TITLE

Does pregnancy affect the metabolic equivalent at rest and during low intensity exercise?

RUNNING TITLE

Metabolic equivalent during pregnancy

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ABSTRACT

Background: One metabolic equivalent (MET) is the amount of oxygen consumed while sitting at rest and is equal to 3.5 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$. METs are often used to provide simple, practical, and easily understood values that reflect the energy cost of physical activity. It is plausible that the increase in body mass and absolute submaximal oxygen uptake during gestation has the potential to affect the MET of pregnant women.

Objective: The aim of this study was to measure the MET during the second trimester of pregnancy and to compare this with non-pregnant women. In addition, the measured MET values were compared to those proposed by the Compendium of Physical Activities (CPA).

Design: Ten pregnant and ten non-pregnant women participated in this study. Ventilatory variables and heart rate (HR) were measured during four conditions on two different days: Condition 1 – sitting, Condition 2 – lying, Condition 3 –treadmill walking and Condition 4 – cycling. The women performed two conditions on each testing day; one resting condition followed by one exercising condition. The data were analysed using a two-way ANOVA with repeated measures. Bonferroni's tests were used when significant differences were detected.

Results: The MET was not significantly different between pregnant and non-pregnant women either at ***rest*** or during ***exercise*** ($p > 0.05$). While cycling, the MET obtained by indirect calorimetry (IC) was significantly higher than the CPA predicted MET, regardless of group (pregnant cycling $p = 0.002$ and non-pregnant cycling $p < 0.001$). During pregnancy, ventilation and heart rate were significantly greater in both the ***resting*** and ***exercising*** conditions ($p > 0.05$). In general (combined pregnant and non-pregnant data), VE and HR were significantly higher during seated rest, when compared with supine rest and all ventilatory variables, HR and ratings of perceived exertion (RPE) were significantly higher during cycling, when compared with walking ($p > 0.05$).

Conclusion: METs were unaffected by pregnancy at rest or when undertaking either walking or cycling exercise during the second trimester of pregnancy. The MET of cycling was significantly underestimated by the CPA, when compared to IC, in both groups.

KEYWORDS: Pregnancy, exercise, rest, metabolic equivalent

INTRODUCTION

Due to the rising prevalence of maternal obesity, and its adverse effects on maternal and foetal health, there is an urgent need to advocate appropriate exercise interventions during pregnancy in order to avoid excessive gestational weight gain and prevent prolonged postpartum weight retention**1**. There are numerous guidelines for prescribing exercise during pregnancy**2,3,4,5**, however, the suggested exercise intensities are often based on standard, non-pregnant values. The most commonly used methods to establish exercise intensity are rating of perceived exertion (RPE), heart rate (HR), oxygen uptake (VO_2) and metabolic equivalent (MET). Metabolic equivalents are a popular way to quantify energy expenditure and intensity in specific activities as they are simple to calculate (1 MET = 3.5 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$) and can be normalised for body mass**6,7**. However, whilst several studies have used standardised MET values for pregnant women**8,9,10,11**, others**12,13** have highlighted the need to measure specific MET value during pregnancy, as the standardised MET value might not represent the true exercise intensity for pregnant women.

During pregnancy total energy expenditure is higher because basal and resting metabolic rates rise, due to biological offspring-related tissue synthesis, which increases oxygen uptake demand**12,14,15,16**. Such increases occur as the additional respiratory gas exchange is required to maintain the new biological tissue. Furthermore, the adipose tissue becomes more metabolically active, which favours a greater energy supply**14**. Thus, there is higher energy expenditure in pregnancy, both at rest and during physical activity**12,17**. Indeed, it has been reported that a continuous increment in basal metabolic rate occurs throughout pregnancy; a longitudinal study**16** found an increase in basal metabolic rate, compared with the pre-pregnancy period, of approximately 5%, 11% and 24% in the first, second and third trimester. In addition to the changes in oxygen uptake experienced during pregnancy, gestational weight gain also has the potential to affect the MET. In some weight-bearing activities, such as walking, the force generated by gravity contributes to an increase in exercise intensity**18**. Therefore, the energy expenditure for pregnant women walking the same distance is higher during late gestation when compared with early gestation, depending on weight gain, and compared with non-pregnant women**19**. Research examining the effects of pregnancy on energy expenditure during weight-supported activities, such as stationary cycling, have yielded inconsistent results. O'Toole**19** suggested that energy expenditure isn't affected by body mass and is only related with external work and mechanic efficiency and does not differ between pregnant and non-pregnant women. Khodiguian et al.**20** found that submaximal exercise, on a cycle ergometer, did not result in significant differences in HR, VO_2, cardiac output (Q), stroke volume (SV) or arteriovenous oxygen difference (A-VO2 diff) between pregnant and non-pregnant women; however, the pregnant women had significantly higher submaximal HR, VO_2 and A-VO2 diff and significantly lower SV when compared with their postpartum values. The authors concluded that these findings indicate that pregnancy/control versus pregnancy/ postpartum conditions produce statistically different results and that future research needs to develop standardised methodologies to evaluate physiological processes during pregnancy.

