were consuming soft drinks at least once a day and less than a fifth practiced physical exercise. At Visit 2, 30% had only one child and more than half were using hormonal contraceptives (Table 1).

Weight at Visit 1 ranged from 36.8 kg to 159.0 kg, with a mean (SD) of 66.7 (13.1) kg. At Visit 2, the mean (SD) weight was 67.5 (13.2) kg, ranging from a minimum of 36.2 kg to a maximum of 158.4 Kg. The weight change from Visit 1 to Visit 2 ranged from a loss of 48.5 kg to a gain of 25.5 kg, the mean being a gain of 0.75 kg.

When considering a model with only random intercepts (Table 2, Model 1), the ICC was 92.3%, demonstrating that the weight differences were mainly between women, with strong individual tracking, that is, those who were heavier at Visit 1 were also heavier at Visit 2. The crude change in weight over time was an average increase of 0.27 kg per year (95%CI: 0.23 to 0.33), varying largely between women (time slope $SD = \sqrt{0.696} = 0.834$ kg/year). The inclusion of random slopes to account for these different individual trajectories explained more residual variance, improving the model's fit (Table 2, Model 2). All results reported hereafter are from models with random intercepts and random slopes at the women's level. A Model 3 was estimated including the fixed effects of potential weight determinants. Despite not further explaining residual variance, this model allowed to explain 12.2% of the weight change between visits and 12.6% of the between-women weight differences at Visit 1 (Table 2).

When adjusting for baseline age and height, women gained on average 0.20 Kg (95%CI 0.15 to 0.26) per calendar year. Independent interindividual determinants of higher weight at Visit 1 were higher height, lower education, having a partner, not being employed, higher number of pregnancies, not using hormonal contraceptives, more years of fertile life, never smoking and higher intake of soft drinks (Table 3).

Some of these variables also modified the effect of time on weight from Visit 1 to Visit 2. Considering marital status, partnered women had an individual weight increase of 0.18 kg/year and not partnered women had a higher weight gain, increasing 0.53 kg/year ($0.18 + 0.35 = 0.53$ kg/year, p for interaction < 0.001). Women with a higher household income had a lower weight gain per year when compared to those who had

a household income of less than 500 euros/month (1001-1500 euros/month: 0.15 kg/year). Although multiparous women were heavier than primiparous ones, they presented lower weight gain per year (≥ 3 pregnancies: 0.11 kg/year). Current users of hormonal contraceptives gained more weight between visits than non-users (0.27 kg/year). Furthermore, women with less than 24 years of fertile life gained weight each year (≤ 16 years: 0.52 kg/year; 16.1-24.0 years: 0.28 kg/year) and those who had more than 31 years of fertile life had an annual weight loss of 0.15 kg/year. Considering lifestyles, women who never smoked and women who reported intake of soft drinks less than once a month had the highest annual weight gain ($\beta=0.30$ kg; 95%CI: 0.23 to 0.37 and $\beta=0.36$ kg; 95%CI: 0.22 to 0.50, respectively) (Table 3).

In a multiple model, independent determinants of higher weight at Visit 1 were higher height, lower education, having a partner, not being employed, higher number of pregnancies, not using hormonal contraceptives, never smoking and a higher intake of soft drinks. Women who were partnered, never smoked and reported the lowest intake of soft drinks (less than monthly) had stable weight from Visit 1 to Visit 2, after adjustment for age, height and the above mentioned determinants of baseline weight between women (change: -0.05 kg/year (95%CI, -0.22 to 0.12)). In contrast, not partnered women gained weight over time and this change was significantly different from the null change of partnered women. Current smokers lost weight, a time change that is significantly different from that of never smokers. Although the intake of soft drinks was associated with being heavier at baseline, differences among categories of this variable tended to attenuate over time, with those who reported intaking soft drinks, particularly if occasionally, losing weight throughout time (Table 4).

DISCUSSION

This study shows a wide variability in weight changes in childbearing women, even over a short period of time. At baseline, height, education, marital status, working condition, number of pregnancies, hormonal contraceptives, and soft drinks intake significantly contributed to explain interindividual variability in weight. Although a substantial proportion of residual variance (78%) remained unexplained with the presently fitted models, marital status, smoking status and soft drinks intake were independently associated with weight change between visits.

This analysis reveals an overall annual weight increase, and, despite a considerable variability between women concerning individual weight over time, our results are coherent with the majority of studies (3, 10, 14) (15). Nevertheless, an American study showed a non-significant annual weight change of -0.2 kg in women (16), highlighting the inconsistency in weight variation. Even when considering similar study periods (*e.g.* prepregnancy - 24 months postpartum), discrepancies in weight change are found (17-19). Different aims and samples, different age ranges, settings, follow-up periods and analytic methods, should be pointed as possible reasons for the differences among studies. However, a recent European study, with an age range more similar to our study (24-39 years), showed an average weight change of 0.45 kg/year in women (20). This larger weight gain can be due more than twice the length of follow-up compared to our work.

Sociodemographic, obstetric and lifestyles variables were predictors of weight differences between women. Most of our results are coherent with previous literature from developed countries showing that education (21), marital status (22), employment status (23), parity (24) and smoking (25) influence weight. Nevertheless, our goal was to add knowledge regarding how these variables affect the time variation of individual weight using prospective data.

In a recent Swiss study, weight gain was negatively associated with age, living in couple and physical activity, and positively associated with current smoking (26). Results considering marital status were surprising, since generally partnered women have a higher increase in body weight (27, 28). What this study adds is that, although partnered women were heavier than not partnered women at Visit 1, not partnered women gained more weight over time. This result highlights that, at least for a specific group of childbearing women, interventions should not be addressed only for partnered women; not partnered women should also be considered, even if they take longer to gain weight.

Concerning smoking habits, Swedish women aged 45-73 years who never smoked had higher weight gain compared to those who smoked (28) while in our study never smokers presented a stable weight. Despite opposite results in occasional studies (26), most of the literature associates smoking with lower weight gain (29). In fact, this is coherent with women's belief that smoking is an effective method for weight control (30) and smokers' attitudes, beliefs, and experiences related to smoking cessation efforts should be explored. In our sample, women with a higher intake of soft drinks were heavier. However, women who consumed more often this type of drinks gained less weight from Visit 1 to Visit 2, this association being significant only for women who took soft drinks more than once per month but not daily. A study among young and middle-aged adults from Finland found an association between high intake of sweet beverages and increased weight gain over six years (20). One of the possible explanations for the discrepancy with our study results can be the lack of a good measure of soft drinks intake and the fact that the frequency of soft drinks intake was only assessed at Visit 1. This can also explain the lack of association between physical exercise and weight gain, since it is stated that being physically active is protective of weight increase over time (15, 19).

Several strengths can be found in this study. This is one of the few studies assessing weight changes longitudinally in a large community sample of childbearing women and all anthropometrics were measured at each time point and not self-reported. Also, a considerable number of potential determinants were tested together, not often found in the literature about weight variation.

Additionally, we used a statistically rigorous method suitable for the analysis of longitudinal data, by allowing the regression coefficients to vary between subjects. Only this kind of statistical methods allows the demonstration that the effect of several variables on weight throughout time is not constant, highlighting that a cross-sectional approach is insufficient to totally understand weight change over time. However, interpretation of the regression coefficients is two-way: for a coefficient of 0.107 1) the between-subjects interpretation indicates that a difference between two subjects of 1 unit in the predictor variable X is associated with a difference of 0.107 units in the outcome variable; 2) the within-subject interpretation indicates that a change within one subject of 1 unit in the predictor variable X over the follow up period is associated with a change of 0.107 units in the outcome variable. The real interpretation is a combination of both relationships (31).

The lack of data in psychological measures could have largely contributed to the low proportion of variance explained. However, at visit 2, a validated Portuguese version of the Hospital Anxiety and Depression Scale (HADS) (32) to assess anxiety

and depression symptoms was applied as well as the Stunkard Silhouettes (33) to assess body image satisfaction. When adding these variables to the multiple model, we observed that feeling too large compared to their ideal silhouette was a predictor of higher weight at Visit 1 and also the impact of this variable was different throughout time, with women feeling too large gaining more weight each year than women who felt satisfied with their silhouette. Higher levels of anxiety and depression were only predictors of higher weight at baseline. Although they cannot be tested as predictors of weight change between Visit 1 and Visit 2 due to the lack of baseline data, these shown results support the importance of psychological features on weight management in women in their thirties.

A relatively short period between Visit 1 and Visit 2, as well as only two point estimates for weight, can partly explain the absence of association between some determinants and weight change over time, and why the fixed part of model was not able to explain a considerable amount of weight variance. However, since these women are mothers of a birth cohort and are also evaluated periodically with their children, it will be possible to assess the impact of these psychological characteristics on weight change in the future. Additionally, we will be able to have more than two estimates for weight, which will allow a better weight change characterization throughout time.

In summary, the influence of sociodemographic, obstetric and lifestyle determinants on weight change over time and a more effective approach for weight control should take into account not only cross-sectional determinants of weight but also their longitudinal impact on weight variation. Understanding the role of modifiable factors and the mechanisms through which they may influence body weight may help to identify childbearing women at increased risk of an unhealthy weight trajectory.

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The authors declare that they have no conflicts of interest.

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Table 1. Participants' characteristics at Visit 1 and Visit 2

	Visit 1 n (%) [*]	Visit 2 n (%) [*]
Age (years)		
Mean (SD)	34.4 (5.2)	37.6 (5.2)
Education (years)		
Median (IQR)	12 (9-16)	12 (9-16)
Marital status		
Partnered	4062 (90.9)	3345 (75.3)
Not partnered	408 (9.1)	1096 (24.7)
Household monthly income (€)		
< 500	156 (3.5)	211 (4.7)
500-1000	993 (22.2)	1038 (23.2)
1001-1500	1269 (28.4)	1257 (28.1)
> 1500	1988 (44.5)	1892 (42.3)
Does not know/ Prefers not to answer	62 (1.4)	76 (1.7)
Working condition		
Employed	3449 (77.1)	3451 (77.4)
Unemployed	709 (15.9)	811 (18.2)
Housewife	200 (4.5)	150 (3.4)
Others	113 (2.5)	47 (1.0)
Number of pregnancies		
1	1649 (36.8)	1313 (29.6)
2	1825 (40.9)	1938 (43.8)
≥ 3	997 (22.3)	1178 (26.6)
Use of hormonal contraceptives		
Never/former	1943 (43.6)	2094 (47.7)
Current	2514 (56.4)	2296 (52.3)
Years of fertile life		
≤ 16.0	645 (14.8)	219 (5.0)
16.1-24.0	2327 (53.2)	1501 (34.2)
24.1-31.0	1249 (28.6)	2119 (48.2)
>31.0	150 (3.4)	553 (12.6)
Smoking status		
Never	2730 (61.0)	2767 (62.0)
Current	1046 (23.4)	1064 (23.8)
Former	697 (15.6)	635 (14.2)
Soft drinks intake		
< once a month	720 (16.2)	NA
> once a month/< once a day	2804 (62.9)	NA
≥ once a day	933 (20.9)	NA
Practice of physical exercise		
No practice	3604 (80.6)	NA
Does any kind of exercise	868 (19.4)	NA
Weight (kg)		
Mean (SD)	66.7 (13.1)	67.5 (13.2)
Height (cm)		
Mean (SD)	159.0 (5.7)	159.4 (5.8)
Body mass index (kg/m²)		
<25.0	2106 (47.1)	2016 (45.1)
25.0-29.9	1439 (32.2)	1493 (33.4)
≥30	929 (20.8)	966 (21.6)

IQR, interquartile range; NA, not available; SD, standard deviation.

^{*}except for age, weight and height summarized as mean and standard deviation, and education summarized as median and interquartile range.

Note: In each variable, the total may not add up to 4475 due to missing data.

Table 2. Random effects parameters of the different models considered for weight change over time

	Model 1[*]	Model 2[†]	Model 3[‡]
Time slope variance (SE)	NA	0.696 (0.183)	0.611 (0.174)
Proportion of explained variance [§] (%)	NA	REF	12.2%
Between-women variance (SE)	161.049 (3.550)	161.555 (3.559)	140.741 (3.68)
Proportion of explained variance (%)	REF	-0.3%	12.6%
Residual variance (SE)	13.415 (0.284)	10.337 (0.748)	10.505 (0.723)

NA, not applicable; REF, reference; SE, standard error.

^{*} Model 1: Crude model with random intercepts for the women;

[†] Model 2: Model 1 plus random slopes for the women;

[‡] Model 3: Model 2 plus adjustment for the fixed effects of height, age at baseline, education, marital status, interaction between marital status and time, work condition, number of pregnancies, use of hormonal contraceptives smoking status, interaction between smoking status and time, soft drinks intake, interaction between soft drinks intake and time;

[§]Proportion of variance explained (%), compared to Model 2: it corresponds to $1 - (\text{variance}[\text{Model 3}] / \text{variance} [\text{Model 2}])$;

^{||} Proportion of explained variance (%), compared to Model 1: for each model (x), it corresponds to $1 - (\text{variance}[\text{Model x}] / \text{variance} [\text{Model 1}])$.

