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Male partners of subfertile couples in which the spouse is obese display adverse weight and lifestyle associated with reduced sperm quality

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ABSTRACT

Objectives: To assess: 1—the spousal concordance of lifestyle and anthropometric characteristics between partners of infertile couples in which the woman is obese; and 2—in men, the influence of these characteristics on their conventional seminal parameters.
Design: Cross-sectional study.
Setting: Fertility clinic of the Centre hospitalier universitaire de Sherbrooke, Canada, between January 2012 and February 2015.
Patients: 97 infertile heterosexual couples in which women were obese and seeking fertility treatments.
Intervention: Not applicable.
Main outcome measures: Weight and percentage of fat mass were evaluated using a scale with foot-to-foot bio-impedance. Abdominal obesity was estimated with waist circumference and lifestyle habits, by a self-reported questionnaire. Seminal parameters were analysed and collected according to the WHO guidelines (Kruger's strict criteria for seminal morphology).
Results: There was a significant spousal concordance for the percentage of fat mass, leisure activities and overall nutritional quality. Accordingly, male participants displayed anthropometric and lifestyle characteristics at higher risk than Canadian men of similar age. Moreover, BMI, daily consumption of fruits & vegetables and sleeping hours in men were independently associated to the total motile sperm count.
Conclusion: This is the first study to report concordance for anthropometric and lifestyle characteristics between partners of infertile couples in which the woman is obese. These characteristics in men were more adverse than in the general population and were associated with reduced sperm quality. Altogether, our results suggest that male partners of infertile couples could benefit from participating in the lifestyle intervention that is already recommended for their spouse affected by obesity.
Capsule: Because partners of subfertile couples in which the woman is obese share adverse anthropometric and lifestyle characteristics, male partners should be implicated in lifestyle interventions already indicated for their spouse.

Introduction

Infertility, defined as the inability to conceive after 12 consecutive months of unprotected intercourse, affects from 10 to 15% of couples in industrial countries [1]. Assisted reproductive technologies (ART) have proven to be very effective in helping couples to achieve a pregnancy, with a worldwide estimate of 375,000 newborns resulting from 1.5 million ART cycles performed [2]. While

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initially used mainly for bilateral tubal occlusion or severe male factor, in vitro fertilisation (IVF) use is recently increasing mostly in couples with a mild male subfertility, older female partners and unexplained subfertility [3]. This increase in its utilisation is responsible for high costs and multiple potential risks [4], and is performed in many cases only to circumvent an underlying problem that is modifiable. Therefore, the research into modifiable risk factors of infertility is necessary for increasing couples' chances of conceiving prior and during fertility treatments.

Obesity has been shown to be a significant risk factor for infertility in women. The impacts of obesity on the women's fertility have been comprehensively studied and reported at different levels of the reproductive function, such as ovulation [5], oocyte [6], embryo development [7,8], uterine receptivity [9] and pregnancy outcomes [8]. Additionally, several studies have reported benefits of weight loss in women with obesity and infertility on ovulation and pregnancy rates, with or without ART treatments [10–12]. Based on these results, multiple health organisations have issued recommendations for women with obesity and infertility, such as to lose 5–10% of their initial weight before attempting to become pregnant using ART treatments or not [13–16].

Although much attention has been oriented towards the impact of obesity on women's fertility, its impact on the male reproductive potential must not be neglected. A large cohort study has reported that independently of woman's BMI, the male partner's obesity increases the risk of infertility for the couple (OR [95% confidence interval (IC)] = 1.49 [1.34–1.64]), and even more so when both partners are obese (OR [95% IC] = 2.74 [2.27–3.30]) [17]. Several studies have also reported negative associations between BMI and conventional seminal parameters (ejaculate volume, sperm concentration, motility, morphology, total motile sperm count (TMSC)) [18,19], as well as erectile dysfunction [20]. A few small studies have shown improvement in seminal characteristics and seminal DNA integrity in obese men after weight loss [21–23]. However up to now, there are no data available on the potential benefits of lifestyle modifications with or without weight loss in men on the pregnancy rate in infertile couples. It is therefore unknown whether lifestyle modifications might be beneficial to improve couples' fertility when the male partner or both partners are obese.

Spousal concordance for health behaviours and health related factors has been previously documented, in particularly for physical activity, dietary habits, alcohol consumption and smoking [24]. Assortative mating has been suggested as a possible explanation, with individuals choosing partners having similar habits, and, in the other hand, partners' interinfluence could explain why some partners are more likely to adopt similar habits [25]. However, in the context of infertile couples in which the woman is obese, lifestyle modification interventions are mainly recommended and have mainly focused on women [18]. Although it is to be expected that male partners of women with obesity seeking fertility treatments may adopt similar deleterious lifestyle habits, there is no published study reporting specifically on this population. If this proves to be the case, this could have an adverse impact on the couple's fertility, because of obesity's negative impacts on the male reproductive potential.

Since lifestyle interventions are recommended in women with obesity seeking fertility treatment, it would be important to know whether their male partners should be implicated in these interventions as well. In that sense, this study aims to determine whether male partners of these women significantly share adverse anthropometric or lifestyle characteristics that would justify their participation in such lifestyle interventions. To answer this important question, we performed this study with three objectives: (1) to compare anthropometric measures and lifestyle habits of infertile couples in which the woman is obese with those of the Canadian population of same sex and similar age; (2) to assess the spousal concordance between male and female anthropometric measures and lifestyle habits within the couples; and (3) to assess the associations of male anthropometric measures and lifestyle habits with seminal characteristics.