Therefore, if changes in body mass, oxygen uptake and, consequently, in energy expenditure are expected during pregnancy, the MET value during some activities might be underestimated when using non-pregnant women as a reference group, especially during the latter stages of pregnancy. This study will expand previous data from Campbell et al.**21** by extending measures of energy expenditure into the second trimester of pregnancy. The aim of this study was to measure the MET between 20 and 27 weeks gestation under four conditions: (1) sitting, (2) lying, (3) walking and (4) cycling and to compare this with non-pregnant women. In addition, the measured MET values were compared to those proposed by the Compendium of Physical Activities. The Compendium of Physical Activities

(CPA) is a popular tool in epidemiologic studies and was designed to normalise the MET intensities used in physical activity questionnaires, by providing a classification system that standardises the MET intensities of physical activities used in survey research**22**. However a limitation of the CPA is that it is unable to account for differences in energy expenditure caused by variations in body mass, adiposity, age, sex, efficiency of movement and the geographic and environmental conditions in which the activities are performed. Therefore, there may be large inter and intra-individual variation in energy expenditure for the same activity and as such the values provided by the CPA may obfuscate the true energy cost for a given individual. This is of particular relevance to pregnant women who are affected by many of these variants.

METHODOLOGY

Participants

Twenty, healthy, sedentary women, 10 pregnant (age 32 ± 6 years; height 161.2± 6.9cm; body mass 65.7 ± 11.2 kg; body mass index 25.2 ± 3.8 $kg{\cdot}m^2$; percentage body fat 33.3±26.9 %; gestational stage 23.6 ± 3.8 weeks; pre-pregnancy weight 59.9± 4.7 kg; pre body mass index 22.8 ± 2.3 $kg{\cdot}m^2$) and 10 non-pregnant (age 27 ± 4 years; height 163.8±7.4 cm; body mass 59.6 ± 8.4 kg; body mass index 22.3 ± 3.2 $kg{\cdot}m^2$; percentage body fat 26.9±6.4 %), volunteered and gave their informed consent to participate in the study. All pregnant women had singleton pregnancies. Participants with restrictive pathologies known to affect physical activity or those taking medication that could interfere with normal physiological responses were excluded from the study. Participants were considered inactive if they scored category 1 (no activity was reported or some activity was reported but not enough to meet categories 2 or 3) on the International Physical Activity Questionnaire Long Version**23**. Permission and eligibility to participate was provided by participants' healthcare provider and all women gave written informed consent. The study was approved by the University Research Ethics Committee (Humans) and participants could withdraw at any time without explanation.

Experimental design

Participants attended the laboratory, at the University of Sao Paulo, on two occasions following the same protocol and restrictions on each visit. Laboratory visits were conducted on different days, exactly 7 days between visits, at the same time of day to ensure that measurements were not affected by circadian variation**24**. Temperature (23 ± 2 ºC) and luminosity were the same for all visits. Participants were asked to eat 2 h prior to each laboratory visit and to abstain from strenuous exercise and alcohol and caffeine consumption in the 24 h before each measurement. Participants completed an informed consent form, health screen and IPAQ questionnaire on the first laboratory visit; height, body mass and percentage body fat were also measured.