Table 3. Age-, height and time-adjusted effects of each sociodemographic, reproductive, psychological and lifestyles factor on weight (β)

	β (95%CI)*
Time (per year)	0.20 (0.15 to 0.26)
Height (per 1 cm)	0.52 (0.46 to 0.57)
Age at baseline	0.07 (-0.01 to 0.14)
Education	-0.44 (-0.52 to -0.37)
Time (per year)	0.18 (0.11 to 0.24)
Marital status	
Partnered	0 (REF)
Not Partnered	-0.99 (-1.54 to -0.45)
Marital status*time	
Partnered*time	0 (REF)
Not Partnered*time	0.35 (0.15 to 0.54)
Time (per year)	0.54 (0.20 to 0.88)
Household monthly income (€)	
< 500	0 (REF)
500-1000	0.79 (-0.07 to 1.66)
1001-1500	0.60 (-0.28 to 1.47)
> 1500	-0.05 (-0.98 to 0.81)
Does not know/ Prefers not to answer	0.94 (-0.56 to 2.44)
Household monthly income (€)*time	
< 500*time	0 (REF)
500-1000*time	-0.42 (-0.80 to -0.04)
1001-1500*time	-0.39 (-0.75 to -0.03)
> 1500*time	-0.29 (-0.64 to 0.06)
Does not know/ Prefers not to answer*time	-0.56 (-1.25 to 0.13)
Working condition	
Employed	0 (REF)
Unemployed	1.13 (0.78 to 1.48)
Housewife	1.23 (0.47 to 1.99)
Others	0.85 (0.01 to 1.70)
Time (per year)	0.30 (0.20 to 0.39)
Number of pregnancies	
1	0 (REF)
2	1.21 (0.70 to 1.74)
≥ 3	2.05 (1.32 to 2.78)
Number of pregnancies*time	
1*time	0 (REF)
2*time	-0.16 (-0.34 to -0.03)
≥ 3 *time	-0.19 (-0.34 to -0.04)
Time (per year)	0.10 (0.01 to 0.19)
Use of hormonal contraceptives	
Never/former	0 (REF)
Current	-0.69 (-1.05 to -0.32)
Use of hormonal contraceptives*time	
Never/former*time	0 (REF)
Current*time	0.17 (0.04 to 0.29)
Time (per year)	0.52 (0.14 to 0.89)
Years of fertile life	
≤ 16.0	0 (REF)
16.1-24.0	0.54 (-0.09 to 1.16)
24.1-31.0	1.13 (0.23 to 2.02)
>31.0	1.91 (0.49 to 3.31)

Years of fertile life*time	
≤ 16.0*time	0 (REF)
16.1-24.0*time	-0.24 (-0.59 to 0.10)
24.1-31.0*time	-0.55 (-1.04 to -0.07)
>31.0*time	-0.67 (-1.35 to -0.01)
Time (per year)	0.30 (0.23 to 0.37)
Smoking status	
Never	0 (REF)
Current	-1.28 (-1.89 to -0.67)
Former	0.52 (-0.05 to 1.09)
Smoking status*time	
Never*time	0 (REF)
Current*time	-0.29 (-0.41 to -0.16)
Former*time	-0.15 (-0.32 to 0.01)
Time (per year)	0.36 (0.22 to 0.50)
Soft drinks intake	
< once a month	0 (REF)
> once a month/< once a day	2.14 (1.09 to 3.18)
≥ once a day	3.07 (1.80 to 4.34)
Soft drinks intake*time	
< once a month*time	0 (REF)
> once a month/< once a day*time	-0.22 (-0.37 to -0.07)
≥ once a day a day*time	-0.10 (-0.28 to 0.09)
Practice of physical exercise	
Sedentary	0 (REF)
Does any kind of exercise	-0.77 (-1.70 to 0.16)

95% CI, 95% confidence interval; REF, reference.

* Estimated by mixed models with random intercepts and random slopes for women, adjusting for time, age at baseline, the interaction between age at baseline with time, and height. As an example of interpretation, a partnered woman gained 0.18 Kg/year, while the remaining ones had an annual weight gain of 0.52 kg (0.18+0.35=0.53).

Table 4. Multivariate-adjusted effects of sociodemographic, reproductive, psychological and lifestyles factors on weight (β)

	β (95%CI)*
Time (per year)	-0.05 (-0.22 to 0.12)
Height (per 1 cm)	0.65 (0.60 to 0.70)
Age at baseline	0.03 (-0.03 to 0.09)
Education	-0.35 (-0.41 to -0.28)
Marital status	
Partnered	0 (REF)
Not partnered	-0.90 (-1.44 to -0.37)
Marital status*time	
Partnered*time	0 (REF)
Not partnered*time	0.37 (0.19 to 0.55)
Working condition	
Employed	0 (REF)
Unemployed	0.71 (0.35 to 1.07)
Housewife	0.96 (0.14 to 1.76)
Others	0.51 (-0.40 to 1.43)
Number of pregnancies	
1	0 (REF)
2	0.76 (0.31 to 1.11)
≥ 3	1.26 (0.63 to 1.89)
Use of hormonal contraceptives	
Never/former	0 (REF)
Current	-0.63 (-0.96 to -0.31)
Smoking status	
Never	0 (REF)
Current	-1.00 (-1.59 to -0.41)
Former	0.27 (-0.31 to 0.84)
Smoking status*time	
Never*time	0 (REF)
Current*time	-0.25 (-0.40 to -0.11)
Former*time	-0.05 (-0.28 to 0.08)
Soft drinks intake	
< once a month	0 (REF)
> once a month/< once a day	1.30 (0.42 to 2.12)
$\geq$ once a day	1.92 (0.87 to 2.98)
Soft drinks intake*time	
< once a month*time	0 (REF)
> once a month/< once a day*time	-0.22 (-0.38 to -0.07)
$\geq$ once a day a day*time	-0.12 (-0.30 to 0.06)

95% CI, 95% confidence interval; REF, reference.

* Estimated by mixed models with random intercepts and random slopes for women and adjusted for all variables in the table. As an example of interpretation, for a woman at the reference class of all variables, the annual weight change was -0.05 Kg/year if partnered, and +0.32 kg/year (-0.05+0.37) if not partnered.

PAPER III

Henriques A, Alves E, Azevedo A, Barros H.

Women's satisfaction with body image before pregnancy and body mass index 4 years after delivery in the mothers of Generation XXI.

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Women's Satisfaction with Body Image before Pregnancy and Body Mass Index 4 Years after Delivery in the Mothers of Generation XXI

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Abstract

Background: Body image satisfaction (BIS) influences body weight regulation and may contribute to long-term healthier lifestyle after pregnancy. Thus, we aimed to assess the association between BIS before pregnancy and body mass index (BMI) 4 years after the index pregnancy.

Methods: As part of the follow-up of a birth cohort, 3612 women with prepregnancy BMI >18.5 kg/m² were reevaluated 4 years after the birth of a child. BIS was defined as the difference between perceived and ideal body size before pregnancy, assessed by Stunkard Silhouettes after birth. The associations of BIS with BMI change (continuous) and BMI classes at 4 years, based on measured weight and height, were estimated using linear and multinomial regression, respectively.

Results: Among women with normal prepregnancy BMI, those who felt too small, regarding their ideal, had a 0.25 kg/m² smaller increase in BMI within 4 years and a lower likelihood of becoming overweight or obese [multivariate-adjusted odds ratio (OR) = 0.63; 95% confidence interval (95%CI): 0.44–0.91 and OR = 0.21; 95%CI: 0.05–0.91, respectively] than those satisfied with body image. Feeling too large was associated with a 0.41 kg/m² larger increase in BMI and a higher risk of becoming overweight or obese (OR = 2.12; 95%CI: 1.73–2.59 and OR = 3.42; 95%CI: 2.02–5.79, respectively). A similar, non-significant, trend was observed for overweight women. Obese women who felt too large had a non-significant decrease in BMI.

Conclusions: BIS plays a role in maternal body weight after delivery. Realistic body size goals may promote the motivation to lose weight and contribute to higher success in attaining them.

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Introduction

Worldwide, obesity is rapidly increasing particularly at younger ages and more women of reproductive age present excess weight [1,2]. In Portugal, the overall prevalence of overweight and obesity is also rising [3,4], with 40% of women in their thirties being overweight or obese [5].

Women are particularly vulnerable to become overweight after pregnancy [6]. A substantial weight increase occurs at this stage of women's reproductive life which may alter their weight change trajectory [7]. Currently, many women gain more weight than recommended during pregnancy [8], carrying an immediate higher risk of pregnancy and delivery complications [9], and gestational weight gain is associated with weight change postpartum [10,11]. A higher prepregnancy body mass index (BMI), higher weight gain during pregnancy and more weight retaining after delivery all contribute to women becoming overweight after pregnancy [6].

There is clear evidence that obesity is linked with poor body image [12–16], particularly in women [17,18] and body image could play a role in the social and psychological experience of being obese. Body image is a complex and multidimensional construct, containing both cognitive (attitudinal) and affective components [19]. It is essential to distinguish which specific dimension each study intends to address, namely considering the mechanisms involved and the potential for intervention, and to choose a tool that better measures that specific dimension [20]. In the present study, the attitudinal dimension will be assessed, specifically focusing on the evaluation component represented by self-ideal discrepancies to measure body satisfaction valuations [21].

Body image satisfaction (BIS) plays an important role in weight gain also during pregnancy [7]. Excessive weight gain during pregnancy and retention after delivery can be justified as common and unavoidable [8], and some women have a more relaxed attitude to weight gain in this period of time. This may reflect the

feeling of less pressure to be thin after pregnancy, as the role of “mother” confers respectability to weight gains that would otherwise be unacceptable [22]. Conversely, some women reported a significant decline in body image satisfaction from pre-pregnancy to early pregnancy [23] and this variation is extended to the postpartum period [7], although the nature of these disparities between women is not clear. Mothers who feel more dissatisfied with their bodies immediately after pregnancy have significantly greater long term weight gains. However, understanding the effect of pre-pregnancy BIS on postpartum weight changes is expected to be more relevant and amenable to planned intervention included in preconception and prenatal care, strengthening spontaneous changes in BIS related with the experience of motherhood [22].

Thus, BIS may be useful to identify women who are more susceptible of gaining excessive weight earlier. Therefore, we tested the hypothesis of a possible association between BIS before pregnancy, using the difference of the measures of current and desired body size, and BMI 4 years after delivery in mothers of a Portuguese population-based birth cohort.

Methods

Ethics Statement

The study protocol was approved by the Ethics Committee of Hospital de São João and by the Portuguese Authority of Data Protection on 27th of April, 2005 and was carried out in accordance with the principles of the 1964 Declaration of Helsinki. Written informed consent was obtained from all participants at baseline and follow-up evaluation. Were eligible to participate all women hospitalized for childbirth in one of the five public maternity units covering the metropolitan area of Porto, Portugal whose obstetric outcome was a live birth with at least 24 weeks of gestation. Of the invited mothers, 91.4% accepted to participate. All potential participants who declined to participate or otherwise did not participate were not disadvantaged in any other way by not participating in the study.

This study is based on the birth cohort Generation XXI which has been previously described [24]. Briefly, in 2005–2006, 8495 women, who gave birth to 8647 infants, were enrolled into the cohort after the child's birth. The recruitment occurred in all five public maternity clinics that at the time covered the metropolitan area of Porto, Portugal. During the hospital stay and within 72 hours after delivery, trained interviewers using structured questionnaires were responsible for data collection on demographic and socioeconomic characteristics, lifestyles, medical history, anthropometrics and body image perception.

Four years later, in 2009–2011, a follow-up evaluation took place, and 84.2% of the mothers were reevaluated. Of all mothers, 67.4% attended a face-to-face interview and physical examination at the study site, 16.8% provided self-reported data by telephone interview, leaving 15.8% lost to follow-up. In this study, women interviewed by telephone were excluded due to the lack of anthropometric data.

For the current analysis, we excluded 313 participants who had been recruited and evaluated from the first trimester of pregnancy to address specific objectives [25], since body image perception is expected to change during pregnancy. We also excluded 131 mothers with BMI <18.5 kg/m² at baseline because they were too few to be analyzed separately and probably very different, regarding BIS, from those with normal BMI to be aggregated in the same category; 164 mothers who were pregnant at the follow-up visit; and 1578 with missing data on any of the socio-economic characteristics, smoking before pregnancy, parity, weight gain

during pregnancy, breastfeeding, BMI before pregnancy and 4 years after delivery, or BIS. Therefore, we included in the analyses 3612 women with pre-pregnancy BMI ≥ 18.5 kg/m² who participated in the re-evaluation of the cohort and had complete information for the key variables considered.

Overall, among all mothers in the baseline cohort, those with complete data to be included in the final sample for analysis were older (≥ 35 years: 18.2% vs. 15.1%, $p < 0.001$) had a higher educational level (schooling > 12 years: 26.3% vs. 22.2%, $p < 0.001$) and higher household income (> 1500 /month: 29.3% vs. 26.8%, $p < 0.001$). Regarding BIS before pregnancy, they were more likely to consider themselves too large regarding their ideal body image (49.9% vs. 42.2%, $p < 0.001$) and they were also more frequently overweight/obese at baseline (BMI ≥ 25.0 : 31.6% vs. 29.1%, $p < 0.001$) than those who did not have all the information for the key variables.

Baseline Evaluation

Age was categorized as less than 25 years, 25 to 29 years, 30 to 34 years and 35 years or above. Education was categorized as less than compulsory elementary schooling (9 years), secondary school (10 to 12 years) and higher education (> 12 years). Household monthly income was inquired using previously defined categories: less than 1000 €, 1001 to 1500 €, more than 1500 € and women who didn't know or preferred not to answer.

Parity was recorded as the number of deliveries for each participant at baseline, including the delivery of the infant included in the cohort Generation XXI.

Assessment of exposure to smoking included information on the daily number of cigarettes smoked before and during pregnancy. Current smokers included both daily and occasional smokers, and those who had previously smoked but not in the last 3 months before pregnancy were considered former smokers.

At birth, pre-pregnancy weight was self-reported to the nearest 0.1 Kg and, assuming that a young adult woman does not have considerable changes in her height over four years [26], we used the height measured at the follow-up to calculate pre-pregnancy BMI. Mother's pre-pregnancy BMI was categorized according to the standard World Health Organization definition: underweight (< 18.5 kg/m²), normal (18.5–24.9 kg/m²), overweight (25.0–29.9 kg/m²) and obese (≥ 30 kg/m²) [23]. Weight gain during pregnancy was considered as the difference between the mother's reported weight immediately before delivery and pre-pregnancy weight, and was categorized as bellow, above or as recommended, according to the Institute of Medicine guidelines [27].

BIS before pregnancy was calculated as the difference between perceived self body size and perceived ideal body size, both assessed at the baseline evaluation, immediately after delivery, by the Stunkard Silhouettes [28]. This scale consists of 9 silhouette figures that increase gradually in size from very thin to very obese (1 to 9, respectively). BIS was categorized as women who were satisfied with their body image (difference between self and ideal body size = 0); women who felt too small regarding their ideal (difference between self and ideal < 0) and women who felt that they were too large regarding their ideal (difference between self and ideal > 0). Overweight or obese women before pregnancy who perceived their body size as too small were scarce and were not considered in this analysis.

Follow-up Evaluation

Four years after the Generation XXI child's birth, trained interviewers carried out face to face interviews regarding the health of the mother and the child and performed anthropometric evaluations of both. Weight was measured and recorded to the

nearest 0.1 kg and height was measured without shoes to the nearest 0.1 cm. BMI at follow-up was categorized according to the same guidelines used for prepregnancy BMI. Duration of breastfeeding was recorded as the period of time that the child received maternal milk exclusively or together with complementary foods, in weeks.

Statistical Analysis

Statistical analysis was performed using the statistical software Stata 11.0 (College Station, TX, 2005). Sample characteristics are presented as counts and proportions for all categorical variables and mean and standard deviation (SD) for normally distributed continuous variables. Proportions were compared using the chi-square test and continuous variables with ANOVA.