Subjects, materials and methods

Study design

This cross-sectional study includes the baseline data of participants to a pilot prospective cohort study of male partners of women who participated to the Obesity–Fertility randomised-controlled trial (RCT) (ClinicalTrials.gov NCT01483612; Registered November 25th, 2011) [26]. For the Obesity–Fertility RCT, women were recruited from the fertility clinic of the Centre hospitalier universitaire de Sherbrooke (CHUS), Québec, Canada, between January 2012 and February 2015.

Participants

All male partners of heterosexual couples participating in the Obesity–Fertility RCT were invited to participate in this study. Participants were eligible if they met the two following inclusion criteria: (1) couple's infertility confirmed by a fertility specialist and (2) the spouse was obese, or with a BMI >27 kg/m^2 if affected by the polycystic ovary syndrome (PCOS), and accepted to participate in the Obesity–Fertility RCT (protocol's details have been previously published [26]). Couples were considered as infertile if they did not achieve a conception after 12 months of regular and unprotected sexual relations or after 6 months if the woman had irregular cycles or was aged ≥35 years. Couples would undergo a standard clinical evaluation, usually involving an exploration of anterior risk factors (eg. previous traumas, surgeries, sexually transmitted diseases, etc.) and a physical exam. A hysterosalpingography was prescribed to the women and a seminal analysis to the men. Couples were excluded if they presented a major male or female factor of infertility (obstruction of both tubes, total motility sperm count (TMSC) <5 million, severe endometriosis, etc.), unless their fertility specialist indicated a chance of spontaneous pregnancy despite investigations suggesting a major infertility factor. For instance, only one individual with a TMSC <5 millions was included in this study because the clinician judged that the couple did not have to undergo IVF as their first treatment option, even if the seminal analysis was considered abnormal. Couples were also excluded if one of the two partners had or was planning to have a bariatric surgery.

A total of 130 women agreed to participate in the Obesity–Fertility RCT. Thirty male partners refused to participate and three were excluded because of severe male factor infertility (discovered after enrollment). Therefore, data for 97 female–male partner dyads (75%) were available for the purpose of the cross-sectional study presented in this article.

Ethical approval

The study was approved by the Research Ethics Committee of the CHUS. Written consent was obtained from all participants enrolled in the study prior to data collection.

Procedure

The research team recruited male partners of women participating in the Obesity–Fertility RCT during their visit at the Fertility Clinic of the CHUS or during their spouse's first research visit. If they were interested to participate, the research coordinator obtained their signed and informed consent prior to data collection.

Measurements

Baseline variables were measured for both the male and female partners during their first evaluation visit. Anthropometric measures included: weight and percentage of body fat measured by foot-to-foot bio-impedance scale (TANITA, Arlington Heights (IL)), waist circumference (WC) measured according to the NIH protocol [27] with a measuring tape positioned at the superior edge of the iliac crests, and the body mass index (BMI) calculated by dividing the weight (kg) by squared height (m^2). BMI categories were assigned according to the World Health Organization (WHO) classifications (underweight: BMI < 18.5 kg/m^2; normal: 18.5 < BMI ≤ 25 kg/m^2; overweight: 25 < BMI ≤ 30 kg/m^2; obese: BMI ≥ 30 kg/m^2) [28]. Lifestyle habits (nutrition, physical and leisure activities, sleep, tobacco and alcohol use) were evaluated with a self-reported questionnaire, as mentioned in the Obesity–Fertility protocol [26].

Specifically, questions related to the consumption of fruits, vegetables and dairy products come from the 2010–2011 version of the National Population Health Survey – Household component, cycle 9 [29] and the question related to the whole grains cereal products comes from the 1994 questionnaire version [30]. Additional questions were added to evaluate other lifestyle behaviors, such as daily number of hours of sleep, daily consumption of dairy products, regular soda beverages and tobacco products consumption, weekly consumption of alcoholic beverages and monthly meal consumption at the restaurant. An adaptation of the Healthy Eating Index (HEI) was used in this study, because not all variables were available in order to use the original HEI [31]. The score of this modified version of the HEI (mHEI) could range from 0 to 100.

Physical activity level was estimated with the daily energy expenditure (DEE) score according to self-reported activities practiced in the past three months. Participants were considered as (1) active if their total DEE score was ≥3 kcal/kg/day, (2) moderately active if their total DEE score was equal or above ≥1.5 kcal/kg/day and <3 kcal/kg/day, or (3) inactive if their total DEE score was <1.5 kcal/kg/day.

Conventional seminal quality parameters (seminal volume, sperm count and percentage of progressive motility (grade A + B)) were available for the majority of the participants (n = 94). These seminal analyses were collected as part of the fertility clinic's standard assessment protocol in order to establish the course of treatment by the clinicians. No supplementary sperm analyses were done specifically for this research. For a majority of our participants (79%), the sperm assessment was done within one year of the research visit. A total of 20 participants had a seminal analysis done more than a year before or after their research visit, of which only three participants had seminal analyses done more than two years before or after their initial research assessment. These last three participants were included in the present analyses, but their inclusion or exclusion did not affect the conclusions of this study.

When multiple sperm analysis results were available within 2 years of the research visit for the same participant, only the sperm analysis with the best concentration and progressive motility was used in our analyses. In cases where the sperm analyses were done by other centres than the CHUS, these results were used only if no other results analysed from the CHUS were available. In those cases, seminal morphology results were not used, because not all centres used Kruger's strict criteria. Accordingly, the percentage of spermatozoids with normal morphology was available only for 67 participants. Semen samples were analysed by the clinical laboratories of each centre where samples were collected in accordance to the WHO guidelines [32]. Sperm analysis was considered normal when the TMSC was ≥20 millions [33]. The TMSC was calculated by multiplying the total seminal volume (ml), sperm count (10^6/ml) and percentage of progressive motility (grades A + B) [33].