Participants completed four conditions during the study; (1) sitting, (2), lying, (3) walking and (4) cycling. The sitting and lying conditions were classified as "resting" and the walking and cycling conditions were classified as "exercising". Participants completed two conditions (one resting and one exercising) at each laboratory visit, which were randomly allocated. Two different resting protocols were used, as previous research has shown different resting values when comparing sitting to lying in non-pregnant participants (2.6 ± 0.4 ml $O_2{\cdot}kg^{-1}{\cdot}min^{-1}$ and 2.8 ± 0.3 ml $O_2{\cdot}kg^{-1}{\cdot}min^{-1}$)**9,25**.

Following a rest condition, participants performed a three minute self-paced warm-up, after which they were required to complete 20 minutes of low intensity (equivalent to 3 METs)**6,7** weight-bearing (Inbrasport ATL® Treadmill, Inbrasport, Brazil) or non-weight bearing (Eletromagnetic Cycle Ergometer Godart-Holland , Godart NV, Lannoy) exercise. Oxygen uptake (VO_2), ventilation (VE), MET and energy expenditure (EE) were measured throughout the resting and exercising conditions by indirect calorimetry using a portable metabolic system (K4b^2, COSMED, Italy); heart rate (HR) was also monitored using a heart rate monitor (T-31, Polar, UK).

Experimental protocol

On the first testing session, height was measured using a standard stadiometer to the nearest 0.1 cm, and body mass was measured, to the nearest 0.1 kg, using a standard electronic body-weight scale; percentage body fat was also measured using the same scale. Self-reported, pre-pregnancy body mass was provided at the first laboratory visit. Participants also provided their age, ethnicity, gravidity and parity.

Both testing sessions followed the same experimental protocol. The participants were fitted with a HR monitor and a gas analysis mask, which they were required to wear throughout the session. Following a two-minute gas analysis calibration process, participants were instructed to either sit or lie, depending on the rest condition, for 20 minutes in order to establish a metabolic steady state. During the rest condition (sitting or lying) participants could listen to music, but were prohibited from using any electronic devices, sleeping or interacting with the experimenter. During the lying condition, pregnant participants were placed in the lateral decubitus position. Following the rest condition, participants were positioned on either a cycle ergometer or treadmill, depending on the exercise condition. Following a three minute, self-paced warm-up, the exercise test was initiated. Participants were required to cycle at 50 W for 20 minutes, or to walk at 2.5 $km \cdot h^{-1}$ on a 1% incline for 20 minutes. Ratings of perceived exertion**26** was measured 30 seconds before cessation of the 20 minute exercise bout. Following the exercise, a three-minute, self-paced cool-down was performed.

Statistical analysis

As the exercise protocols were not steady state during the first five minutes, only values obtained in the last five minutes of each condition were used for data analysis. All data are represented as mean ± SD. Shapiro-Wilk normality tests were used to establish if data were normally distributed. Data that was not normally distributed underwent a logarithmic transformation to meet the normality assumption. Groups and conditions were compared using a two-way ANOVA with repeated measures, followed by Bonferroni post-hoc analysis. One-sample t-test were used to detect differences between observed (IC) and predicted (CPA) MET values. The MET value measured by IC was calculated by dividing the total oxygen consumption during an activity (rest or exercise) by 3.5 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$. The level of significance was set at $P < 0.05$.

RESULTS

Both groups had similar anthropometric characteristics; there were no significant differences in age, body mass, height and body mass index between the groups ($P > 0.05$). However, pregnant women had a significantly higher percentage body fat (33.3 ± 6.4 %) compared with non-pregnant women

(26.9 ± 6.4 %); p =0.04. Participants were predominately Caucasian, with the exception of one participant who identified themselves as Japanese and white, and para 1 (primiparous), with the exception of one woman who was para 2 (multiparous).

Self-reported pre-pregnancy body mass was 59.9± 4.7 kg, which was significantly lower than during pregnancy (65.7 ± 11.2 kg; p = 0.011), which is equivalent to a gestational weight gain of approximately 6 kg and an overall 10% increase in body mass.

Rest conditions: sitting and lying

Table 1. Mean ± SD values for ventilation, oxygen uptake, heart rate, metabolic equivalent and energy expenditure for pregnant and non-pregnant women during both resting conditions (lying and sitting).