We defined BMI change as the difference between the BMI at follow-up and the prepregnancy BMI. To evaluate the association between BIS and BMI change over 4 years (continuous variable), linear regression models were used, taking women who were satisfied with their image as the reference class of exposure. Crude and adjusted coefficients were calculated with the respective 95% confidence intervals (95% CI). Multinomial logistic regression models were used to compute odds ratios (OR) and 95% CI for the association between BIS and BMI 4 years after delivery (categorical variable). In each baseline BMI stratum, the reference category of the outcome (BMI at 4 years) corresponded to no change in BMI category. There were no obese women before pregnancy with normal weight at 4 years. Separate models were built for women with normal body mass index (BMI), overweight and obese before pregnancy, considering the hypothesis of different effects of BIS on later BMI according to those classes (formally an interaction and not confounding issue). The final model in each pre-pregnancy BMI group was fitted to quantify the association between BIS (independent variable or exposure) on BMI at 4 years (dependent variable or outcome), adjusting for age at delivery, education, income, smoking before pregnancy, parity, weight gain during pregnancy and duration of breastfeeding, which were a priori considered potential confounders of the association, taking into account the literature review. The multivariable adjusted odds ratios are the final estimates considered to best represent the independent effect of the exposure on the outcome. Both the exposure and the outcome have more than 2 classes and the effects are expressed for each class in comparison with the reference.

Results

The characteristics of the study participants are summarized in Table 1, according to women's prepregnancy BMI. Overall, at birth, 35.2% of women were 25 to 29 years of age, 45.2% had less than 10 years of education and 34.7% had a household monthly income below 1000 euros. Before pregnancy, 26.0% of participants were overweight and 10.6% were obese. Women who were obese before pregnancy were older, had a lower educational level and a lower household monthly income than women with normal prepregnancy BMI. The proportion of women who smoked before pregnancy was lower among obese women than among normal and overweight women. Before pregnancy, overweight and obese women more frequently considered themselves too large regarding their ideal. Overweight women were also more likely to gain more weight than recommended during pregnancy and to present a lower increase in BMI over 4 years. Furthermore, obese women were less likely to breastfeed.

During the first 4 years after pregnancy, BMI increased, on average, 2.02 kg/m². Four years after delivery, 28.6% of women

with normal BMI before pregnancy were overweight, 39.9% of overweight women at baseline were obese and more than 90% of the obese women before pregnancy remained in the same BMI category (Table 1).

Among women who had normal prepregnancy BMI, those who felt too small regarding their ideal had a smaller increase in BMI ($\beta = -0.25$ kg/m²; 95%CI: -0.54 to 0.03) than women who were satisfied with their body image, after adjustment for confounders. In the same BMI category, those who felt too large had a significant additional increase of 0.41 kg/m² (95%CI: 0.23 to 0.60) in BMI during the same period of time than women who were satisfied with their body image. In overweight women, a non-significant higher increase in BMI was observed ($\beta = 0.12$; 95%CI: -0.32 to 0.56) among too large women than in those who considered themselves satisfied. In obese women, those who felt too large had a non-significantly lower increase in BMI ($\beta = -0.18$; 95%CI: -1.49 to 1.12) (Table 2).

Table 3 presents the association between BIS before pregnancy and BMI 4 years after delivery, by categories of prepregnancy BMI. After adjustment for the same variables, among women with normal BMI before pregnancy, those feeling that their body was too small regarding their ideal were significantly less likely to become overweight than to remain normal 4 years after delivery (OR = 0.63; 95%CI: 0.44 – 0.91), compared to those satisfied with their body image, and even less likely to become obese in the same period of time (OR = 0.21; 95%CI: 0.05 – 0.91). In the same BMI category, a significant opposite association was observed for women who felt that their body was too large regarding their ideal, with these women being more likely to become overweight and obese 4 years after delivery (OR = 2.12; 95%CI: 1.73 – 2.59 and OR = 3.42; 95%CI: 2.02 – 5.79 , respectively) than those satisfied with their body image. Overweight women, and despite the lack of statistical significance, who felt too large regarding their ideal were 36% less likely to decrease in BMI category and 33% more likely to increase BMI during the same period of time. Among women obese before pregnancy, BIS was not associated with change in BMI class (Table 3).

Discussion

In this sample of Portuguese mothers, the prevalence of overweight/obesity was high and weight increased considerably over 4 years after pregnancy, moving a large proportion of women upwards across BMI categories. The results of this study suggest that BIS before pregnancy was associated with weight change in the postpartum period and this association depended on the BMI before pregnancy.

Prevalence estimates of overweight/obesity in women before pregnancy vary across countries and the variability of methods in data collection among different studies increases the difficulty in making valid comparisons. A study conducted in the United States, using self-reported data, reported 22% of prepregnancy obesity in 2002–2003 [29]. Another study in the same country only with low-income women reported a prevalence of 28.3% of obesity before pregnancy in 2008, using measured height and self-reported prepregnancy weight [30]. Taking into account only measured data, a Portuguese study showed a female overweight and obesity prevalence of 34.4% and 13.4%, respectively, in 2003–2005 [3]. Relying on self-reported weight and height, the 2005/2006 Portuguese National Health Survey presented an overweight prevalence of 19.6% and obesity of 9.4% among women aged 18 to 44 years old [31].

The results of this study reveal that women were heavier 4 years after delivery than they were before pregnancy. We believe that it

Table 1. Participants' characteristics, according to prepregnancy BMI (n = 3612).

	Pregnanancy BMI				p
	Total	Normal	Overweight	Obese	
	n (%) ^a	n (%) ^a	n (%) ^a	n (%) ^a	
Age (years)					
<25	656 (18.2)	446 (19.5)	159 (16.9)	51 (13.3)	
25–29	1272 (35.2)	818 (35.7)	314 (33.4)	140 (36.6)	
30–34	1028 (28.5)	639 (27.9)	278 (29.6)	111 (29.0)	
≥35	656 (18.2)	386 (16.9)	189 (20.1)	81 (21.2)	0.015
Education (years)					
≤9	1633 (45.2)	885 (38.7)	496 (52.8)	252 (65.8)	
10–12	1028 (28.5)	664 (29.0)	283 (30.1)	81 (21.2)	
>12	951 (26.3)	740 (32.3)	161 (17.1)	50 (13.1)	<0.001
Household income (€/month)					
<1000	1253 (34.7)	709 (31.0)	356 (37.9)	188 (49.1)	
1001–1500	994 (27.5)	615 (26.9)	273 (29.0)	106 (27.7)	
≥1501	1058 (29.3)	758 (33.1)	229 (24.4)	71 (18.5)	
Does not know/Prefers not to answer	307 (8.5)	207 (9.0)	82 (8.7)	18 (4.7)	<0.001
Smoking before pregnancy					
Never smokers	2273 (62.9)	1411 (61.6)	594 (63.2)	268 (70.0)	
Current smokers	900 (24.9)	609 (26.6)	224 (23.8)	67 (17.5)	
Former smokers	439 (12.2)	269 (11.8)	122 (13.0)	48 (12.5)	0.003
Body image satisfaction					
Too small	256 (7.1)	238 (10.4)	16 (1.7)	2 (0.5)	
Satisfied	1553 (43.0)	1260 (55.1)	256 (27.2)	37 (9.7)	
Too large	1803 (49.9)	791 (34.6)	668 (71.1)	344 (89.8)	<0.001
Parity					
1	2092 (57.9)	1450 (63.4)	473 (50.3)	169 (44.1)	
2	1195 (33.1)	680 (29.7)	358 (38.1)	157 (41.0)	
≥3	325 (9.0)	159 (7.0)	109 (11.6)	57 (14.9)	<0.001
Weight gain during pregnancy^a					
Below recommended	817 (22.6)	638 (27.9)	88 (9.4)	91 (23.8)	
As recommended	1294 (35.8)	911 (39.8)	289 (30.7)	94 (24.5)	
Above recommended	1501 (41.7)	740 (32.3)	563 (59.9)	198 (51.7)	<0.001
BMI at follow-up (kg/m²)					
18.5–24.9	1641 (45.4)	1563 (68.3)	78 (8.3)	0 (0.0)	
25.0–29.9	1178 (32.6)	654 (28.6)	487 (51.8)	37 (9.7)	
≥30	793 (22.0)	72 (3.2)	375 (39.9)	346 (90.3)	<0.001
BMI change (kg/m²)^b					
Mean (SD)	2.02 (2.71)	1.85 (2.19)	2.40 (3.13)	2.10 (3.99)	<0.001
Breastfeeding					
Never	216 (6.0)	122 (5.3)	62 (6.6)	32 (8.4)	
≤26 weeks	2074 (57.4)	1306 (57.1)	537 (57.1)	231 (60.3)	
>26 weeks	1322 (36.6)	861 (37.6)	341 (36.3)	120 (31.3)	0.040

BMI, body mass index; SD, standard deviation.

^aAccording to the Institute of Medicine classification (2009).^bComputed as the difference between BMI 4 years after delivery and BMI before pregnancy.^cexcept for BMI change, summarized as mean and standard deviation.

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mainly resulted from an excessive weight gain during pregnancy which is retained after delivery. In fact, a temporal trends analysis of maternal prepregnancy body weight in Canada, showed that

the critical age for weight gain before pregnancy is between 20 and 24 years [32], at the transition from adolescence to adulthood, when women gain independence in food choices and preparation.

Table 2. Crude and adjusted mean difference (β) of BMI change from before to 4 years after pregnancy estimated by linear regression, according to body image satisfaction, in normal, overweight and obese women before pregnancy.

	BMI change (at 4 years – before pregnancy)		
	β (95%CI)		
	Mean (SD)	Crude	Adjusted*
Normal BMI before pregnancy			
Too small	1.61 (2.04)	−0.05 (−0.35 to 0.25)	−0.25 (−0.54 to 0.03)
Satisfied	1.66 (2.07)	0 (Ref)	0 (Ref)
Too large	2.23 (2.38)	0.57 (0.38 to 0.76)	0.41 (0.23 to 0.60)
Overweight before pregnancy			
Satisfied	2.36 (3.11)	0 (Ref)	0 (Ref)
Too large	2.43 (3.14)	0.08 (−0.38 to 0.52)	0.12 (−0.32 to 0.56)
Obese before pregnancy			
Satisfied	2.45 (3.01)	0 (Ref)	0 (Ref)
Too large	2.06 (4.10)	−0.39 (−1.75 to 0.96)	−0.18 (−1.49 to 1.12)

95%CI, 95% confidence interval; BMI, body mass index.

*Adjusted for age (<25; 25–29; 30–34; ≥ 35), education (≤ 9 ; 10–12; ≥ 12), household monthly income (<1000€; 1001–1500€; ≥ 1501 ; does not know/prefers not to answer), smoking before pregnancy (never, current, former), parity(1;2; ≥ 3), weight gain during pregnancy (below recommended; as recommended; above recommended) and duration of breastfeeding (never; ≤ 26 weeks; > 26 weeks).

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In our sample, the mean age of women was almost 30 years which is above the “critical age” threshold for spontaneous weight gain unrelated with pregnancy and childbirth.

Pregnancy causes direct changes in body size and weight, which have a high potential to influence BIS. In this context, most studies have focused on body image during pregnancy [33,34] and not after childbirth. Within the ANC project, 2.5 years after delivery, excessive weight gain was associated with increased maternal dissatisfaction with body size: mothers who felt too large regarding their ideal immediately after pregnancy had significantly greater

long term weight gains than women who had no dissatisfaction [22].

A relation between body size perception and change in BMI over 13 years has been recently reported, in a community sample of blacks and whites from the CARDIA study [35]. In this study, normal weight white women who were satisfied with their body size had a lower annual BMI change than did normal weight white women who perceived that they were a bit too large, suggesting that greater satisfaction with body size results in better weight control. A different pattern emerged among obese women, with those who perceived their body size as much too large gaining less

Table 3. Adjusted odds ratio for the association between body image satisfaction before pregnancy and BMI 4 years after delivery estimated by multinomial logistic regression, stratified by prepregnancy BMI.

	BMI 4 years after delivery		
	OR (95%CI)*		
	Normal	Overweight	Obese
Normal BMI before pregnancy			
Too small	1	0.63 (0.44–0.91)	0.21 (0.05–0.91)
Satisfied	1	1	1
Too large	1	2.12 (1.73–2.59)	3.42 (2.02–5.79)
Overweight before pregnancy			
Satisfied	1	1	1
Too large	0.64 (0.38–1.08)	1	1.33 (0.96–1.84)
Obese before pregnancy			
Satisfied	—	1	1
Too large	—	1.76 (0.38–8.15)	1

95% CI, 95% confidence interval; BMI, body mass index; OR, odds ratio.

*Adjusted for age (<25; 25–29; 30–34; ≥ 35), education (≤ 9 ; 10–12; ≥ 12), household monthly income (<1000€; 1001–1500€; ≥ 1501 ; does not know/prefers not to answer), smoking before pregnancy (never, current, former), parity(1;2; ≥ 3), weight gain during pregnancy (below recommended; as recommended; above recommended) and duration of breastfeeding (never; ≤ 26 weeks; > 26 weeks).

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weight than obese women who were more satisfied with their body size. Comparing to the current study, with almost exclusively white women, similar results were obtained except for the obese women for whom we found only a non-significant decrease in BMI. In this particular category, 80% of women considered themselves too large regarding their ideal silhouette and only 10% changed BMI category from overweight to obese. Therefore, our approach may have had low sensitivity to reach more solid conclusions for the obese women.

The longitudinal nature of the study allowed us to test the temporal relation between body image and BMI change. Also, the large number of participants allowed the control for many important confounders of this association. However, some limitations should be pointed. First, prepregnancy weight was self-reported and, because weight tends to be underreported by women [36], it may lead to an underestimation of the overweight and obesity prevalence, and consequently an overestimation of subsequent weight gain. However, self-reported prepregnancy body weights correlate very well with current measured body weights in women of reproductive age, although the size of the error varies according to ethnicity, socioeconomic position and prepregnancy body size, being larger among overweight women [26]. Nevertheless, the change in BMI category may be less subject to bias from reporting errors, compared with average postpartum weight change [26]. Therefore, self-reported prepregnancy weight provides reasonable estimates of BMI category since the reporting error (1–2 Kg) is a small percentage of total body weight. Also, when considering the analysis with BMI 4 years after delivery using self-reported weight (data not shown), the results were unchanged, supporting that the associations between BIS and BMI did not result mostly from the use of misreported prepregnancy weight and objectively measured weight at 4 years.

Regarding BIS, an important limitation of the study is that the silhouettes assessed at birth are representing prepregnancy body shapes and this retrospective characterization may reflect mothers' tendency to idealize their prepregnant figure. Despite these limitations, Stunkard silhouettes have some advantages, allowing a uniform approach to study subjects in a not overly time-consuming procedure. The credibility of this method for scientific research is reinforced by the application of this tool in recent investigations [37–39]. Despite the methodological problems with the use of figural drawing scales, these are the most widely adopted measures of dissatisfaction with body size [40]. Even knowing that the Stunkard silhouettes may not be sensitive enough to pick up subtle differences in body size perception, [41], our results showed strong and significant effects with this measure, reinforcing the high impact of BIS on weight control.