Statistical analysis

All statistical analyses were performed using SPSS version 20.0 (SPSS Inc., Chicago, IL, USA) with a significance level (α) set at 0.05. Means ± standard deviations (SD) were calculated for normally distributed continuous variables. Several variables were transformed and normalised by natural logarithm, squared root or its inverse (1/value), as specified in tables. These transformed variables are reported as geometric means with their interquartile range. Non-normally distributed continuous variables, which could not be normalised by transformation, are presented by medians with [interquartile range] and categorical variables are presented as proportions.

Comparisons of our sample's characteristics (women and men) to those of the Canadian general population, according to data from Statistics Canada [34–37], were done using one-sample *t*-tests for continuous variables and the one-sample chi-square test for proportions. Pearson and Spearman correlation coefficients were used to investigate relationships between partners' anthropometric characteristics and lifestyle habits, as well as between male characteristics and conventional seminal parameters. Stepwise multivariate linear regression models were used to identify independent predictors of the TMSC, because it is considered the best parameter of the WHO classification system to grade the severity of male infertility [33]. All lifestyle characteristics associated with the TMSC with a *p*-value ≤0.10 were consecutively included into the model, beginning with the variable with the strongest association with TMSC, according to its p-value. At each step, variables that were not independently, significantly associated with TMSC (*p*-value > 0,05) were removed from the model.

Results

Comparisons of study partners' characteristics to the general Canadian population

Characteristics of the male and female partners of our sample were compared to those of the Canadian male and female population [34–37] of similar age and are presented in Table 1. As compared to the Canadian general population, male and female partners of our sample were more often overweight and obese (BMI ≥ 25 kg/m^2, $p < 0.001$ for both sexes; or BMI ≥ 30 kg/m^2, $p = 0.006$ and <0.001, respectively). This was obviously expected for women because a BMI ≥ 30 kg/m^2, or >27 kg/m^2 if they had PCOS, was required for them to be eligible to the Obesity–Fertility RCT [26]. Higher proportions of individuals in our sample displayed increased WC ($p < 0.001$ both sexes) and less had normal blood pressures ($p < 0.001$ both sexes). Our participants were also characterised by a lower quality of their diet (eating ≥5 fruits and vegetables/day, $p < 0.001$ for both sexes, and eating breakfast every day, $p < 0.001$ for both sexes) and had lower proportions of individuals considered as active or moderately active ($p < 0.001$ for both sexes). On the other hand, the proportions of smokers were similar between our population and the reference Canadian population.

Concordance between the characteristics of both partners of study couples

Multiple significant and positive correlations were observed between our female-male dyads (Table 2). Although there were no significant associations between the weight, BMI and WC of partners, there was a significant positive association for fat mass (kg) ($p = 0.043$). In contrast, almost all nutritional and physical activity

Table 1
Comparison of male and female baseline characteristics to the Canadian population of similar age and same sex.

Characteristics	Men (n = 97)	Canadian men[b]	*p*-Value[a]	Women (n = 97)	Canadian women[b]	*p*-Value[a]
Age, years	33.2 ± 6.13	N/A	N/A	30.1 ± 4.73	N/A	N/A
Weight, kg	95.9 ± 23.3	82.7	<0.001	106.9 ± 21.6	69.1	<0.001
BMI, kg/m^2	30.8 ± 7.5	26.5	<0.001	39.4 [34.2-45.3]	25.9	<0.001
Obese (BMI ≥ 30 kg/m^2)	45.4% (44)	24.5%	<0.001	92.8% (90)	20.3%	<0.001
Overweight (BMI 25.0–29.9 kg/m^2) or obese	80.4% (78)	63.5%	<0.001	100% (97)	46.0%	N/A
WC, cm	105.2 ± 18.2	90.7	<0.001	116.1 ± 14.4	82.9	<0.001
WC ≥ 102 cm for men or ≥ 88 cm for women	52.1% (50)	16%	<0.001	100% (97)	33	N/A
Systolic BP, mmHg	119.2 ± 11.9	110	<0.001	114.8 ± 12.4	101	<0.001
Diastolic BP, mmHg	78.4 ± 8.75	72	<0.001	75.64 ± 8.63	67	0.003
Normal BP (≤120/80)	71.9% (69)	93.9%	<0.001	84.4% (81)	96.8%	<0.001
≥5 fruits and vegetables/day	11.3% (11)	32.6%	<0.001	14.4% (14)	46.5%	<0.001
Eats breakfast everyday	36.1% (35)	86.7%	<0.001	39.1% (38)	89.2%	<0.001
Active or moderately active	30.9% (30)	58.2%	<0.001	22.7% (22)	51.3%	<0.001
Smokers	26.8% (26)	28.3%	0.742	23.7% (23)	18.0%	0.305

Abbreviations: BMI: body mass index; BP: blood pressure; cm: centimeter; kg: kilograms; m^2: square metres; mmHg: millimetre of mercury; N/A: not available or not applicable; WC: waist circumference.
Mean ± standard deviations presented for continuous variables and proportions (n) for categorical variables.
[a] Comparisons between sample and Canadian population was done using one-sample *t*-tests for continuous variables and one-sample chi-square tests for proportions.
[b] Canadian population's data are reported as collected by Statistics Canada through national surveys (Canadian Health Measures Survey and Canadian Community Heath Survey), for which samples sizes vary between 4,500 to 130,000 individuals assessed and/or interviewed. References: Statistics Canada [34–37].

Table 2
Correlation between female and male partners' characteristics and health behaviors.