	Pregnant (n = 10)		Non-pregnant (n = 10)	
Variables	Lying	Sitting	Lying	Sitting
Metabolic equivalent	0.98 ± 0.14	1.10 ± 0.26	0.98 ± 0.19	0.96 ± 0.18
Energy expenditure (kcal)	67.87 ± 13.46	74.99 ± 13.87	60.85 ± 16.73	61.66 ± 14.80
Ventilation ($l \cdot min^{-1}$)	8.58 ± 1.83*	9.76 ± 1.41^{a}	6.47 ± 1.42^{b}	7.18 ± 1.9$^{a\ b}$
Oxygen uptake ($ml \cdot kg^{-1} \cdot min^{-1}$)	3.46 ± 0.51	3.87 ± 0.92	3.44 ± 0.69	3.39 ± 0.63
Heart rate ($beats \cdot min^{-1}$)	83 ± 7	96 ± 14^{a}	61 ± 10^{b}	71 ± 7$^{a\ b}$

^{a}significantly different from lying ***condition***, ^{b}significantly different from pregnant ***group***, *log transformed data

For both groups (combined data from pregnant and non-pregnant women), seated rest caused significantly higher VE ($p < 0.001$; $\eta^2 = 0.916$) and HR ($p = 0.001$; $\eta^2 = 0.469$) than supine rest, which demonstrates a ***condition effect*** of seated rest on VE and HR. At rest (seated and supine), non-pregnant participants had significantly lower VE ($p = 0.003$; $\eta^2 = 0.394$) and HR ($p < 0.001$; $\eta^2 = 0.991$) when compared to pregnant women, which demonstrates a ***group effect*** of pregnancy on VE and HR. No other significant differences, either between groups or conditions, were found (Table 1).

Exercise conditions: walking and cycling

Table 2. Mean ± SD values for ventilation, oxygen uptake, heart rate, metabolic equivalent, energy expenditure and rating of perceived exertion for pregnant and non-pregnant women during both exercise conditions (walking and cycling).

	Pregnant (n = 10)		Non-pregnant (n = 10)	
Variables	Walking	Cycling	Walking	Cycling
Metabolic equivalent (MET)	3.04 ± 0.49	4.05 ± 0.76^{a}	3.06 ± 0.48	4.04 ± 0.45^{a}
Energy expenditure (kcal)	70.51 ± 13.07	92.84 ± 12.42^{a}	62.22 ± 13.36	85.38 ± 9.38^{a}
Ventilation ($l \cdot min^{-1}$)	23.15 ± 4.53	30.80 ± 4.82^{a}	17.28 ± 3.84^{b}	23.16 ± 3.42^{ab}
Oxygen uptake ($ml \cdot kg^{-1} \cdot min^{-1}$)	10.85 ± 1.35	14.20 ± 2.66^{a}	10.71 ± 1.69	14.14 ± 1.59^{a}
Heart rate ($beats \cdot min^{-1}$)	127 ± 24*	137 ± 14^{a}	94 ± 10^{b}	119 ± 14^{ab}
Rating of perceived exertion	9 ± 2	12 ± 2^{a}	8 ± 2	11 ± 2^{a}

^{a}significantly different from walking ***condition***, ^{b}significantly different from pregnant ***group***, *log transformed data

For both groups (combined data from pregnant and non-pregnant women), cycling caused significantly higher values than walking for all of the analysed measures [VE - $p < 0.001$; $\eta^2 = 0.738$), VO_2 - $p < 0.001$; $\eta^2 = 0.730$, HR - $p < 0.001$; $\eta^2 = 0.992$, MET - $p < 0.001$; $\eta^2 = 0.746$, EE - $p < 0.001$; $\eta^2 = 0.781$ and RPE - $p < 0.001$; $\eta^2 = 0.651$], which demonstrates a ***condition effect*** of cycling on all variables. During exercise (cycling and walking), non-pregnant participants had significantly lower VE ($p < 0.001$; $\eta^2 = 0.492$) and HR ($p < 0.001$; $\eta^2 = 0.523$) when compared to pregnant women, which demonstrates a ***group effect*** of pregnancy on VE and HR.