Although this is clearly an incomplete view of the body image construct, the meaning of body image satisfaction is clear and relevant for non-specialists, and, from a public health perspective, we wanted to demonstrate that the evaluation of this dimension with this scale has the potential to identify women who are more susceptible of becoming overweight or obese and, therefore, to contribute to prevent the rising rates of obesity.

Since prenatal care is one of Portugal's health care system most successful areas, with practically 100% coverage and adequate prenatal care in the vast majority of pregnancies, these stage of women's life should be seen as an opportunity for prevention, not only for the children but also for their mothers. BIS could be an important factor to earlier identify women who are more

susceptible of gaining weight during pregnancy and maintain it after delivery in order to optimize women's wellness and subsequent pregnancy outcomes.

This scale is validated to the Caucasian population [42] and previous research in this cohort showed that only 3% of the cohort was not Portuguese or, at least, not European [43].

Furthermore, despite our large sample size, there were few obese women before pregnancy who felt satisfied with their own body image (9.7%). Therefore, the estimates are more imprecise for this group of women.

Despite the high proportion of participation at follow-up, mothers who attended the follow-up re-evaluation were older, more educated, had a higher income and were more likely to felt too large regarding their ideal before pregnancy. Since higher socioeconomic status is associated with lower BMI [44], we may be underestimating overweight and obesity 4 years after delivery and, consequently, the associations that were found could be stronger.

Maternal body weight increases with parity [45]. Therefore, to eliminate the possible effect of weight gain due to previous pregnancies, we performed a stratified analysis by parity and no differences were found between primiparous and multiparous women (data not shown).

One needs to address possible contributing mechanisms to explain the reported association. Low body image perceptions are associated with higher incidences of depression [46], mostly due to the discrepancy between current beauty ideals and body size of real women [47]. However, depression is a very complex phenomenon and it is not clear if it is a cause or a consequence of body image dissatisfaction, since the onset of both conditions is difficult to define precisely in time. A diagnosis of depression before pregnancy (ever) or during the 4 years after delivery were not associated with BIS or BMI in this cohort (data not shown), but these are likely to be insensitive to capture the mood changes within the spectrum of non-pathological mental health that would be relevant in this causal pathway.

In conclusion, our results suggest that satisfaction with body size plays an independent role in maternal body weight 4 years after the birth of a child, not only in women who already belonged to a high risk category, but also for those with a normal BMI who would not be considered a vulnerable group *a priori*. This apparently "healthy" group may be masked before pregnancy but also constitutes an important target for public health interventions. These findings support the importance of working on expectations and motivations to attain a goal, since more realistic body size goals can make women less susceptible of gaining weight during pregnancy and maintaining it after delivery.

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All the authors of the article had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. The authors gratefully acknowledge all the staff of the Generation XXI team for their contribution to this work.

Author Contributions

Conceived and designed the experiments: HB AA. Performed the experiments: AH EA. Analyzed the data: AH EA HB AA. Wrote the paper: AH.

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Prepregnancy Body Image and Later Adiposity

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PAPER IV

Henriques A, Alves L, Alves E, Silva S, Barros H, Azevedo A.
Social trajectory and body image satisfaction in childbearing women.
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Social Trajectory and Body Image Satisfaction in Childbearing Women

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Abstract Advantaged socioeconomic position (SEP) is associated with lower body image satisfaction (BIS) among women. However, motherhood and social trajectory (an individual's path from childhood SEP to adulthood SEP) could change this relationship. We aimed to assess the association between social trajectory and BIS immediately before getting pregnant in primiparous and multiparous mothers of a birth cohort. The birth cohort Generation XXI was assembled after delivery, in Porto, in 2005–2006. This analysis includes 5,470 women. Women's and their parents' education were used as indicators of adulthood and childhood SEP, respectively. Social trajectory was

classified as stable-high, upward, stable-low, downward, according to both education variables. BIS was assessed with Stunkard silhouettes immediately after birth as the difference between perceived body size before the index pregnancy and ideal body size. Odds ratios (OR) between social trajectory and BIS were computed using multinomial logistic regression (women satisfied with body image were the outcome reference category), adjusting for age and prepregnancy body mass index. In primiparous women, no association was found between childhood SEP, adulthood SEP or social trajectory and feeling too small or too large regarding their ideal figure. Multiparous women with a downward social trajectory presented a higher likelihood of dissatisfaction [too small: adjusted OR 2.21, 95 % confidence interval (95 % CI) 1.10–4.46; too large: adjusted OR 1.64, 95 % CI 1.07–2.51]. Downward social trajectory was associated with a higher likelihood of dissatisfaction with body image in multiparae, while there was no effect among primiparae.

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Keywords Social trajectories · Body image satisfaction · Motherhood · Parity

Introduction

Body image is a multidimensional construct that relates to a person's perceptions, feelings and thoughts about his or her body and contains both cognitive (attitudinal) and affective dimensions. One of the components of the attitudinal dimension is the evaluative component represented by the discrepancy between self and ideal perceived images to measure body satisfaction [1, 2]. Although body image is a complex construct, the major research focus has been on body's appearance, mainly in high income settings

across the world, where a female beauty ideal emphasizes the desirability of thinness [3, 4].

Socioeconomic position (SEP) is an aggregate term that includes resource-based (income, wealth, educational credentials) and prestige-based measures (ranked in a social hierarchy evaluated with reference to people's access to goods, services and knowledge), linked to both childhood and adulthood social class [5]. Most often, only some of these indicators are used and previous studies have shown that education is the component of adult SEP that contributes most to body dissatisfaction [6].

In Western societies, women from a higher SEP are thinner than women from lower SEP [7], illustrating how social conditions are written into the bodies, producing population patterns of health [8]. Part of the protection against weight gain in this group could result from a higher frequency of weight monitoring, a lower threshold for defining themselves as overweight, and a greater likelihood of deliberate efforts at weight control [9].

Several studies have demonstrated that, for a given body size, women from a higher SEP are more often dissatisfied with their body than women from a lower SEP [9, 10]. However, these findings have been based on women's SEP in adulthood, and little attention has been paid to the household SEP during her childhood or to intergenerational social trajectory taking into account a life course perspective. Social trajectory is a lifelong evolution of the volume and composition of an individual's capital (social, cultural, economic and/or symbolic), combined with his/her parents' asset volume and structure and can be described as upward, downward or stationary [11]. Changes in social circumstances, or intergenerational movement between social classes, might entail a transition in terms of priorities and resources related to weight and appearance, or a shift in experience of social norms regarding the appeal of particular body types [6], particularly when considered in the context of women who have recently given birth.

The experience of pregnancy, with marked physical and emotional changes, raises questions in a woman about her body image perception [12]. The weight and shape changes related to pregnancy can be distressing for some women but neutral or even liberating for others [13]. Moreover, there is a substantial discrepancy between the expectations and the reality of motherhood specially for primiparous women, for whom motherhood is associated with much uncertainty, leaving them more prone to a romanticized vision of this new role [14]. Body image satisfaction (BIS) influences maternal body weight after delivery [15], making it relevant to understand the determinants of BIS in specific subgroups of childbearing women.

Within this framework, the aim of this study was to assess the relation of childhood SEP, adulthood SEP and

social trajectory with BIS immediately before pregnancy in primiparous and multiparous mothers of a Portuguese birth cohort.

Methods

Study Design

This study is based on the birth cohort Generation XXI which has been previously described [16]. Briefly, 8,495 mothers, who gave birth to 8,647 infants, were recruited in 2005–2006 at all five public maternity units covering six municipalities of the metropolitan area of Porto, Portugal. All mothers residing in the catchment area who delivered a live-born child (gestational age ≥ 24 weeks) in one of the five units were eligible and subsequently invited to join the study, 24–72 h after delivery. At birth, 91.4 % of the invited mothers accepted to participate.

For the current analysis and since body image perception is expected to change during pregnancy, we excluded 313 participants who had been recruited during the first trimester of pregnancy to address specific objectives [17]. Women with missing data on potentially confounding variables of the relationship between social trajectory and BIS were excluded from analysis. Thus, 2,712 women without data on education, household monthly income, working condition, highest parents' education, having a maid, going away on vacations, car ownership, home ownership, body mass index (BMI), or BIS were excluded. The present study is based on 5,470 women who were recruited and evaluated during their hospital stay for childbirth and had complete information regarding the key variables considered.

Compared to excluded women, those included in the analyses were younger (mean [standard deviation (SD)]: 29.0 (5.6) vs. 30.4 (5.4) years, independent sample *t* test: $p < 0.001$), had a lower household income ($>1,500$ euros/month: 26.8 % vs. 29.5 %, Chi-square test: $p = 0.049$), less frequently had a car, maid or went away on vacations when they were 12 years old (all amenities: 8.4 vs. 9.8 %, Chi-square test: $p = 0.024$) and were more often unemployed (21.1 vs. 17.9 %, Chi-square test: $p = 0.001$), despite the negligible magnitude of differences. However, included and excluded women did not differ in relation to the main variables such as a women's education, highest parents' education, parity, BMI, BIS or social trajectory.

Data Collection and Variables Definition

Trained inquirers collected data on demographic, socioeconomic, lifestyles, obstetric history, anthropometrics and body image (self and ideal) characteristics, in face-to-face

interviews using standardized questionnaires. Data collection took place 24–72 h after delivery, during the hospital stay.

The outcome variable, BIS before pregnancy, was calculated as the difference between perceived self body size and ideal body size, both assessed after delivery, by the Stunkard silhouettes [18]. This scale consists of nine numbered silhouette figures that increase gradually in size from very thin to very obese (1–9, respectively). Self body size was the number of the figure selected by participants in response to “choose the figure that reflects how you think you looked before you got pregnant” and ideal body size in response to “choose your ideal figure”. BIS was categorized as being satisfied with one’s body image (difference between self and ideal body size = 0); feeling too small regarding one’s ideal (difference between self and ideal < 0); and feeling too large regarding one’s ideal (difference between self and ideal > 0).

We studied multiple variables as potential predictors of women’s BIS. Women reported their age at the time of delivery, and this was later categorized it into four ordinal categories: <25, 25–29, 30–34 and ≥ 35 years. Parity was recorded as the number of deliveries, including the index one and was afterwards categorized into having only one delivery (primiparous) and more than one (multiparous). Women were inquired about their prepregnancy weight to the nearest 0.1 kg. Immediately after birth, height was measured (without shoes) by the inquirers to the nearest 0.1 cm and, when measurement was not possible, height was reported by the mother as registered in the identity card. Mother’s prepregnancy BMI was calculated and later categorized into four ordinal categories according to the standard World Health Organization definition: underweight (<18.5 kg/m²), normal (18.5–24.9 kg/m²), overweight (25.0–29.9 kg/m²) and obese (≥ 30 kg/m²) [19]. Women’s and their parents’ education were self-reported by the delivering women as the total number of years of formal education completed and subsequently converted into ordinal categories (women’s: ≥ 12 , 10–11, 5–9, ≤ 4 ; their parents: ≥ 12 , 9–11, 6–8, 4–5, <4). Household monthly income was inquired using previously defined categories (less than 500 €, 500–1,000 €, 1,001–1,500 €, more than 1,500 €). Working condition was defined as employed, unemployed, housewife and others (student or retired). Amenities including having a car, maid and/or going away on vacations were categorized according to the number of possessions these women had when they were 12 years of age.

Concerning the main exposure variables, and since education is often used as a generic measure of SEP [20], adulthood SEP was defined using mother’s education immediately after delivery. Childhood SEP was defined according to the highest parents’ education when these women were 12 years old. Thus, we categorized women’s education and their parents’ education into four and five categories, respectively, to explore the graded shape and the location of any thresholds in the association between

education and BIS (supplementary file, available online). After that, and based on the interpretation of those associations, the researchers decided which were the best cut-off points for both variables in order to use only two classes (high and low) for the definition of social trajectory from childhood to adulthood. Then, parents’ education was considered high if at least one of the parents had 6 or more years of education and women’s education was high when they had more than 9 years of education. To examine the effect of social trajectory on BIS, a variable comprising the four different combinations of childhood and adulthood SEP categories was defined: stable-high: parents’ education ≥ 6 and woman’s education >9 years; upward trajectory: parents’ education <6 and woman’s education >9 years; stable-low: parents’ education <6 and woman’s education ≤ 9 years and downward trajectory: parents’ education ≥ 6 and woman’s education ≤ 9 years.

Statistics

Statistical analyses were performed using Stata 11.0 (College Station, TX, 2009). Sample characteristics were presented as counts and proportions for all categorical variables and mean and standard deviation (SD) for normally distributed continuous variables. Proportions were compared using the Chi-square test and continuous variables with independent-sample *t* test. Odds ratios (OR) with the respective 95 % confidence intervals (95 % CI) for the association between childhood SEP, adulthood SEP and social trajectory with BIS were computed using multinomial logistic regression models, taking women satisfied with their body image as the reference category of the outcome. Multinomial logistic regression was used due to the existence of more than two categories in the dependent variable.

Separate models were built for primiparous and multiparous women because we found different effects of social trajectories on BIS according to parity (*p* for the interaction in the age and BMI-adjusted model considering the too large extreme: 0.012). For each group, two final models were fitted: one adjusting only for age and another adjusting additionally for BMI before pregnancy. From a list of a priori potential confounders, these two were the only variables significantly associated with BIS (*p* < 0.05) and confounding the main association (assessed by the change of the association between social trajectory and BIS by at least 10 %).

Ethics

The study protocol was approved by the Ethics Committee of Hospital de São João. All participants received an explanation of the purposes and design of the study and gave written informed consent for the evaluation.