	Coefficient	p-Value
Age (n = 97)	0.67	<0.001
Anthropometric measures		
Weight (n = 97)	0.15	0.138
BMI (n = 97)	0.11	0.109
Fat mass (n = 97)	0.21	0.043
Waist circumference (n = 96)	0.10	0.332
Systolic blood pressure (n = 97)	0.01	0.956
Diastolic blood pressure (n = 97)	0.06	0.580
Heart rate (n = 97)	0.15	0.146
Nutritional behaviors		
Fruits/day[b] (n = 97)	0.23	0.024
Vegetables/day[c] (n = 97)	−0.19	0.066
Fruits and vegetables/day[b] (n = 97)	0.21	0.039
Whole wheat products/day (n = 97)	0.24[d]	0.017
Dairy products[b] (n = 97)	0.08	0.426
Breakfasts/week (n = 97)	0.26	0.011
Restaurant meals/month[b] (n = 97)	0.49	<0.001
Regular soda beverages/day (n = 97)	0.35[d]	0.001
Consumption alcoholic beverages/week (n = 97)	0.25[d]	0.012
mHEI (n = 97)	0.28	0.005
Physical activity behaviors		
Total daily expenditure[a] (n = 97)	0.26	0.012
Time spent in front of a computer[b] (n = 97)	0.39	<0.001
Time spent watching TV[a] (n = 97)	0.45	<0.001
Total time spent doing sedentary leisure activities in front of a screen[a] (n = 97)	0.45	<0.001
Total time spent doing sedentary leisure activities[b] (n = 97)	0.36	<0.001
Other lifestyle behaviors		
Total daily consumption of tobacco products (n = 97)	0.37[d]	<0.001
Hours of sleep/night (n = 97)	0.14[d]	0.180

Abbreviations: BMI: body mass index; mHEI: modified healthy eating index.
[a] Pearson's correlation coefficient presented with transformed data by square root.
[b] Pearson's correlation coefficient presented with transformed data by natural logarithm.
[c] Pearson's correlation coefficient presented with transformed data by its inverse (1/variable).
[d] Spearman's correlation coefficient presented.

lifestyle habits assessed in our study were significantly positively correlated within female-male dyads. Tobacco consumption was also positively associated between partners. As shown in Table 2, the only lifestyle habits that were not significantly positively associated between partners were the consumption of vegetables and dairy products, and the number of hours of sleep per night.

Table 3
Seminal characteristics.

Total motile sperm count (TMSC), millions	115.5 [50.5–179.0]
Normal sperm analysis (TMSC ≥ 20 millions)	90.4% (85)
Volume[a], ml (n = 94)	2.79 [2.0–4.0]
Hypospermia (volume < 1.5 ml)	13.8% (13)
Sperm count[b] (× 10^6) * (n = 94)	61.2 [32.9–98.3]
Oligospermia (count < 15 × 10^6)	3.2% (3)
Motility, % (n = 94)	58.9 ± 13.0
Asthenospermia (progressive motility < 32%)	1.1% (1)
Morphology[b], % (n = 67)	7.79 [5.0–12.0]
Teratospermia (normal morphology < 4%)	20.9% (14)

Mean ± standard deviations are presented for normally distributed continuous variables and proportions (n) for categorical variables.
Abbreviations: ml: milliliter.
[a] Normalised distribution after transformation by square root. Median with [interquartile interval] are presented.
[b] Normalised distribution after transformation by natural logarithm (ln). Median with [interquartile interval] are presented.

Seminal characteristics of male partners and relationships with their anthropometric and lifestyle parameters

Seminal characteristics were available for 94 men in our sample (Table 3). Since men with severely abnormal seminal characteristics were excluded from this study (see section "Participants"), it is not surprising that 90.4% of men presented a normal seminal analysis, according to the TMSC. Table 4 shows that the seminal volume was significantly associated with daily consumption of fruits ($p = 0.044$) and the combination of fruits and vegetables ($p = 0.026$), as well as with weekly consumption of breakfasts ($p = 0.021$) and, unexpectedly, of alcoholic beverages ($p = 0.021$). There was a tendency towards a significant association between seminal volume and mHEI ($p = 0.072$). The sperm total count was significantly and inversely correlated with anthropometric measures ($p = 0.02$ for all), and positively with sleeping hours ($p = 0.032$). The percentage of progressively motile spermatozoa was significantly and negatively associated with BMI ($p = 0.026$) and WC ($p = 0.049$), with a trend for age ($p = 0.088$) and weight ($p = 0.078$). No significant association was found between the percentage of normal morphology and baseline characteristics assessed in this study.

Overall, the TMSC showed an inverse relationship with multiple anthropometric measures, as well as positive associations with nutritional and sleeping hours (Table 4). The stepwise multivariate linear regression model determined that among all parameters associated with the TMSC in univariate analyses, the factors inde-

Table 4
Correlation coefficients between seminal characteristics and age, vital signs, anthropometric measures and lifestyle habits.