Indirect calorimetry versus the Compendium of Physical Activities

There was a significant difference between the observed and predicted MET value for cycling ($p < 0.001$) but not for walking ($p = 0.626$), when the pregnant and non-pregnant women were combined. As such, the CPA significantly underestimated the MET for cycling. When separated by group (pregnant and non-pregnant) these trends remained (pregnant cycling $p = 0.002$ and non-pregnant cycling $p < 0.001$ and pregnant walking $p = 0.783$ and non-pregnant walking $p = 0.699$).

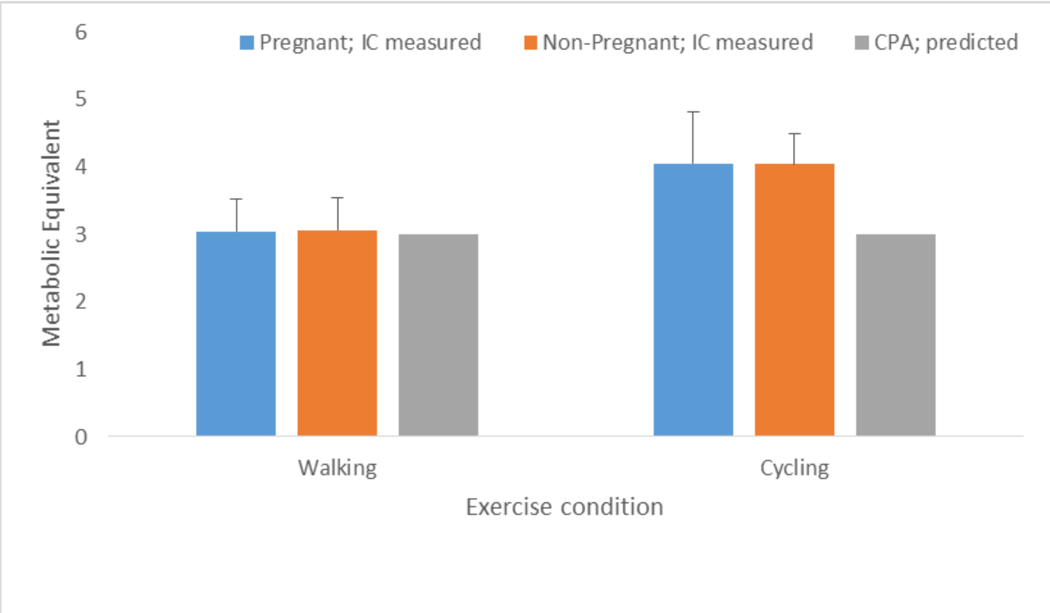

Figure 1. Measured (indirect calorimetry [IC]) versus predicted (Compendium of Physical Activities [CPA]) metabolic equivalents for cycling and walking for pregnant and non-pregnant women.

DISCUSSION

The purpose of this study was to measure the MET at rest and during exercise during the second trimester of pregnancy and to compare these values with non-pregnant women and the predicted MET from the CPA. There were no significant differences in the MET between the pregnant and non-pregnant groups either at rest (seated or supine) or during exercise (cycling or walking). However the observed MET, measured by IC, was significantly higher than the predicted MET by the CPA, highlighting a significant underestimation by this classification tool.

Pregnancy is associated with a 10% to 20% increase in total energy expenditure and resting metabolic rate[27], which is proportional to the weight gained during this period[16, 27]. Such increases are necessary to meet the oxygen requirement for new tissues synthesis. Heenan, Wolfe and Davies[28] did not show any significant differences between pregnant and non-pregnant women for absolute VO_2 during a maximal exercise testing. In addition, Khodiguian et al.[20], did not show any significant differences for absolute VO_2 following cycling at 25W, 50W and 75W, however they demonstrated lower values for VO_2 of 8.6%, 10.7% and 8.2%, respectively. The increase in cardiovascular and respiratory load, added by the increased tissues synthesis, results in an increase in BMR[12]. As such, BMR can be represented through its MET multiples. As there was no difference in MET at rest, between the groups, it is conceivable that there was no difference in BMR also, possibly as the pregnant women in this study did not have a significantly different body mass than the non-pregnant control group. Indeed, it has been reported that the difference in BMR associated with pregnancy does not appear until the twentieth gestational week[14]. During the third trimester there is usually a pronounced increase in maternal body mass, as this is the period for rapid foetal weight gain, suggesting a relationship between weight gain and BMR when considering absolute values. Similarly, Melzer et al[27] also noted that pregnant women in the third trimester had a significantly higher BMR when compared with 40 weeks postpartum, representing periods of weight gain and weight loss. As such, future studies should concentrate on the third trimester, rather than the second trimester as in the current study.