Table 1 Participants' characteristics, according to parity (n = 5,470)

	Parity		<i>p</i>
	Primiparae n (%)	Multiparae n (%)	
Overall	3,166 (57.9)	2,304 (42.1)	
Age (years)			
<25	992 (31.3)	292 (12.7)	
25–29	1,283 (40.5)	627 (27.2)	
30–34	659 (20.8)	739 (32.1)	
≥35	232 (7.3)	646 (28.0)	<0.001
BMI before pregnancy (Kg/m ²)			
<18.5	162 (5.1)	69 (2.9)	
18.5–24.9	2,206 (69.7)	1,352 (58.7)	
25.0–29.9	585 (18.5)	605 (26.3)	
≥30	213 (6.7)	278 (12.1)	<0.001
Body image satisfaction			
Too small	317 (10.0)	179 (7.8)	
Satisfied	1,521 (48.0)	918 (39.8)	
Too large	1,328 (42.0)	1,207 (52.4)	<0.001
<i>Childhood SEP</i>			
Highest parents' education (years)			
≥12	446 (14.1)	247 (10.7)	
9–11	305 (9.6)	143 (6.2)	
6–8	379 (12.0)	181 (7.9)	
4–5	1,786 (56.4)	1,433 (62.2)	
<4	83 (2.6)	155 (6.7)	
Does not know	167 (5.3)	145 (6.2)	<0.001
Amenities (car, maid, vacations)			
All	291 (9.2)	171 (7.4)	
2	803 (25.4)	439 (19.0)	
1	1,081 (34.1)	602 (26.1)	
None	991 (31.3)	1,092 (47.4)	<0.001
<i>Adulthood SEP</i>			
Education (years)			
≥12	1,547 (48.9)	746 (32.4)	
10–11	286 (9.0)	154 (6.7)	
5–9	1,246 (39.4)	1,102 (47.9)	
≤4	87 (2.8)	302 (13.1)	<0.001
Household monthly income (€)			
>1,500	856 (27.0)	612 (26.6)	
1,001–1,500	855 (27.0)	541 (23.5)	
500–1,000	931 (29.4)	745 (32.3)	
<500	179 (5.6)	185 (8.0)	
Does not know/prefers not to answer	345 (10.9)	221 (9.6)	<0.001
Working condition			
Employed	2,306 (72.8)	1,533 (66.5)	
Unemployed	626 (19.8)	527 (22.9)	
Housewife	89 (2.8)	223 (9.7)	
Others	145 (4.5)	21 (0.9)	<0.001

Table 1 continued

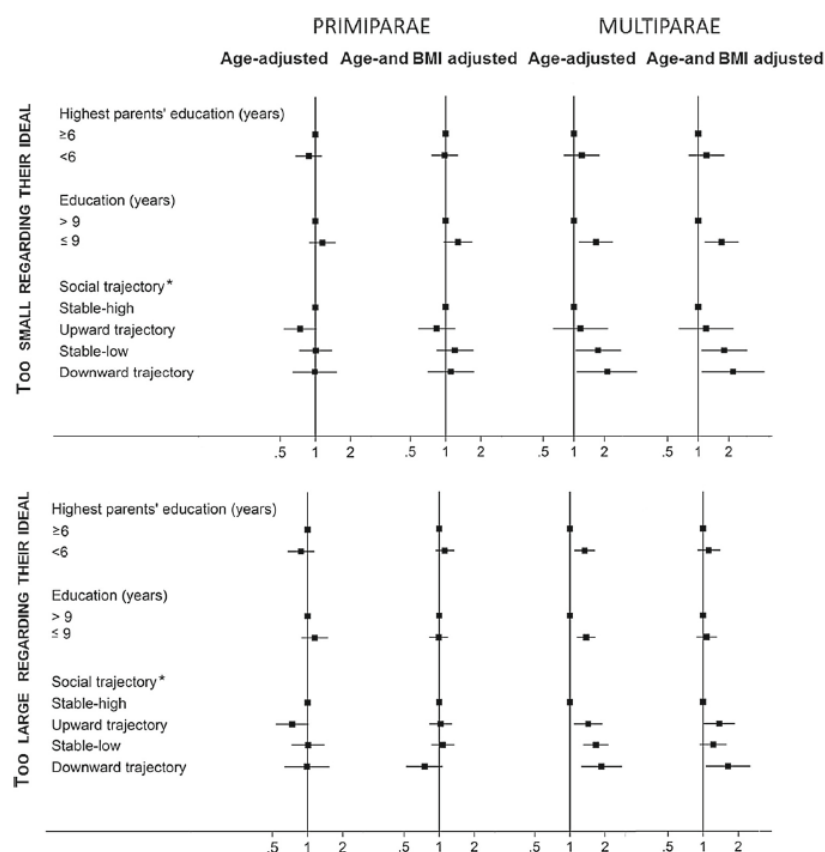
	Parity		<i>p</i>
	Primiparae n (%)	Multiparae n (%)	
<i>Intergenerational SEP</i>			
Social trajectory (parents' and women's education)*			
Stable-high	856 (28.5)	404 (18.7)	<0.001
Upward trajectory	921 (30.7)	476 (22.0)	
Stable-low	948 (31.6)	1,112 (51.5)	
Downward trajectory	274 (9.1)	167 (7.7)	

Comparisons between primiparae and multiparae were made using the Chi-square test

BMI body mass index, *SEP* socioeconomic position

* *n* = 5,158 due to the exclusion of women who did not know their parents' education

Fig. 1 Age-adjusted and age- and body mass index-adjusted odds ratio for the association between highest parents' education, woman's education and social trajectory with body image satisfaction, estimated by multinomial logistic regression, among primiparous and multiparous women. *Stable-high: parents' education ≥ 6 and woman's education > 9 years; upward trajectory: parents' education < 6 and woman's education > 9 years; stable-low: parents' education < 6 and woman's education ≤ 9 years and downward trajectory; parents' education ≥ 6 and woman's education < 9 years



*Stable-high: parents' education ≥ 6 and woman's education > 9 years; upward trajectory: parents' education < 6 and woman's education > 9 years; stable-low: parents' education < 6 and woman's education ≤ 9 years and downward trajectory; parents' education ≥ 6 and woman's education < 9 years

Results

In this sample of Portuguese women, 57.9 and 42.1 % were primiparous and multiparous, respectively. Also, 7.3 % of primiparae and 28.0 % of multiparae were at least 35 years old and the prevalence of obesity was higher among multiparous women (12.1 vs. 6.7 %). Concerning BIS, more than half of the multiparous women reported a self body image larger than their ideal and this prevalence was lower among primiparous women (52.4 vs. 42.0 %).

With regards to women's childhood, both parents of 59.0 % of primiparae had less than 6 years of education, while this percentage was considerably higher in multiparae (68.9 %). Almost one-third of primiparae and half of the multiparae possessed none of the 3 types of amenities considered. Regarding their own education, almost six out of ten primiparous women had more than 9 years of education while less than four out of ten multiparous women had the same degree. In both primiparae and multiparae, 27 % had a household monthly income above 1,500 euros and multiparous were slightly more frequently unemployed (22.9 vs. 19.8 %). Almost a third of primiparae were in the stable-low category of social trajectory compared to more than half of multiparae in this same class (Table 1).

The detailed analysis on the association of socioeconomic characteristics concerning women's childhood and adulthood with BIS is presented in the supplementary file, available online. In general, when compared to the reference category for each variable, socioeconomically disadvantaged women were more likely to be dissatisfied with body image. The associations were stronger among multiparae and the effects on feeling too large regarding one's ideal body were attenuated by the adjustment for BMI.

Figure 1 depicts the association of childhood SEP, adulthood SEP, and social trajectory with BIS among primiparous and multiparous women. In both groups and after adjusting for age and BMI, no significant association was found between highest parents' education and feeling too small in both groups of women (primiparous: age- and BMI-adjusted OR 0.98, 95 % CI 0.76–1.28; multiparous: age- and BMI-adjusted OR 1.21, 95 % CI 0.82–1.79).

Likewise, there were no differences in feeling too large between women whose parents had less than 6 years of education and 6 or more (primiparous: age- and BMI-adjusted OR 1.12, 95 % CI 0.94–1.32; multiparous: age- and BMI-adjusted OR 1.11, 95 % CI 0.90–1.39). A significant association was found between women with 9 or less years of education and feeling too small, among multiparae (age- and BMI-adjusted OR 1.70, 95 % CI 1.16–2.48).

The association of mother's adulthood SEP with dissatisfaction towards the "too large extreme" was explained by BMI before pregnancy in primiparous and multiparous women (age- and BMI-adjusted OR 0.99, 95 % CI

0.82–1.18 and age- and BMI-adjusted OR 1.07, 95 % CI 0.87–1.31, respectively).

Overall, for women with only one delivery, no effect of social trajectory was observed towards both extremes of dissatisfaction, after taking age and BMI into account. In multiparous women, the likelihood of feeling too small, independently of age and BMI, increased progressively across categories of social trajectory up to an age- and BMI-adjusted OR of 2.21, 95 % CI 1.10–4.46 in the downward trajectory class. Regarding the too large extreme of body image dissatisfaction, though women's and parents' education did not have a considerable impact per se, the odds of feeling too large increased across the categories of social trajectory up to an age- and BMI-adjusted OR of 1.64, 95 % CI 1.07–2.51 in the downward trajectory class (Fig. 1).

Discussion

We examined the relation of childhood SEP, adulthood SEP and social trajectory with BIS before pregnancy in mothers of a Portuguese birth cohort. Among primiparous women, there was no association between childhood SEP, adulthood SEP or social trajectory and being dissatisfied with body image. In this group of women, BMI was the main determinant of feeling too small or too large, with no additional effect of SEP or social trajectory. In multiparous women, patterns of social trajectory had differential effects on the discrepancy between perceived and ideal body size, and those who experienced a downward social trajectory from childhood to adulthood had the highest probability of being dissatisfied with their appearance in either direction.

Several studies indicate that socioeconomically advantaged women are more often dissatisfied with their bodies than socioeconomically disadvantaged women [10, 21] probably due to a higher pressure for thinness induced by social norms that is commonplace in high-income regions [4]. A cohort of middle-aged British women showed that those who experienced a downward trajectory were more satisfied with their appearance than stable non-manual women, independently of their BMI [6]. Our results in women who recently delivered a child point to an opposite direction, probably due to the recent experience of motherhood that can change how women perceive their appearance and their physical ideals.

It is well established that childbearing is associated with permanent weight gain in women [22] and the reversibility of weight gain is known to be a concern [23], possibly anticipating dissatisfaction with body image [24]. To eliminate the possible effect of weight gain on BIS due to previous pregnancies, we performed a stratified analysis by parity. Since clearly distinct associations were observed by parity, the results were presented separately for primiparous and multiparous. This dissatisfaction may be less apparent in

primiparae, attenuated by the enchantment of motherhood and all uncertainty regarding the unknown role of mother and the body changes to be expected. Thus, women may view the body changes as transient and unique, being able to assimilate them without distress independently of their SEP. In women who had been pregnant before, BIS may decline due to previous experience, such as the difficulty in returning to their prepregnancy weight and this decline may be larger in women presenting a downward social trajectory.

Women who experienced a downward trajectory were the ones who felt more frequently dissatisfied, not only by feeling too large but also too small, and the association was stronger than the association between adulthood SEP and BIS. This pattern is highly suggestive of how social conditions become embodied and generate dissatisfaction with body image [25], particularly when these are worse than in earlier stages of life [26].

To help interpret the results, they should be framed within the socioeconomic and cultural context that shapes the access to education in Portugal in the last three decades. Our sample encompasses a generation who grew up after important national political and social changes. Women in particular, became more involved in all businesses, professions, schools and universities, culminating in considerable changes involving the role of women in society [27]. In this context, women of this generation who experienced a downward trajectory are a particularly disadvantaged group since their trajectory is opposite to the national trend.

Some limitations of this study should be discussed. The Stunkard silhouettes have some limitations and offer an incomplete view of the body image construct; however this instrument also has some advantages, allowing a uniform approach to study subjects that is not overly time-consuming. The credibility of this tool for scientific research is reinforced by its application in recent investigations [28, 29] and figure drawing scales are still the most widely adopted measures of dissatisfaction with body size [30]. Moreover, this scale is validated in the Caucasian population [31] and only 3 % of this cohort was not European [32]. We are aware that the measurement procedure may determine the significance and strength of the associations between SEP and BIS estimated in a study, which can contribute to the differences between our results and previous literature. Despite the incomplete approach to the body image construct, the meaning of body image satisfaction using a simple measure based on the Stunkard silhouettes is clear and relevant for non-specialists and, from a public health perspective, we believe our estimates validly demonstrate that patterns of social trajectory can have differential effects on the discrepancy between perceived and ideal body size. We used this tool to address BIS before pregnancy. There are no validation studies for the reference to a past time and it would be fruitful to validate the method for this purpose in a future study.

Concerning the social trajectory and SEP measurement, education is not the only variable that measures SEP and, when considering social trajectory, education only covers the social and cultural capital. SEP is a complex attribute and there is not a set of indicators that can describe a person's SEP. Each has advantages and disadvantages [20, 33]. Formal education is nowadays one of the key elements in both the organization of people's daily lives and life courses. Similarly, it is currently one of the axes that are decisive to the unequal distribution of resources and opportunities, conditioning people's social life in different ways and strongly contributing to the structuration of class relationships [27]. We relied on education due to its important established role in health behaviors and outcomes, because it is the most commonly used variable as a generic *measure* of SEP [20]. Also, previous work showed that education is the component of SEP that contributes most to body dissatisfaction [6]. Approximately 3 % of the women in the cohort were still students at the time of evaluation. However, only 6.8 % of women in the downward trajectory category and 1.7 % of women in the stable-low category of social trajectory could still move across categories with their ongoing education and we believe this is not enough to change the strength of the associations substantially. About the thresholds used to categorize education, our first thought was to define a dichotomous variable comprising having or not completed compulsory education both for mothers and their parents. However, although compulsory education formally changed from 4 to 6 years in 1964 in Portugal, the conditions for the completion of 6 years of compulsory schooling everywhere were only definitively established in the late 1970s. Therefore, for more than 10 years, there was much uncertainty around this subject and it was not possible to define what was compulsory education for each child in different regions over those years. Therefore, since the access to education clearly changed in these last three decades and these two generations had different opportunities to study, it was expected to have different thresholds to define high and low education for women and their parents.

In conclusion, this study provides evidence that social trajectories influences BIS and parity may modify this association: downward social trajectory was associated with a lower BIS in multiparae, while there was no effect among primiparae. This work suggests that social trajectories have different effects on the discrepancy between perceived and ideal body size, likely by influencing both an individual's ideal and the ability to attain it. Taking into account the fact that BIS before pregnancy influences maternal body weight after delivery, a deeper understanding of BIS could help to outline more specific and adequate interventions to women, in order to prevent excessive weight rates in this particular population.

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PAPER V

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Healthy excessive weight in Portuguese women 4 years after delivery of a liveborn

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ABSTRACT

Objective. To quantify the prevalence of healthy excessive weight and determinants of metabolic profile, considering women's reproductive life.

Methods. We evaluated 1847 mothers of a birth cohort assembled after delivery and reevaluated 4 years later. A healthy profile was defined as the absence of hypertension, diabetes, dyslipidemia, C-reactive protein <3 mg/l and being below the second tertile of HOMA-IR. Adjusted odds ratios (OR) and confidence intervals (95% CI) were computed using multinomial logistic regression, taking women with normal BMI as the reference category of the outcome.

Results. Four years after delivery, 47% of women had normal BMI, 33% were overweight and 20% obese. In each BMI class, 61%, 33% and 12% presented a healthy metabolic profile, respectively. Family history of CVD/ cardiometabolic risk factors was associated with a higher probability of obesity with a not healthy metabolic profile (OR = 1.39 95% CI: 0.98–1.98). Women who breastfed the enrolled child for >26 weeks and practiced physical exercise were less likely to be obese and metabolically unhealthy (OR = 0.39 95% CI: 0.23–0.68; OR = 0.48 95% CI: 0.33–0.70, respectively), with no effect on healthy excessive weight.