Variables	√(Volume) (n = 94)	LN(Count) (n = 94)	Motility (n = 94)	LN(Morphology) (n = 67)	√(TMSC) (n = 94)
Age (n = 97)	0.08	−0.18	−0.18[*]	−0.05	−0.11
Systolic blood pressure (n = 97)	0.01	−0.14	0.07	−0.01	−0.09
Diastolic blood pressure (n = 97)	−0.07	−0.13	−0.03	0.12	−0.13
Weight (n = 97)	−0.07	−0.24[**,***]	−0.18[*,****]	−0.08	−0.23[**,****]
% of fat mass (n = 97)	−0.02	−0.21[α**,***]	−0.12	−0.19	−0.17[a,*]
BMI (n = 97)	−0.14	−0.25[**,****]	−0.23[**,****]	−0.02	−0.28[**,****]
Waist circumference (n = 96)	−0.10	−0.24[**,****]	−0.20[**,****]	−0.08	−0.26[**,****]
Fruits[b] (n = 97)	0.21[**,****]	0.14	−0.05	−0.03	0.23[**,****]
Vegetables[d] (n = 97)	−0.15	−0.02	−0.11	−0.17	−0.12
Fruits & vegetables[b] (n = 97)	0.23[**,****]	0.13	0.01	0.07	0.24[**,****]
Whole wheat cereal products[a] (n = 97)	0.04	0.04	−0.03	0.09	0.06
Dairy products[b] (n = 97)	0.05	0.10	0.02	0.14	0.09
Breakfast/week[a] (n = 97)	0.24[**]	0.10	−0.02	−0.12	0.19[*]
Regular soda beverages[a] (n = 97)	−0.15	−0.12	0.06	−0.20	−0.14
Restaurant[b] (n = 97)	−0.08	0.04	0.14	0.02	−0.01
Alcohol consumption[a] (n = 97)	0.25[**]	−0.06	0.09	0.11	0.06
mHEI (n = 97)	0.19[*,***]	0.11	−0.07	0.11	0.19[*,****]
Total daily expenditure[d] (n = 97)	−0.13	−0.05	−0.11	−0.05	−0.12
Computer[b] (n = 97)	0.06	0.03	0.01	0.12	0.02
Television[c] (n = 97)	−0.16	0.12	−0.12	−0.04	−0.02
Total screen sedentary activities[c] (n = 97)	−0.16	0.11	−0.12	−0.04	−0.02
Total sedentary activities[c] (n = 97)	−0.05	0.17	−0.05	0.06	0.07
Hours of sleep (n = 97)	0.10	0.22[a,**]	−0.09	0.02	0.18[a,*]
Tobacco products consumption[a] (n = 97)	−0.15	0.02	0.01	−0.05	−0.09

Abreviations: BMI: body mass index; LN: natural logarithm; mHEI: modified healthy eating index.
Volume: seminal volume (ml); Count: total number of spermatozoids (10^9); Motility: percentage of progressively motile sperm (grade A + B); Morphology: percentage of normal spermatozoa according to the Tygerberg stric criteria; TMSC: total motile sperm count, calculated by multiplying the volume, the total count and the percentage of progressively motile sperm.
Pearson's correlation coefficient presented for normally distributed variables, or after logarithmic, squared root or inverse transformation.
[a] Spearman's correlation coefficient reported.
[b] Data transformed by natural logarithm.
[c] Data transformed by square root.
[d] Data transformed by its inverse (1/variable).
[*] *p*-Value < 0.10.
[**] *p*-Value < 0.05.
[***] *p*-Value < 0.10, after correcting for age.
[****] p-Value < 0.05, after correcting for age.

pendently associated to TMSC with a *p*-value ≤0.10 were: (1) BMI (β = −3.80, *p* = 0.020); (2) daily consumption of fruits and vegetables (β = 52.5, *p* = 0.046) and 3) sleeping hours (β = 20.2, *p* = 0.088), which was almost statistically significant. This model was highly statistically significant (*p*-value = 0.006) and explained 13% of the overall variability of TMSC (R^2 = 0.13).

Discussion

This study found that among infertile couples in which the women is obese, or overweight with PCOS, not only female but also male partners present a more adverse health profile and lifestyle than the average Canadian population of similar age. Indeed, men and women from our sample were characterised by: (1) higher percentages of overweight and obesity (including abdominal obesity), (2) less healthy nutritional behaviours, and (3) lower proportions of active or moderately active subjects. Moreover, we found multiple significant spousal concordances between the lifestyle habits of both partners, suggesting that couples tend to adopt a similar lifestyle. Finally, our results showed that anthropometric measures and lifestyle habits of our male partners were significantly associated with their conventional seminal parameters, even if the vast majority had normal seminal analyses, since a major male factor was an exclusion criterion of the study.

Our results have shown that lifestyle habits tend to be moderately associated between partners, suggesting that couple's partners can influence each other's lifestyle habits. Very few studies have assessed the concordance between anthropometric and lifestyle characteristics among female-male dyads. Davillas & Pudney [38] have reported significant associations between men and women's BMI and WC, which were not found in our study. This is possibly due to the fact that women were all overweight or obese, according to the Obesity–Fertility study's design, which was not an inclusion criterion for men. This has reduced the statistical variation for that variable in women only. Significant concordance between spouses for smoking, alcohol drinking and physical activity behaviours are in accordance with findings from Jurj et al. who assessed 66,130 Chinese couples [39]. In a systematic review on health concordance within couples [24], dietary habits have been reported to be associated within couples' dyads, specifically for the consumption of fruits and vegetables. Moreover, the longitudinal study of Jackson et al., examining the impacts of positive behavioural changes of one partner on the behavioural changes of the other partner, suggests that aiming couples instead of individuals could increase considerably the effectiveness of lifestyle interventions [25]. This is even more relevant in the context of infertile couples in which the spouse is obese, because partners share a common objective, which is to conceive and give birth to a healthy baby.

Regarding the associations between the anthropometric characteristics of male partners and their seminal parameters, another meta-analysis including 30 studies, for a total sample of 115,158 individuals, has reported no association between BMI and conventional seminal parameters, except for morphology [40]. More recently, a study of 4440 men observed a significant decrease in ejaculate volume, total sperm count, concentration, morphology and progressive motility with increasing BMI, even after correcting for age [19]. We also found a significant association between

BMI and lower sperm count and motility, independently of age, although we did not find a correlation with seminal volume and morphology. This difference may be explained by a lack of statistical power with our much smaller sample (n = 94), the subjective evaluation of certain seminal parameters (e.g. morphology) and the known variability of seminal measures [41]. Fejes et al. have reported correlations between WC and sperm count and TMSC, as found in our study, but also with a lower seminal volume [42]. More recently, Hammiche et al. have also reported in infertile couples a significant decrease in sperm concentration and TMSC with increasing WC [43], but they did not find a significant relationship with total progressive motility.