There was no significant difference in relative VO_2 and energy expenditure between the pregnant and non-pregnant groups during either exercise mode. Previous research has also shown that there were no significant differences in relative VO_2 in physically active pregnant women when compared with non-pregnant women, during light intensity treadmill walking (2.3 to 3 METs)[29]. The greatest difference between these groups was only found during maximal exercise (7 to 9 METs), in which the non-pregnant women showed higher relative VO_2 values (50%) than the pregnant women. Therefore, we suggest that further research is needed to examine the dose-response between exercise intensity and energy expenditure during pregnancy.

In the present study, there were no significant differences between groups in any of the other cardiorespiratory variables, with the exception of HR and VE, either at rest or during exercise. HR and VE may have been higher due to a heightened perception of sitting (versus lying) and cycling (versus walking) in the pregnant group. In the present study RPE was not measured during the rest condition, however RPE was significantly higher during the cycling protocol for both groups, with a tendency to be highest in the pregnant group. Therefore, we should carefully consider the mode of rest and exercise during pregnancy, as the modality may affect the rating of perceived exertion, which may in turn influence cardiorespiratory function.

In general, seated rest (both groups combined) caused significantly higher VE and HR than supine rest, which is unsurprising as this is a natural physiological response that is well documented[30]. These results are supported by Miles-Chan et al[31] who showed that energy expenditure was not significantly different in the sitting position when compared to supine (<2% difference), but heart rate was significantly higher by 7 beats/min ($p < 0.05$). These results suggest that the position, lying versus sitting, is a legitimate consideration for research design.

Cycling caused significantly higher values than walking for all of the variables measured, when the groups were combined, thus demonstrating a condition effect for cycling. These results agree with previous research[32] showing that HR was higher during cycling when compared to treadmill walking in normal weight and obese women. As in present study, participants[32] were sedentary, with a lower ability to transfer energy and poorer cycling mechanical efficiency.

Besides representing a variable of absolute intensity[4], the MET system also allows the energy expenditure during certain activities to be calculated[33]. The cycling protocol used in this study (cycling for 20 minutes at 50 W) was quantified as low intensity/mild (≤ 3 METs) by the CPA[6,7]. However, in the present study, the MET values obtained by IC reflected a more moderate intensity activity (3.1 – 6.0 METs). As such, this implies a 33% underestimation of the energetic cost of this type of cycling protocol by the CPA[6]. Chasan-Taber et al.[13] also noted differences between the values obtained by IC and the values estimated by the CPA[6], for pregnant women during household tasks. They reported a reduction of 17% and 23% for window washing and vacuuming and an increase of 8% and 43% for dusting and laundry. It is important to clarify that the CPA[6] was developed using young, lean, primarily male participants, and is estimated using 3.5 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$ as the reference baseline[34]. Thus, it is likely that the MET values reported can be inaccurate for people with different body mass and/or body fat percentage[35].

CONCLUSION

There was no significant difference in MET or relative VO_2 between groups at rest or during either mode of exercise. During the cycling protocol both MET and VO_2 were significantly higher than during the walking protocol. Moreover, the MET values obtained by IC were different from those proposed by the CPA; re-classifying this activity from low to moderate intensity. As such the CPA can be used by health care professionals to prescribe exercise intensity for pregnant women walking at 4 $km \cdot h^{-1}$. However, it may not be suitable for other modes of exercise, due to its underestimation of intensity as seen in this study. These findings will help design more effective and appropriate exercise programmes for pregnant women, which may help prevent excessive gestational weight gain and reduce the risk of pregnancy-related obesity and its complications on maternal and foetal health.

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