Conclusions. These results support the existence of a healthy excessive weight phenotype in women after motherhood, influenced by anthropometrics, genetic and lifestyles characteristics.

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Introduction

Overweight and obesity are increasingly prevalent worldwide and expected to be one of the major public health problems of the XXI century (Finucane et al., 2011). In Portugal, 20% of women in their thirties are overweight and 8% obese (Carreira et al., 2012) and this increase in excessive body weight will have an important impact on the global incidence of several diseases, (Visscher and Seidell, 2001). However, a subset of obese subjects seems to be protected from obesity-related cardiovascular and cardiometabolic abnormalities (Pataky et al., 2011; Stefan et al., 2008; Karelis, 2008; Manu et al., 2012). The phenotype called healthy obesity is characterized by a favorable metabolic profile: high levels of insulin sensitivity, no hypertension, as well as a favorable inflammatory (Phillips and Perry, 2013), lipid, hormonal and immune profile (Primeau et al., 2011). The importance of recognizing this phenotype is strengthened by the fact that weight loss may adversely impact the favorable metabolic profile (Karelis et al., 2008; Shin et al., 2006).

Despite the absence of a uniform definition for this subtype of obesity, the literature shows a high prevalence of healthy obese individuals (Wildman, 2009; Bluher, 2010), ranging from 6% to 37% (Kuk and Ardern, 2009; Brochu et al., 2001; Phillips et al., 2013). Even when unique criteria are used, considerable variability in the prevalence of healthy obesity is found across different European countries (Van Vliet-Ostapchouk et al., 2014) and, to the best of our knowledge, there are no estimates for Portugal.

Abdominal fat seems to be linked to a more adverse cardiometabolic profile (Thomas et al., 2012; Jensen, 2008). The increase of fat deposition in abdominal visceral adipose tissue is favored after pregnancy due to increased abdominal compliance, rendering women more susceptible to abdominal obesity after childbirth (Gunderson et al., 2008) and it remains unclear to which extent this abdominal fat is associated with metabolic complications.

Thus, it is interesting to characterize overweight and obesity phenotypes in women who had a child, thus supporting or not the need for preventive action directed at this segment of the population. Specifically, we intend to (a) quantify the prevalence of healthy excessive weight in a cohort of Portuguese women 4 years after delivering a child, (b) assess the dependence of a healthy metabolic profile on the distribution and BMI evolution from pre-pregnancy to 4 years later and

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(c) identify if sociodemographic characteristics, family history of cardiovascular diseases (CVD) or cardiometabolic risk factors, reproductive history and lifestyles are associated with this metabolically healthy phenotype.

Materials and methods

Study design and participants

This study is based on the birth cohort Generation XXI described elsewhere (Alves et al., 2012). Briefly, in 2005–2006, 8495 women, who gave birth to 8647 infants, were enrolled into the cohort after the child's birth. They were recruited in the maternity clinics of five public hospitals covering the metropolitan area of Porto, Portugal within 72 h after delivery.

Four years after birth, in 2009–2011, a follow-up took place and 84.2% of the mothers were reevaluated. Of all mothers, 5729 (67.4%) attended a face-to-face evaluation, comprising questionnaires and physical examination (anthropometrics and blood pressure) and 1428 (16.8%) provided self-reported data by telephone interview. Women interviewed by telephone were excluded due to the lack of physical examination data. Among those who attended the face-to-face interview, half were randomly selected to provide a fasting blood sample. From the 2733 mothers who provided a fasting blood sample, we excluded from the current analysis 553 who had subsequent pregnancies after the baseline evaluation, 175 with a C-reactive protein level above 10 mg/l, which suggests a clinically relevant inflammatory condition (Yeh and Willerson, 2003), 28 with body mass index (BMI) < 18.5 kg/m² at follow-up and 130 with missing data on BMI, waist circumference, diabetes, dyslipidemia, hypertension, C-reactive protein or insulin resistance, leaving 1847 women for the current analysis.

Exposure variables

During reevaluation, socioeconomic characteristics, personal and family history of disease, obstetric history and lifestyles of the women were self-reported. Women's age was collected as a continuous variable. Education was collected as a continuous variable considering the complete years of schooling and later categorized. Working condition was defined as employed, unemployed, housewife and others (student or retired). Marital status at follow-up was categorized as married/living together and others (separated, divorced, widow or single). Family history of CVD or cardiometabolic risk factors was considered when women reported having at least one parent or sibling with diabetes, hypertension, dyslipidemia, stroke or myocardial infarction. The number of pregnancies was recorded including the enrolled infant and the mode of delivery was classified as vaginal or caesarean section. Duration of breastfeeding was recorded as the period of time that the child received maternal milk exclusively or together with complementary foods, in weeks. Information about hormonal contraceptives included ever use of hormonal contraceptives (contraceptive pill, patch or ring and subdermal implant) and duration of use, and women were then classified as never, former and current users.

Current smokers included both daily and occasional smokers, and ex-smokers those that did not smoke for at least 6 months. Physical exercise was considered as the practice of any type of exercise regardless of the intensity or duration.

Waist circumference was measured midway between the lowest rib and the superior border of the iliac crest and a waist circumference > 88 cm defined abdominal obesity (Grundy et al., 2005). To study the BMI evolution from prepregnancy to 4 years later a variable was defined as the difference between prepregnancy BMI and BMI 4 years later and comprised three categories: those who had an increase, a decrease and those who maintained the same BMI during this period.

Outcome variables

Weight was measured and recorded to the nearest 0.1 kg in light clothing, and height was measured without shoes to the nearest 0.1 cm and mothers' BMI 4 years after delivery was categorized according to the World Health Organization (1998). The same procedure was used for the prepregnancy BMI but using self-reported weight. Blood pressure was measured by non-physician trained interviewers. Two measurements of blood pressure separated by 5 min were taken with an automatic upper arm blood pressure monitor (OMRON M6 comfort (HEM-7000-E)) after 10-minute rest, on the dominant upper arm resting at the heart level. The mean was calculated and when the

difference was larger than 5 mm Hg for systolic or diastolic blood pressure a third measurement was taken and the mean of the 2 closest values was considered. Hypertension was defined as systolic and/or diastolic blood pressure $\geq$ 140/90 mm Hg and/or self-reported antihypertensive drug therapy prescribed for Hypertension Guidelines (2007).

Blood was sampled after an overnight fast of at least 10 h and all the parameters were measured using automatic standard enzymatic methods. Dyslipidemia was considered when one of these conditions was verified: total cholesterol $\geq$ 240 mg/dl, high-density lipoprotein (HDL) $\leq$ 40 mg/dl, low-density lipoprotein (LDL) $\geq$ 160 mg/dl, triglycerides $\geq$ 200 mg/dl or self-reported antidiabetic drug therapy (ATP III Report, 2002). Diabetes mellitus was defined as fasting plasma glucose concentration $\geq$ 126 mg/dl or self-reported antidiabetic drug therapy prescribed specifically for diabetes (IDF, 2014). Regarding C-reactive protein, more than > 3 mg/l was defined as the threshold beyond which women were considered to have a higher risk for cardiovascular events (Cox et al., 2012). Homeostasis model assessment of insulin resistance (HOMA-IR) was derived from fasting glucose and insulin concentrations as [(fasting plasma glucose (mmol/l) * fasting serum insulin (μ U/ml)) / 22.5] (Matthews et al., 1985). Low HOMA-IR values indicate high insulin sensitivity, whereas high HOMA-IR values indicate low insulin sensitivity (insulin resistance). The entire sample was divided into insulin-resistant (upper third of HOMA) and insulin-sensitive (lower and middle thirds of HOMA). The sample-derived HOMA cut-off value for insulin resistance was 1.803.

A metabolically healthy profile was defined as the absence of hypertension, diabetes, dyslipidemia, a level of C-reactive protein until 3 mg/l and being below the second tertile of HOMA.

To define the main outcome, we considered several obesity profiles considering BMI (normal/overweight/obese) and metabolic profile (healthy/not healthy) resulting in five groups: women with normal BMI, overweight women metabolically healthy, overweight women metabolically not healthy, obese women metabolically healthy and obese women metabolically not healthy.

Statistical analysis

Statistical analysis was performed using the statistical software Stata 11.0 (College Station, TX, 2009). Sample characteristics are presented as counts and proportions for categorical variables and mean and standard deviation (SD) for normally distributed continuous variables. Proportions were compared using the chi-square test and continuous variables with independent sample Student's *t* test, Kruskal–Wallis test or ANOVA. The association of putative determinants with the outcome was assessed using multinomial logistic regression. Crude and adjusted odds ratios (OR) and 95% confidence intervals (95% CI) were computed, taking women with normal BMI as the reference category of the outcome. From a list of a priori potential determinants, a final model was conducted comprising only variables associated with the outcome.

Ethics

All the phases of the study complied with the Ethical Principles for Medical Research Involving Human Subjects expressed in the Declaration of Helsinki. The study was approved by the University of Porto Medical School/Centro Hospitalar de São João ethics committee and a signed informed consent was obtained from all participants.

Results

Four years after delivery, 46.9% of women had a normal BMI, 33.2% were overweight and 19.9% obese. In this sample, obese women were the oldest, with a mean (SD) age of 35.3 (5.3) years. Compared to women with normal BMI, obese women more often had lower levels of education, were unemployed and had three or more pregnancies. Regarding the index pregnancy, the prevalence of caesarean section was higher among obese women than among normal or overweight women. At the time of the follow-up evaluation, more than half of the women with normal BMI and overweight were using hormonal contraceptives. Obese women less often practiced any type of regular physical exercise. Almost 90% of the obese women had a waist circumference above 88 cm contrasting with only 2% of women with normal BMI. Almost all women with normal BMI 4 years after delivery were already

in this BMI category before pregnancy, while in both categories of excessive weight more than half of the women had recently gained considerable weight enough to move across BMI categories (Table 1).

There was a gradient between all metabolic parameters considered and women's BMI 4 years after delivery, with obese women presenting the least favorable profile. Among obese women 4 years after delivery, 1 out of 10 had a metabolic healthy profile, compared to 3 out of 10 of the overweight and 6 out of 10 of the women with normal BMI (Table 2).

Fig. 1 illustrates the prevalence of the healthy metabolic phenotype according to women's waist circumference and BMI evolution from prepregnancy to 4 years later, by women's BMI. Within each BMI stratum, a waist circumference below 88 cm was associated with a significantly higher prevalence of a healthy metabolic profile (for example, among the obese: 28.2% vs. 10.3%, $p = 0.001$). However, BMI evolution from prepregnancy to 4 years later did not influence the prevalence of a

metabolically healthy profile, independently of the BMI category (Fig. 1).

In the crude analysis and compared to women with normal BMI, being unemployed or a housewife was associated with a higher likelihood of being obese with a not healthy metabolic profile (unemployed: OR = 1.69; 95% CI: 1.21–2.36; housewife: OR = 2.22; 95% CI: 1.21–4.09). Having a family history of CVD/cardiometabolic risk factors was associated with a higher probability of having excessive weight and a non-healthy metabolic profile, this association being stronger for obese women (OR = 1.41 95% CI: 1.00–1.98). The number of previous pregnancies increased the odds of having a higher BMI independently of the metabolic profile, but with a stronger association with healthy excessive weight. Breastfeeding was gradually and inversely associated with BMI, with a stronger association for not healthy than healthy excessive weight. Compared to women with normal BMI, women who

Table 1
Participants' characteristics 4 years after delivery of a liveborn, according to BMI (Portugal, 2009–2011).

	Body mass index 4 years after delivery			p
	Normal n (%) ^a	Overweight n (%) ^a	Obese n (%) ^a	
Overall	867 (46.9)	612 (33.2)	368 (19.9)	
Age				
Mean (SD)	34.4 (5.2)	35.2 (5.2)	35.3 (5.3)	0.002
Education (years)				
≤9	323 (37.3)	318 (52.0)	214 (58.2)	
10–12	256 (29.6)	177 (28.9)	94 (25.5)	
>12	286 (33.1)	117 (19.1)	60 (16.3)	<0.001
Working condition				
Employed	700 (81.2)	461 (75.3)	266 (72.3)	
Unemployed	119 (13.8)	120 (19.6)	70 (19.0)	
Housewife	26 (3.0)	19 (3.1)	22 (6.0)	
Others	19 (2.2)	12 (2.0)	10 (2.7)	0.004
Marital status				
Married/living together	614 (87.5)	453 (89.2)	255 (87.9)	
Others	88 (12.5)	55 (10.8)	35 (12.1)	0.658
Family history of CVD/cardiometabolic risk factors ^b				
No	181 (20.9)	113 (18.5)	60 (16.3)	
Yes	686 (79.1)	499 (81.5)	308 (83.7)	0.151
Number of pregnancies (including index)				
1	423 (48.8)	252 (41.2)	144 (39.2)	
2	328 (37.8)	240 (39.2)	128 (34.9)	
≥3	116 (13.4)	120 (19.6)	96 (25.8)	<0.001
Type of delivery (index pregnancy)				
Vaginal	566 (65.8)	386 (63.9)	207 (56.7)	
Caesarean	294 (34.2)	218 (36.1)	158 (43.3)	0.010
Breastfeeding (index child)				
Never	33 (3.8)	34 (5.6)	33 (9.0)	
≤26 weeks	515 (59.7)	333 (54.8)	216 (58.7)	
>26 weeks	314 (36.4)	241 (39.6)	119 (32.3)	0.002
Use of hormonal contraceptives				
Never	45 (5.2)	24 (3.9)	26 (7.1)	
Former	318 (36.8)	225 (36.9)	181 (49.3)	
Current	502 (58.0)	361 (59.2)	162 (43.6)	<0.001
Smoking status				
Never	475 (54.8)	364 (59.5)	217 (59.0)	
Former	251 (29.0)	145 (23.7)	91 (24.7)	
Current	141 (16.2)	103 (16.8)	60 (16.3)	0.203
Regular physical exercise				
No	681 (78.6)	485 (79.4)	321 (87.2)	
Yes	186 (21.4)	126 (20.6)	47 (12.8)	0.001
Waist circumference (cm)				
≤88	850 (98.0)	380 (62.1)	39 (10.6)	
>88	17 (2.0)	232 (37.9)	329 (89.4)	<0.001
BMI evolution (Pregnancy — 4 years later)				
Same prepregnancy BMI	775 (89.4)	272 (44.4)	153 (41.6)	
Recent increase in BMI	29 (3.5)	298 (50.6)	195 (56.0)	
Recent decrease in BMI	31 (3.7)	19 (3.2)	NA	<0.001

BMI, body mass index; CVD, cardiovascular diseases; NA, not applicable; SD, standard deviation.

Note: In each variable, the total may not add up to 1847 due to missing data.

^a Except for age, summarized as mean and standard deviation.

^b Family history of CVD or cardiometabolic risk factors was considered when women reported having at least one parent or sibling affected by diabetes, hypertension, dyslipidemia, stroke or myocardial infarction.