Different hypotheses may explain the negative association between obesity and seminal parameters, such as lower testosterone and higher estradiol levels, secondary hypogonadotrophic hypogonadism, increased levels of leptin, altered adipokines secretion, and elevated intra-testicular ROS levels, which is associated with increased DNA fragmentation [44]. In addition, adipose tissues in the lower abdominal and genital region can impair spermatogenesis by increasing scrotal temperature and exposure of spermatozoids to liposoluble environmental toxins, such as pesticides, solvents and polybromodiphénylethers [45].

In addition to BMI, nutritional and sleep behaviors were also independently correlated to TMSC in our study. Although no other study has reported on the association between TMSC and nutritional habits, one systematic review [46] and one meta-analysis [47] concluded that men adhering to a healthy dietary pattern (characterised by a high consumption of vegetables, fruits, whole grains, fish, poultry, olive oil, soy and low-fat dairy products) had a higher seminal quality than those with a unhealthy dietary pattern (high consumption of red and/or processed meat, refined grain, sweets, high-fat dairy products, butter/margarine, potato, high-fat gravy). Gaskins et al. reported that a diet with a high consumption of fish, fruits and vegetables, and whole grains was positively associated with the percentage of progressively motile sperm (after multiple adjustments) [48]. Similarly, Braga et al., in study in 250 couples undergoing IVF-ICSI cycles, reported a significant positive correlation between sperm motility and the consumption of fruits ($\beta = 7.5$, $p = 0.028$) and cereals ($\beta = 11.0$, $p < 0.01$) [49]. Chen et al. have reported an U-inversed relationship between sleep duration and semen volume or sperm count [50].

Surprisingly, we observed a significant increase in seminal volume with increasing consumption of alcoholic beverages, as opposed to Braga et al. and Gaskins et al. The mean alcohol consumption in our sample was only 1.5 [0.25–4.0] beverages per week, in contrast to consumption of alcoholic beverages on a daily basis in most studies reporting negative associations with altered seminal characteristics. It is possible that in our cohort the low consumption of alcoholic beverages was associated with an otherwise healthy behaviour that confounded the correlation with seminal parameters.

The main strength of our study is the availability of several anthropometric and health behaviour data that were collected prospectively for both partners and compared with data collected by Health Canada on a similar Canadian population. Anthropometric measures were measured directly instead of being self-reported. Both anthropometric measures and lifestyle habits were evaluated within a one-month period for both partners. Additionally, information was available on semen parameters for 72.3% of our sample.

One possible limitation of our study is that women of couples selected for the Obesity–Fertility study might have a higher level of obesity than women with obesity seeking fertility in general, due to selection bias. Additionally, because seminal analyses were done approximately within one year of the anthropometric and lifestyle habits assessment, it is possible that men's lifestyle and anthropometric profiles do not reflect their condition at the moment of seminal collection, which could have weaken the associations observed between seminal characteristics and clinical parameters. Furthermore, lifestyle habits were collected through self-reported questionnaires and participants were asked to give a general profile of their lifestyle habits representing the last 6 months, which is susceptible to social desirability and recall biases. Finally, it could be argued that this study is limited by a relatively low number of participants, especially for correlation analyses. Accordingly, a non-significant correlation does not mean that such correlation does not exist, since it could result from a lack of power. Significant associations, however, are robust and reliable.

In conclusion, our study is the first to report that male partners of subfertile couples in which the woman is obese present worse anthropometric characteristics and lifestyle habits than the male population of corresponding age. We also showed that these adverse health characteristics tend to be similar between both partners of the couples and were directly associated with reduced sperm quality in men. This study highlights that anthropometric characteristics and nutritional behaviours can have a negative impact on the male reproductive potential, reinforcing the importance of counselling men to adopt a healthy lifestyle in order to improve their own fertility potential, in addition to that of their couple. Therefore, male partners might benefit from the lifestyle intervention already recommended for their spouse, which could in turn improve the couple's fertility, instead of focussing mainly on the woman.

Authors' roles

All eight authors approved the publication of this version and agreed to be accountable for all aspects of its content.

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Conflict of interest

None.

CRediT authorship contribution statement

M. Belan: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing, Visualization, Project administration. **B. Carranza-Mamane:** Conceptualization, Methodology, Writing - review & editing. **M.H. Pesant:** Conceptualization, Methodology, Writing - review & editing. **Y. AinMelk:** Conceptualization, Methodology, Writing - review & editing. **K. Duval:** Conceptualization, Methodology, Investigation, Writing - review & editing, Project administration, Funding acquisition. **F. Jean-Denis:** Conceptualization, Methodology, Investigation, Writing - review & editing, Project administration, Funding acquisition. **M.F. Langlois:** Conceptualization, Methodology, Writing - review & editing. **J.P. Baillargeon:** Conceptualization, Methodology, Formal analysis, Writing - review & editing, Visualization, Supervision, Project administration, Funding acquisition.

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References

[1] Bushnik T, Cook JL, Yuzpe AA, Tough S, Collins J. Estimating the prevalence of infertility in Canada. Hum Reprod 2012;27:738–46, http://dx.doi.org/10.1093/humrep/der465.

[2] Mansour R, Ishihara O, Adamson GD, Dyer S, de Mouzon J, Nygren KG, et al. International Committee for Monitoring Assisted Reproductive Technologies world report: assisted reproductive technology 2006. Hum Reprod 2014;29:1536–51, http://dx.doi.org/10.1093/humrep/deu084.

[3] Kamphuis EI, Bhattacharya S, van der Veen F, Mol BWJ, Templeton A, for the Evidence Based IVF Group. Are we overusing IVF? BMJ 2014;348, http://dx.doi.org/10.1136/bmj.g252, g252–2.

[4] Society of Obstetricians and Gynaecologists of Canada, Okun N, Sierra S. Pregnancy outcomes after assisted human reproduction. J Obstet Gynaecol Can 2014;36:64–83.

[5] Bolúmar F, Olsen J, Rebagliato M, Sáez-Lloret I, Bisanti L. Body mass index and delayed conception: a European Multicenter Study on Infertility and Subfecundity. Am J Epidemiol 2000;151:1072–9.

[6] Purcell SH, Moley KH. The impact of obesity on egg quality. J Assist Reprod Genet 2011;28:517–24, http://dx.doi.org/10.1007/s10815-011-9592-y.

[7] Bellver J, Busso C, Pellicer A, Remohí J, Simón C. Obesity and assisted reproductive technology outcomes. Reprod Biomed Online 2006;12:562–8, http://dx.doi.org/10.1016/S1472-6483(10)61181-9.

[8] Maheshwari A, Stofberg L, Bhattacharya S. Effect of overweight and obesity on assisted reproductive technology—a systematic review. Hum Reprod Update 2007;13:433–44, http://dx.doi.org/10.1093/humupd/dmm017.

[9] DeUgarte DA, DeUgarte CM, Sahakian V. Surrogate obesity negatively impacts pregnancy rates in third-party reproduction. Fertil Steril 2010;93:1008–10, http://dx.doi.org/10.1016/j.fertnstert.2009.07.1005.

[10] Clark AM, Thornley B, Tomlinson L, Galletley C, Norman RJ. Weight loss in obese infertile women results in improvement in reproductive outcome for all forms of fertility treatment. Hum Reprod 1998;13:1502–5.

[11] Sim KA, Dezarnaulds GM, Denyer GS, Skilton MR, Caterson ID. Weight loss improves reproductive outcomes in obese women undergoing fertility treatment: a randomized controlled trial. Clin Obes 2014;4:61–8, http://dx.doi.org/10.1111/cob.12048.

[12] Mutsaerts MAQ, van Oers AM, Groen H, Burggraaff JM, Kuchenbecker WKH, Perquin DAM, et al. Randomized trial of a lifestyle program in obese infertile women. N Engl J Med 2016;374:1942–53, http://dx.doi.org/10.1056/NEJMoa1505297.

[13] Thessaloniki ESHRE/ASRM-Sponsored PCOS Consensus Workshop Group. Consensus on infertility treatment related to polycystic ovary syndrome. Hum Reprod 2008;23:462–77, http://dx.doi.org/10.1093/humrep/dem426.

[14] American Dietetic Association, American Society of Nutrition, Siega-Riz AM, King JC. Position of the American Dietetic Association and American Society for Nutrition: obesity, reproduction, and pregnancy outcomes. J Am Diet Assoc 2009;109:918–27, http://dx.doi.org/10.1016/j.jada.2009.03.020.

[15] ESHRE Task Force on Ethics and Law, Dondorp W, de Wert G, Pennings G, Shenfield F, Devroey P, et al. Lifestyle-related factors and access to medically assisted reproduction. Hum Reprod 2010;25:578–83, http://dx.doi.org/10.1093/humrep/dep458.

[16] American College of Obstetricians and Gynecologists. Obesity in pregnancy. Committee opinion no. 549. Obstet Gynecol 2013;121:213–7.

[17] Ramlau-Hansen CH, Thulstrup AM, Nohr EA, Bonde JP, Sorensen TIA, Olsen J. Subfecundity in overweight and obese couples. Human Reproduction 2007;22:1634–7, http://dx.doi.org/10.1093/humrep/dem035.

[18] Belloc S, Cohen-Bacrie M, Amar E, Izard V, Benkhalifa M, Dalléac A, et al. High body mass index has a deleterious effect on semen parameters except morphology: results from a large cohort study. Fertil Steril 2014;102:1268–73, http://dx.doi.org/10.1016/j.fertnstert.2014.07.1212.

[19] Bieniek JM, Kashanian JA, Deibert CM, Grober ED, Lo KC, Brannigan RE, et al. Influence of increasing body mass index on semen and reproductive hormonal parameters in a multi-institutional cohort of subfertile men. Fertil Steril 2016;106:1070–5, http://dx.doi.org/10.1016/j.fertnstert.2016.06.041.

[20] Diaz-Arjonilla M, Schwarcz M, Swerdloff RS, Wang C. Obesity, low testosterone levels and erectile dysfunction. Int J Impot Res 2009;21:89–98, http://dx.doi.org/10.1038/ijir.2008.42.

[21] Mir J, Franken D, Andrabi SW, Ashraf M, Rao K. Impact of weight loss on sperm DNA integrity in obese men. Andrologia 2018;50:e12957, http://dx.doi.org/10.1111/and.12957.

[22] Håkonsen LB, Thulstrup AM, Aggerholm AS, Olsen J, Bonde JP, Andersen CY, et al. Does weight loss improve semen quality and reproductive hormones? Results from a cohort of severely obese men. Reprod Health 2011;8:24, http://dx.doi.org/10.1186/1742-4755-8-24.

[23] Faure C, Dupont C, Baraibar MA, Ladouce R, Cedrin-Durnerin I, Wolf JP, et al. In Subfertile couple, abdominal fat loss in men is associated with improvement of sperm quality and pregnancy: a case-series. PLoS One 2014;9:e86300, http://dx.doi.org/10.1371/journal.pone.0086300.

[24] Meyler D, Stimpson JP, Peek MK. Health concordance within couples: a systematic review. Soc Sci Med 2007;64:2297–310, http://dx.doi.org/10.1016/j.socscimed.2007.02.007.

[25] Jackson SE, Steptoe A, Wardle J. The influence of partner's behavior on health behavior change: the English Longitudinal Study of Ageing. JAMA Intern Med 2015;175:385–92, http://dx.doi.org/10.1001/jamainternmed.2014.7554.