Table 2

Metabolic Characteristics of women 4 years after delivery of a liveborn, according to BMI (Portugal, 2009–2011).

	Body mass index 4 years after delivery			p
	Normal	Overweight	Obese	
Systolic blood pressure (mm Hg), mean (SD)	103.7 (10.8)	108.7 (12.5)	111.0 (12.7)	<0.001
Diastolic blood pressure (mm Hg), mean (SD)	70.4 (8.6)	74.7 (9.8)	77.8 (10.2)	<0.001
Fasting glucose (mg/dl), mean (SD)	80.2 (12.1)	82.3 (7.9)	85.7 (10.7)	<0.001
C-reactive protein (mg/l), median (IQR)	1.1 (0.5–2.6)	1.9 (0.9–4.0)	3.2 (1.7–5.4)	<0.001
Total cholesterol (mg/dl), mean (SD)	188.6 (33.5)	196.0 (38.8)	200.0 (34.6)	<0.001
LDL cholesterol (mg/dl), mean (SD)	111.8 (27.6)	119.0 (32.3)	124.6 (30.2)	<0.001
HDL cholesterol (mg/dl), mean (SD)	60.4 (13.2)	57.5 (11.8)	53.5 (11.9)	<0.001
Triglycerides (mmol/l), median (IQR)	74 (56–99)	86 (63–117)	95 (75–132)	<0.001
HOMA-IR ^a , median (IQR)	1.1 (0.8–1.5)	1.6 (1.2–2.2)	2.2 (1.7–3.1)	<0.001
Metabolically healthy ^b , n (%)	525 (60.6)	200 (32.7)	45 (12.2)	<0.001

BMI, body mass index; IQR, interquartile range; LDL, low-density lipoprotein; HDL, high-density lipoprotein; HOMA-IR, homeostasis model assessment of insulin resistance; SD, standard deviation.

^a Computed as fasting plasma glucose (mmol/l) × fasting serum insulin (μU/ml) / 22.5.^b Defined as the absence of hypertension, diabetes, dyslipidemia, a level of C-reactive protein below 3 mg/l and being below the second tertile of HOMA.

were using hormonal contraceptives at the time of the evaluation had more chances of being overweight and having a not healthy metabolic profile (OR = 2.32 95% CI: 1.18–4.56) but a different trend was found considering obese women with the same phenotype (OR = 0.59 95% CI: 0.35–1.01). Doing any kind of regular physical exercise was associated with a lower likelihood of being obese and having a not healthy metabolic phenotype (OR = 0.50 95% CI: 0.35–0.73) (Table 3).

Table 4 presents the results of the multivariate analysis. Having a family history of CVD/cardiometabolic risk factors was associated with a higher probability of having excessive weight and a not healthy metabolic profile, this association being stronger for obese women (OR = 1.39 95% CI: 0.98–1.98), whereas no association was observed with a healthy excessive weight. A graded inverse association was found between breastfeeding the Generation XXI child for more than 26 weeks and BMI at 4 years with a not healthy metabolic profile (obesity, not healthy – OR = 0.39 95% CI: 0.23–0.68), and the effect was null on healthy excessive weight. The pattern described in the crude analysis for hormonal contraceptive use was independent of confounders. Finally, doing any kind of physical exercise remained

associated with a lower likelihood of being obese and having a not healthy metabolic profile (OR = 0.48 95% CI: 0.33–0.70).

Discussion

Our results support the existence of a healthy metabolic profile in women 4 years after delivery, with 3 out of 10 overweight women and 1 out of 10 obese women presenting this phenotype. Abdominal obesity strongly influences the prevalence of a healthy metabolic profile, whereas BMI evolution from prepregnancy to 4 years after birth does not. Genetic, reproductive and lifestyles features are associated with this healthy phenotype and can help to better characterize this metabolic profile.

The prevalence of the healthy obesity phenotype varies according to obesity markers and criteria used to define metabolic abnormalities, impairing the comparability among studies (Velho et al., 2010). When healthy obesity is defined as having none or one of the six more common cardiometabolic abnormalities (elevated blood pressure, elevated triglyceride level, decreased HDL level, elevated glucose level, insulin

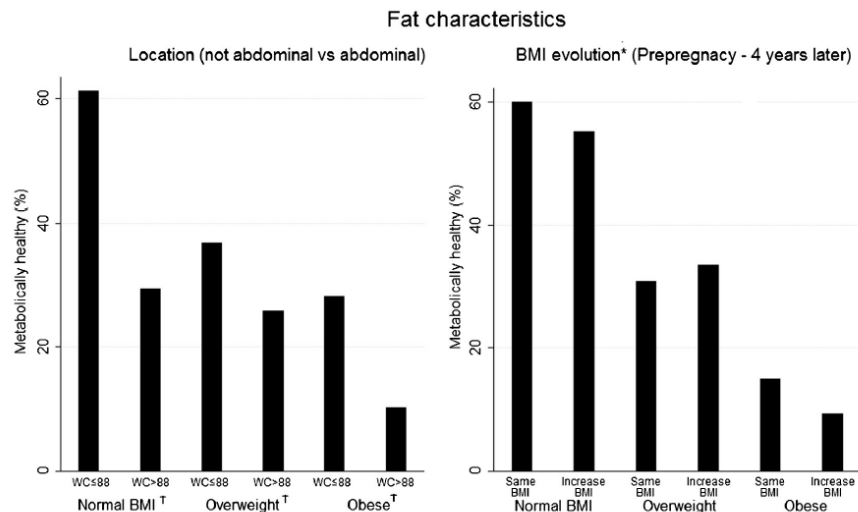


Fig. 1. Prevalence of healthy metabolic profile by body mass index and fat characteristics in mothers of a Portuguese birth cohort, 2009–2011 (Left panel: location; Right panel: body mass index evolution). BMI, body mass index; WC, waist circumference. *Computed as the difference between BMI 4 years after delivery and BMI before pregnancy. Women with a decrease in BMI were scarce and were not considered. [†]p < 0.05 for the comparison between WC ≤ 88 and WC > 88.

Table 3

Crude odds ratio for the association between demographic, genetic, reproductive and behavioral characteristics and metabolic profile, according to body mass index, in mothers of a Portuguese birth cohort, 2009–2011.

	Normal BMI	Overweight		Obese	
		Healthy	Not healthy	Healthy	Not healthy
Overall, n (%)	867 (46.9)	200 (10.8)	412 (22.3)	45 (2.4)	323 (17.5)
		Crude OR (95% CI)			
Age	1	1.04 (1.01–1.07)	1.03 (1.00–1.05)	1.09 (1.02–1.15)	1.03 (1.00–1.05)
Education (years)					
≤9	1	1	1	1	1
10–12	1	0.90 (0.63–1.30)	0.62 (0.47–0.82)	0.50 (0.24–1.01)	0.56 (0.41–0.76)
>12	1	0.63 (0.43–0.92)	0.33 (0.24–0.46)	0.24 (0.10–0.60)	0.33 (0.23–0.46)
Work condition					
Employed	1	1	1	1	1
Unemployed	1	1.51 (1.01–2.26)	1.54 (1.12–2.11)	0.65 (0.23–1.87)	1.69 (1.21–2.36)
Housewife	1	0.88 (0.33–2.34)	1.22 (0.63–2.37)	2.24 (0.65–7.76)	2.22 (1.21–4.09)
Others	1	0.97 (0.32–2.89)	0.95 (0.41–2.20)	2.05 (0.46–9.13)	1.28 (0.55–2.97)
Marital status					
Married/living together	1	1	1	1	1
Others	1	0.78 (0.45–1.35)	0.88 (0.59–1.32)	1.16 (0.44–3.08)	0.93 (0.60–1.45)
Family history of CVD/cardiometabolic risk factors					
No	1	1	1	1	1
Yes	1	0.99 (0.68–1.45)	1.27 (0.94–1.72)	1.06 (0.50–2.23)	1.41 (1.00–1.98)
Number of pregnancies					
1	1	1	1	1	1
2	1	1.37 (0.97–1.93)	1.16 (0.90–1.51)	1.75 (0.86–3.54)	1.08 (0.81–1.45)
≥3	1	1.94 (1.26–2.99)	1.65 (1.18–2.30)	3.12 (1.41–6.94)	2.33 (1.65–3.28)
Type of delivery					
Vaginal	1	1	1	1	1
Cesarean	1	0.98 (0.70–1.35)	1.14 (0.89–1.46)	1.76 (0.96–3.23)	1.43 (1.10–1.86)
Breastfeeding					
Never	1	1	1	1	1
≤26 weeks	1	0.75 (0.35–1.62)	0.58 (0.34–1.00)	0.51 (0.15–1.79)	0.41 (0.24–0.69)
>26 weeks	1	0.97 (0.45–2.11)	0.66 (0.38–1.16)	0.63 (0.18–2.25)	0.35 (0.20–0.61)
Use of hormonal contraceptives					
Never	1	1	1	1	1
Former	1	1.21 (0.63–2.32)	1.47 (0.73–2.93)	1.60 (0.47–5.44)	0.90 (0.53–1.55)
Current	1	0.52 (0.27–1.02)	2.32 (1.18–4.56)	0.24 (0.06–0.93)	0.59 (0.35–1.01)
Smoking status					
Never	1	1	1	1	1
Current	1	1.06 (0.74–1.51)	0.63 (0.47–0.84)	0.69 (0.34–1.41)	0.81 (0.60–1.10)
Former	1	1.23 (0.81–1.87)	0.84 (0.60–1.17)	0.45 (0.16–1.30)	1.01 (0.71–1.44)
Practice of physical exercise					
Sedentary	1	1	1	1	1
Does any kind of exercise	1	0.97 (0.67–1.42)	0.94 (0.70–1.26)	0.79 (0.36–1.73)	0.50 (0.35–0.73)

95% CI, 95% confidence interval; BMI, body mass index; CVD, cardiovascular diseases; OR, odds ratio; WC, waist circumference.

Table 4

Multivariate-adjusted odds ratio for the association between age, family history of cardiovascular diseases/cardiometabolic risk factors, breastfeeding, use of hormonal contraceptives and physical exercise with metabolic profile, according to body mass index, in mothers of a Portuguese birth cohort, 2009–2011.

	Normal BMI	Overweight		Obese	
		Healthy	Not healthy	Healthy	Not healthy
		Adjusted OR (95% CI) ^a			
Age	1	1.02 (0.98–1.05)	1.04 (1.01–1.06)	1.04 (0.98–1.11)	1.01 (0.99–1.04)
Family history of CVD/cardiometabolic risk factors					
No	1	1	1	1	1
Yes	1	0.93 (0.63–1.38)	1.21 (0.89–1.66)	0.87 (0.40–1.88)	1.39 (0.98–1.98)
Breastfeeding					
Never	1	1	1	1	1
≤26 weeks	1	0.84 (0.39–1.82)	0.58 (0.33–1.00)	0.65 (0.18–2.33)	0.44 (0.26–0.74)
>26 weeks	1	1.10 (0.50–2.40)	0.64 (0.37–1.12)	0.85 (0.23–3.08)	0.39 (0.23–0.68)
Use of hormonal contraceptives					
Never	1	1	1	1	1
Former	1	1.22 (0.63–2.36)	1.35 (0.67–2.73)	1.66 (0.48–5.69)	0.88 (0.50–1.52)
Current	1	0.55 (0.23–1.07)	2.55 (1.29–5.04)	0.27 (0.07–1.09)	0.60 (0.35–1.04)
Practice of physical exercise					
Sedentary	1	1	1	1	1
Does any kind of exercise	1	0.93 (0.63–1.36)	0.92 (0.68–1.23)	0.71 (0.32–1.56)	0.48 (0.33–0.70)

95% CI, 95% confidence interval; BMI, body mass index; OR, odds ratio; WC waist circumference.

Note: performed only with women with information for all the variables considered (n = 1825).

^a Each factor in the table is adjusted for every other factor in the table.

resistance and systemic inflammation), data suggest that 35.4% of North American obese women possess a healthy phenotype but it decreases drastically when we restrict the criteria to not having any of the cardiometabolic risk factors with only 16.6% maintaining the same phenotype (Wildman et al., 2008). In Europe, a lower prevalence was found in cohort studies, ranging from 7% in Finland to 28% in the United Kingdom, using the same criteria in all countries (Van Vliet-Ostapchouk et al., 2014). The most common definitions of healthy obesity were compared in a Swiss population-based sample and less than 5% of all obese subjects were considered metabolically healthy by all definitions used and irrespective of the anthropometric markers used (Velho et al., 2010). The prevalence found in our work among obese women was similar to only one study mentioned above (Karelis, 2008). Nevertheless, in our study we considered a particular population: women who recently experienced pregnancy, which brings specific body fat characteristics that needed to be studied in order to determine their impact on women's metabolic profile.

Concerning the definition of our outcome, the majority of published work uses similar parameters (Manu et al., 2012; Stefan et al., 2008; Van Vliet-Ostapchouk et al., 2014; Velho et al., 2010) and for diabetes, dyslipidemia, C-reactive protein and blood pressure the cut-off values are well defined. For insulin, there is no cut-off clearly separating insulin sensitive and resistant subgroups (Bluher, 2010). It is common to define insulin resistance using the three upper quartiles (Karelis et al., 2008) of HOMA-IR or above the 90th percentile (Wildman et al., 2008); however, mean values of HOMA-IR in our sample were considerably lower. Therefore, we used another threshold that was also previously used in samples that have HOMA-IR values closer to ours (Manu et al., 2012). Additionally, the cut-off of 1.803 that we used is only slightly lower than thresholds for insulin resistance in recent population studies which ranged from 2.1 to 3.8 (Manu et al., 2012).

Since central fat deposition is strongly associated with CVD risk independently of BMI (Demerath et al., 2008), it was hypothesized that waist circumference could play a role in the distinction between healthy and not healthy profile. In this sample of Portuguese women who achieved a successful pregnancy, abdominal obesity was associated with a lower probability of having a healthy metabolic profile in every BMI stratum. Given the important role of visceral adipose tissue in the genesis of both insulin resistance and inflammation (Diamant et al., 2005), it is not surprising that a relatively lower amount of abdominal adiposity could explain a more favorable metabolic profile even in women who recently gained weight.

It remains unclear whether this favorable profile represents a permanent characteristic or is just a step in the natural history of obesity. Longitudinal data concerning this subject are scarce. A recent study showed that among overweight/obese metabolically healthy subjects at baseline, 57% developed one or more cardiometabolic risk factor 3 years later (Bobbioni-Harsch et al., 2012). Moreover, a recent meta-analysis highlights that the incidence of cardiometabolic disturbances is not linear over time among healthy obese people and the duration of follow-up can be a critical element in this evaluation, since differences between healthy and not-healthy subjects in the incidence of events were evident only after 10 years (Kramer et al., 2013). Concerning our study population, longitudinal studies are needed and it is expected that the next follow-ups of the Generation XXI cohort will provide more information to address all the uncertainty regarding the duration of this healthy phenotype.