[26] Duval K, Langlois M-F, Carranza-Mamane B, Pesant M-H, Hivert M-F, Poder TG, et al. The Obesity–Fertility Protocol: a randomized controlled trial assessing clinical outcomes and costs of a transferable interdisciplinary lifestyle intervention, before and during pregnancy, in obese infertile women. BMC Obes 2015;2:47, http://dx.doi.org/10.1186/s40608-015-0077-x.

[27] Patry-Parisien J, Shields M, Bryan S. Comparison of waist circumference using the World Health Organization and National Institutes of Health protocols. Health Rep 2012;23:53–60.

[28] World Health Organization. Obesity and overweight. WHO, n.d.

[29] Statistics Canada. National Population Health Survey – Household Component Cycle 9 (2010–2011); 2011.

[30] Statistics Canada. National Population Health Survey Supplements; 1994.

[31] Guenther PM, Casavale KO, Reedy J, Kirkpatrick SI, Hiza HAB, Kuczynski KJ, et al. Update of the Healthy Eating Index: HEI-2010. J Acad Nutr Diet 2013;113:569–80, http://dx.doi.org/10.1016/j.jand.2012.12.016.

[32] World Health Organization. WHO laboratory manual for the examination and processing of human semen. 5th ed; 2010.

[33] Hamilton JA, Cissen M, Brandes M, Smeenk JM, de Bruin JP, Kremer JA, et al. Total motile sperm count: a better indicator for the severity of male factor infertility than the WHO sperm classification system. Hum Reprod 2015;30:1110–21, http://dx.doi.org/10.1093/humrep/dev058.

[34] Statistics Canada. Table 105-0501 — Health indicator profile, annual estimates, by age and sex, Canada, provinces, territories, health regions (2013 boundaries) and peer groups; 2016.

[35] Statistics Canada. Table 105-0507 — Measured adult body mass index (BMI), by age group and sex, household population aged 18 and over excluding pregnant females Canada (excluding territories); 2009. p. 1–3.

[36] Statistics Canada. Canadian Health Measures Survey—Cycle 1 Data Tables 2007 to 2009; 2010.

[37] Statistics Canada. Table 105-2012 — Reported occasion of food consumption by age group and sex, household population aged 1 and over, Canadian Community Health Survey (CCHS 2.2), Canada and provincesoccasional; 2012.

[38] Davillas A, Pudney S. Concordance of health states in couples: analysis of self-reported, nurse administered and blood-based biomarker data in the UK Understanding Society panel. J Health Econ 2017;56:87–102, http://dx.doi.org/10.1016/j.jhealeco.2017.09.010.

[39] Jurj AL, Wen W, Li H-L, Zheng W, Yang G, Xiang Y-B, et al. Spousal correlations for lifestyle factors and selected diseases in Chinese couples. Ann Epidemiol 2006;16:285–91, http://dx.doi.org/10.1016/j.annepidem.2005.07.060.

[40] Campbell JM, Lane M, Owens JA, Bakos HW. Paternal obesity negatively affects male fertility and assisted reproduction outcomes. Reprod Biomed Online 2015;31:593–604, http://dx.doi.org/10.1016/j.rbmo.2015.07.012.

[41] Coetzee K, Kruge TF, Lombard CJ. Predictive value of normal sperm morphology: a structured literature review. Hum Reprod Update 1998;4:73–82.

[42] Fejes I, Koloszár S, Szöllosi J, Závaczki Z, Pál A. Is semen quality affected by male body fat distribution? Andrologia 2005;37:155–9, http://dx.doi.org/10.1111/j.1439-0272.2005.00671.x.

[43] Hammiche F, Laven JSE, Twigt JM, Boellaard WPA, Steegers EAP, Steegers-Theunissen RP. Body mass index and central adiposity are associated with sperm quality in men of subfertile couples. Hum Reprod 2012;27:2365–72, http://dx.doi.org/10.1093/humrep/des177.

[44] Palmer NO, Bakos HW, Fullston T, Lane M. Impact of obesity on male fertility, sperm function and molecular composition. Spermatogenesis 2012;2:253–63, http://dx.doi.org/10.4161/spmg.21362.

[45] Abdelouahab N, Ainmelk Y, Takser L. Polybrominated diphenyl ethers and sperm quality. Reprod Toxicol 2011;31:546–50, http://dx.doi.org/10.1016/j.reprotox.2011.02.005.

[46] Salas-Huetos A, Bulló M, Salas-Salvadó J. Dietary patterns, foods and nutrients in male fertility parameters and fecundability: a systematic review of observational studies. Hum Reprod Update 2017;23:371–89, http://dx.doi.org/10.1093/humupd/dmx006.

[47] Arab A, Rafie N, Mansourian M, Miraghajani M, Hajianfar H. Dietary patterns and semen quality: a systematic review and meta- analysis of observational studies. Andrology 2018;6:20–8, http://dx.doi.org/10.1111/andr.12430.

[48] Gaskins AJ, Colaci DS, Mendiola J, Swan SH, Chavarro JE. Dietary patterns and semen quality in young men. Hum Reprod 2012;27:2899–907, http://dx.doi.org/10.1093/humrep/des298.

[49] Braga DP, Halpern G, Figueira Rde C, Setti AS, Iaconelli Jr A, Borges Jr E. Food intake and social habits in male patients and its relationship to intracytoplasmic sperm injection outcomes. Fertil Steril 2012;97:53–9, http://dx.doi.org/10.1016/j.fertnstert.2011.10.011.

[50] Chen Q, Yang H, Zhou N, Sun L, Bao H, Tan L, et al. Inverse U-shaped association between sleep duration and semen quality: longitudinal observational study (MARHCS) in Chongqing, China. Sleep 2016;39:79–86, http://dx.doi.org/10.5665/sleep.5322.