To date, little is known about the factors that delay the onset of or protect individuals with excessive weight from developing metabolic disturbances. Physical activity influences the prevalence of a healthy cardiometabolic profile (Velho et al., 2010; Wildman, 2009; Yoo et al., 2013). Moderate regular physical activity is associated with higher insulin sensitivity, an improved lipid profile, and a decrease in components of metabolic syndrome (Caro et al., 2013) and this fact can explain the lower probability of being obese and metabolically not healthy among women who practice any kind of physical exercise.

Having a family history of CVD or cardiometabolic risk factors increases the chances of having a non-healthy metabolic profile among obese women which suggests that this phenotype can also be the expression of a genetic trait. Knowing that fat deposition on the visceral area is influenced by genes (Fox et al., 2007), genetic background possibly influences healthy metabolic profile, however up to now no evidence supports this hypothesis.

No study was found that tried to ascertain the impact of the use of hormonal contraceptives and the duration of breastfeeding on healthy metabolic profile. It is already established that duration of breastfeeding is inversely associated with mother's obesity (Turcksin et al., 2014) and this study adds that, even among obese women, the longer one breastfeeds the lower the probability of having an adverse metabolic profile, confirming the beneficial effect of breastfeeding also at a metabolic level. Regarding the use of hormonal contraceptives, discrepant results were observed in overweight and obese women and we believe that this difference can be partly explained by reverse causality: contraception is often feared in women with chronic medical problems like obesity and these women might not be using hormonal contraceptives at the time of the evaluation in consequence of their obesity.

Our study has several strengths including a large sample size of women who recently were mothers and the assessment of this healthy phenotype in this particular population which was unexplored so far. Also, using objective measures of height, weight and waist circumference allowed us to have a more accurate estimation of overweight and obesity. However, some limitations can also be identified. BMI was used to classify overweight and obese women and does not discriminate between lean and fat body mass. Moreover, the cross sectional study design limited our ability to make an inference about causal relationships between exposure and outcome variables.

Conclusions

These results support the existence of a healthy metabolic phenotype in overweight and obese women after motherhood, influenced by anthropometrics, genetic and lifestyles characteristics. Since pregnancy promotes abdominal obesity, young adult women with excessive weight might need a close surveillance of their cardiometabolic parameters as well as prevention for further weight gain.

Disclosure statement

The authors declare that there are no conflicts of interest.

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GENERAL DISCUSSION

Overall, with this thesis, we demonstrate that weight varies across different stages of reproductive life and that several biological, psychological and social factors not only explain differences in weight between women but also influence its variation throughout time and interact with the experience of reproduction.

In Portugal, prevalences of excessive weight are considerably high among adult women (40, 41, 43) and a similar scenario is observed in both cohorts used in this thesis. In the EPIPorto cohort, 63% of women had excessive weight at baseline (42) and 30% of mothers from the Generation XXI birth cohort presented excessive weight before the index pregnancy (146). Since weight increases with age throughout the majority of adult years (Paper I and II), interventions should target young women, ideally before they start gaining excessive weight. Through a better understanding of how biological, psychological and social factors influence weight in this population, findings from this dissertation may provide important clues for better weight control recommendations. Moreover, women's interactions with the healthcare system during pregnancy and the postpartum period present an opportunity to provide them with behavioural interventions and support. However, few such programs have been described in the literature (196).

The framework of the main findings of this thesis is illustrated in Figure 8, below.

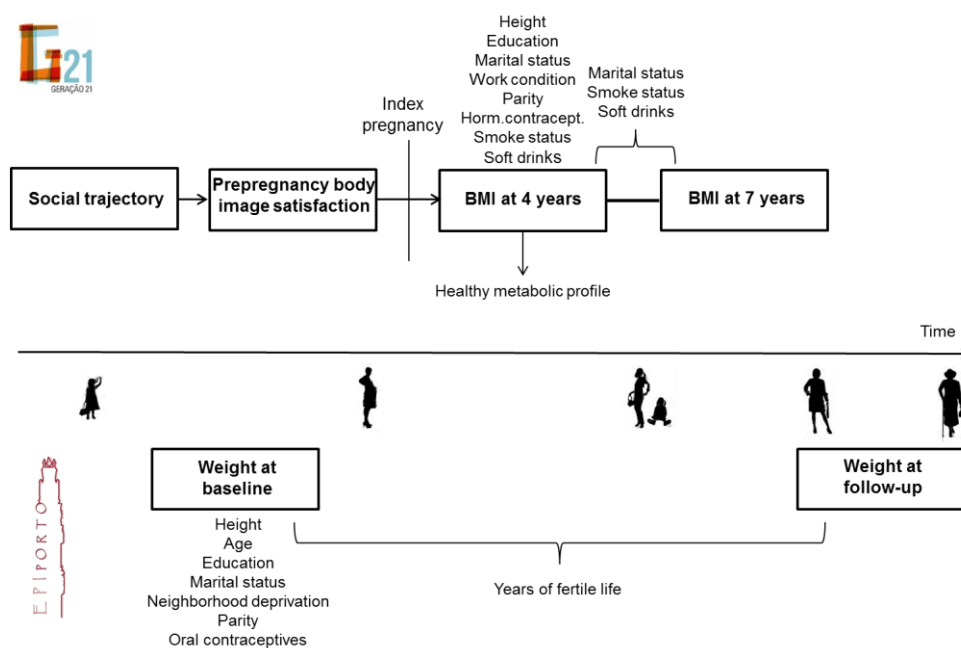


Figure 8. A biopsychosocial approach to the interrelation between reproduction and excessive weight in women.

With the first two papers of this dissertation, we were able to characterize weight evolution and demonstrate that determinants of weight variation are not the same throughout women's adult life. Despite the confirmation of several cross-sectional weight determinants in both analyses, in Paper I only years of fertile life were associated with weight change over time, while in Paper II, marital status, smoking status and soft drinks intake had impact on the same outcome. To pursue these goals, we used a statistically rigorous method suitable for the analysis of longitudinal data, by allowing the regression coefficients to vary between subjects. Only this type of statistical method allows the demonstration that the effect of several variables on weight throughout life is not constant, highlighting that a cross-sectional approach is insufficient to fully understand weight change over time (194). Additionally, we were able to test in the same sample several determinants representing different dimensions, namely sociodemographic (individual and contextual), reproductive and lifestyles features. Some of these features are modifiable, supporting their relevance for the potential prevention of further weight gain.

Some limitations concerning Papers I and II should also be discussed. The lack of data on psychological measures could have largely contributed to the low proportion of variance of weight explained in both studies. Measures of depression, anxiety and self-esteem are known to be associated with excessive weight (197); therefore, future longitudinal evaluations should comprise these themes, in order to achieve a more complete evaluation of the impact of biological, psychological and social factors on weight. Furthermore, the lack of an association of dietary intake and physical activity variables with weight might at first sight suggest a limitation namely regarding the quality of the data. Besides soft drinks intake, which is the only dietary feature that appears related to weight or weight change in both papers, other nutritional exposures were tested in both cohorts, such as fruits, vegetables and cakes consumption and none of them was associated with any of the outcomes. Previously published data concerning the EPIPorto cohort also showed no association between dietary patterns and central obesity after adjustment for confounders (198). Concerning physical activity, only the practice of physical exercise was available for mothers of Generation XXI cohort and only 18% of those evaluated 4 years after delivery practiced any kind of physical exercise. We believe that this low prevalence, together with the lack of longitudinal assessment concerning physical exercise can explain the lack of association found in Paper II. Additionally, social desirability and social approval may influence self-reported physical activity, resulting in overreporting of activity (199), which might also affect the results from both cohorts. Despite the lack of association

concerning physical activity or dietary intake on weight, the periodic assessments of all participants from our cohorts will allow us to collect information on both determinants, as well as to continue to study these associations longitudinally.

In Paper I, we were able to test several weight determinants in a heterogeneous sample of women, contrasting with the sample from Paper II comprising only recent mothers in their thirties. Using a sample with a large age range, in Paper I, allowed us to test the impact of several events related to women's reproductive health such as menarche, pregnancy or menopause and to test additional variables, such as years of fertile life, with a higher variability among women. This difference between samples may explain why we found an association between years of fertile life and weight change in Paper I but not in Paper II. At the same time, a larger and more homogeneous sample, in Paper II, allowed us to have more statistical power and less confounding in our results that can contribute to a higher number of weight change determinants in young mothers than in women from the general population.

The sample of mothers from Generation XXI allowed us to emphasize an important psychological variable. Knowing that BIS can impact on weight trajectories during this life stage (154), we hypothesized that BIS before pregnancy was associated with BMI 4 years after delivery (Paper III). Two main findings should be highlighted from this work. First, childbearing women were considerably heavier 4 years after giving birth, reflecting a lack of efficacy in the recommendations for weight management during and immediately after pregnancy. Second, satisfaction with body size plays an independent role in maternal body weight 4 years after the birth of a child, mainly in women with a normal BMI before pregnancy who would not be considered a vulnerable group *a priori*. With this work, we were able to show that BIS before pregnancy not only has impact on weight immediately after pregnancy, but also influences weight trajectories some years later and the need to work on this construct during this period of women's life is reinforced. Exploring goals, expectations, beliefs and self-perceptions and getting individuals more (and better) motivated in self-managing their weight can help prevent obesity (79) and our work highlights that this aspect is also valid in the context of motherhood. Moreover, reducing motivation to its quantitative dimension could be an important limiting factor in current weight loss interventions and the type of motivation should also be considered (153). "Internal motivation to lose weight" and "self-motivation" have been identified as predictors of successful weight control (200). Therefore, in this context, working on the feelings of competence, autonomy and self-esteem, that will probably induce a more positive body

image, rather than simply focusing on immediate behaviour change, could lead to better results concerning long-term weight control.

Knowing that the social and cultural context influences women's perception of body size and body ideals (87), we aimed to assess the relation of childhood SEP, adulthood SEP and social trajectory with BIS immediately before pregnancy in the mothers of Generation XXI birth cohort (Paper IV). The main results support the existence of distinct associations by parity: in multiparous women, patterns of social trajectory had differential effects on BIS, and those who experienced a downward social trajectory from childhood to adulthood had the highest probability of being dissatisfied with their appearance regarding both extremes of dissatisfaction; in primiparous women, no effect was found. These findings are highly suggestive of how social conditions become embodied and generate dissatisfaction with body image, particularly when these are worse than in earlier stages of life. Different results in primiparae may reflect the enchantment of motherhood experienced for the first time, making women more convicted that body changes are transient, being able to assimilate them without distress independently of their SEP. Another interesting result regarding Paper IV is that, at least in the context of motherhood, women who experienced a downward trajectory were the ones who felt more frequently dissatisfied, not only by feeling too large but also too small. With this work, we were able to provide separate results concerning two extremes of dissatisfaction, which is not often seen in the literature.

In both papers discussed above (Papers III and IV), two limitations should be mentioned regarding the BIS construct. First, the silhouettes assessed at birth represented prepregnancy body shapes and this retrospective characterization may reflect mothers' tendency to idealize their prepregnant figure. This fact may have led to a higher proportion of satisfied women and a lower proportion of dissatisfied ones, compared to the measurement of BIS before pregnancy. Therefore, the associations between both extremes of dissatisfaction and BMI 4 years after delivery may be underestimated. Second, the use of Stunkard Silhouettes is clearly an incomplete view of the body image construct. However, from a public health perspective, this measure was sufficient to demonstrate that the evaluation of this dimension with this scale has the potential to identify women who are more susceptible of becoming overweight or obese and, therefore, to contribute to prevent the rising rates of obesity. In the future, it would be interesting to follow a group of childbearing women still in preconception care, allowing us to measure BIS in the present moment and to collect objective prepregnancy anthropometrics. More complete measures of BIS could be used for the

assessment of both attitudinal dimensions of this construct, the evaluative and investment component, and a comparison with the use of Stunkard Silhouettes could also be done.

In the first three articles of this thesis, weight (Paper I and II) or BMI (Paper III) were the main outcomes. Since young adult women do not have considerable changes in height over four years (34), looking at changes in weight or BMI in the same person over time is essentially the same. Changes in weight are more intuitive to interpret. Also, continuous outcomes are more powerful and sensitive to small changes (201), arguing in favor of the use of weight as the dependent variable in Papers I and II, particularly because the relation with both determinants and consequences is gradual, at least from normal weight upwards (202). On the other hand, research results are crucial as a support for public health and clinical practice where decisions are typically categorical in nature. Despite the fact that BMI does not distinguish between excess fat, muscle, or bone mass, nor does it provide any indication of the distribution of fat among individuals, it is a simple, inexpensive, and noninvasive surrogate measure of body fat, visceral adiposity and a good indicator of insulin resistance in young adults (24). Categories of BMI are well established and their clinical meaning validated (21), and when used as the outcome variable in paper III this strategy reinforces that the associations found are relevant. Also, this choice attenuates the impact of a putative overestimation of weight gain due to underestimation of self-reported weight before pregnancy.

In Paper III, we observed that mothers gained substantial weight from before pregnancy to four years later, with more than half of them presenting excessive weight at that time. However, excessive weight is a highly heterogeneous condition (16) and, since the increase of fat deposition in abdominal visceral adipose tissue is favoured after pregnancy (130), we thought it would be interesting to characterize the obesity phenotype in women who had a child, to assess the extent to which their obesity is healthy or is conveying a higher risk of cardiovascular disease (Paper V). Our results support the existence of a healthy metabolic profile in women 4 years after delivery, influenced by anthropometrics, genetic and lifestyles characteristics. Most of the literature on healthy obesity used samples of women aged over 40 years and, as far as we know, no study concerning this subject has been conducted in a homogenous group of childbearing women. Despite the controversy associated with this phenotype, with longitudinal studies suggesting that this profile is just a step in the natural history of obesity and not a permanent characteristic (188, 189), we believe that, if this phenotype really exists, an early characterization of this healthy excessive weight

would add knowledge about the establishment of this phenotype in women's life. Once again, the longitudinal assessment of the mothers of the Generation XXI birth cohort will enable us to do a detailed analysis of the evolution of this phenotype in the future. Due to all the uncertainty regarding this topic, targeting only women with an adverse metabolic profile for intervention can be risky; therefore, all childbearing women with excessive weight should be monitored.

Overall, the results of this thesis emphasize that there are several factors that could lead a woman to be overweight or obese and a biopsychosocial approach contributes to understand these relations comprehensively. Moreover, a life course approach for weight management is essential, since factors associated with weight variation are not always the same throughout life. Furthermore, we contributed to better identify women more likely to benefit from interventions to prevent weight gain and that the context of reproduction can be a critical period to intervene.

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