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Ventilation Rates during the Aggregate Daytime Activities of Working Females in Hospitals: Data before their Pregnancy and at their 9th, 22nd and 36th Week of Gestation

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Abstract

Working females in hospitals may inhale pharmaceutical agents, chirurgical smokes, organic solvents, bacteria and/or viruses. These inhaled agents may generate adverse effects in gravid females, their embryo or fetus. Therefore, minute ventilation rates (VE) during the aggregate daytime activities of under (n=68), normal (n=268), overweight (n=42), obese class 1 (n=68) and classes 2-3 (n=51) females working in hospitals were determined before and during their pregnancy using published measurements of energy expenditures. For comparison purposes, VE values were also calculated for the same females at rest. Activity energy expenditures were based on disappearance rates of oral doses of water isotopes (i.e. ^2H_2O, $H_2{}^{18}O$) monitored in urine samples of free-living hospital workers during 175 days by gas-isotope-ratio mass spectrometry. Basal energy expenditures were obtained by indirect calorimetry, whereas energy costs for pregnancy were measured in a room calorimeter. Sleep durations (7.30 ± 1.59 to 8.09 ± 1.25 hours/day; mean ± standard deviation) and ventilatory equivalents (31.7 ± 0.93 to 39.3 ± 3.3 L of air inhaled/L of oxygen consumed) during pregnancy were determined and integrated into the calculation process. Based on VE percentiles some non-pregnant and pregnant female workers inhale more air (thus more air pollutants), than the default VE value of 20.83 L/min (i.e. 10 m^3 in an 8 hour workday) notably used for calculations of hygienic standards for airborne xenobiotics. Highest 99th percentiles of 34.28, 29.27 26.49 and 29.52 L/min were found in obese classes 2-3 female workers, before their pregnancy and at their 9th, 22nd and 36th week of gestation, respectively. Considering what precedes and the fact that the human chorionic gonadotropin is detected in the blood or urine samples of women after the implantation of their blastocyst, which occurs many days after fertilization, the non-exposure of female workers to teratogenic agents in hospitals is recommended before and during their pregnancy. The same applies for the exposure to carcinogens which may generate procarcinogenic DNA damage in the fetus.

Keywords: Ventilation rates; Oxygen consumption rates; Female workers in hospitals; Pregnancy; Physical activity levels; Risk assessment; Ventilatory equivalent; Energy expenditure

Abbreviations

α: Data for the aggregate daytime activities of females; β: Data for females under resting conditions; AEE: Activity Energy Expenditure; BEE: Basal Energy Expenditure (BMR expressed on a 24-hour basis); BMI: Body Mass Index; BMR: Basal Metabolic Rate (punctual measurement); BSA: Body Surface Area; BTPS: Body Temperature and Saturated with water vapour; Bw: Body Weight; DLW: Doubly Labeled Water; H: oxygen uptake factor; volume of oxygen (at STPD) consumed to produce 1 kcal of energy expended, PAL: Physical Activity Level Based on a 24-h period (TDEE/BEE ratio); $PALVO_2$: Physical Activity Level during the aggregate daytime activities; Sld: Sleep Duration; STPD: Standard Temperature and Pressure Dry air; TDEE: Total Daily Energy Expenditure; VCO_2 carbon dioxide production rate; VE: Minute Ventilation Rate; VO_2: Oxygen consumption rate (also known as the oxygen uptake); VQ: Ventilatory Equivalent for VO_2 (VE at BTPS /VO_2 at STPD)

Introduction

Pregnancy in the workplace has become a relatively common occurrence over the last three decades [1-26]. However, acceptable working conditions in non-pregnant females may no longer be so in gravid females, notably by considering respiratory parameters for the latter compared to those for the former. Oxygen consumption rates (VO_2 in L/min) in pregnant females at rest and during submaximal weight-bearing exercises (e.g. walking, stepping, and treadmill exercise) are significantly increased, compared with the non-gravid state [27-30]. The same applies for minute ventilation rates (VE) when expressed in L/min [29,31-42]. These higher VE values result from an increase of tidal volumes with little or no change of respiratory frequencies [34,35,39]. Since the physiological dead space to tidal volume ratio in pregnancy remains unchanged, alveolar ventilation rates (VA) also increase as a function of incremental VE values [32,36,42-48]. Higher respiratory drive during the reproductive cycle has been showed to increase the intake of inhaled air pollutants on a 24 h basis in gravid females [49]. The same conclusion could be observed in pregnant workers. In spite of what precedes, VE values during the aggregate daytime activities of working pregnant females have never been determined. These calculations can be conducted by converting activity energy expenditures (AEE) of gravid females into VE values, as done by Brochu *et al.* [50,51] for males and non-gravid females. The AEE value corresponds to the subtractions of the basal energy expenditure (BEE) from the total daily energy expenditure (TDEE), both data obtained by indirect calorimetry and spectrometric values respectively measured in the same subjects during the doubly labeled water (DLW) method (IDECG 1990) [52]. In turn, AEE values can be converted into VE data by using three key input parameters [50,51], namely the oxygen

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uptake factor (H in L of O_2 consumed/kcal expended), the ventilatory equivalent (VQ in L of air inhaled/L of oxygen consumed) and the sleep duration (Sld in hours/day). The order of magnitude of H data already has been published and depends on types of combusted metabolic fuels [53]. Values for VQ and Sld have been determined for non-gravid women [51,53], but not for pregnant females.

An impressive number of women are working in hospitals [15,54-65], even during their pregnancy [1,15,23,66-68], and notably as cleaners, nurses, physicians, pharmacists, laboratory or pharmacy technicians. They notably may be exposed to and affected by 1) bacteria and/or viruses [54,67,69,70], 2) pharmaceutical agents including antineoplastic agents, aerosolized drugs, volatile anesthetic gases [71-80], 3) chirurgical smokes [81-86], 4) organic solvents for cleaning and sterilization of workplaces and operation rooms [8,9,87-91], and finally, 4) ionizing radiations during radiology, nuclear medicine, tomography, cancer therapy or cardiac catheterization [92-95]. The breathing process allows the penetration of occupational air pollutants and notably viruses into the respiratory airways [96]. Therefore, the aim of this study is to determine mean, standard deviation (S.D.) and percentile values for VE during the aggregate daytime activities of working pregnant females in hospitals. Prior observations indicate that heavier subjects inhale more air (thus more air pollutants during similar exposure conditions), compared to their thinner counterparts [51]. Consequently, calculations in this study will be performed for under-weight, normal-weight, overweight and obese females. Prior to these calculations, values for VQ, Sld, AEE, VO_2 and physical activity levels (PAL) will be determined for pregnant females.

Methodology

Study design

Mean, S.D. and percentile values for VO_2 and VE were calculated in the same non-pregnant and pregnant females aged 18 to 45 years (n=457) at rest (referred to as β) and during their aggregate daytime activities (referred to as α), when having full-time hospital jobs (referred to as active females). Values for VO_2 and VE during pregnancy were calculated at the 9th, 22nd and 36th week of gestation. These calculations have been performed for five cohorts of women classified according to following body mass index (BMI) cut-offs recommended for ideal pregnancies (IOM 1990): under-weight (BMI <19.8 kg/m²; n=68), normal weight (BMI from 19.8 to <27 kg/m²; n=268), overweight (BMI from 27 to <30 kg/m²; n=42), obese class 1 (BMI from 30 to <35 kg/m²; n=68), obese classes 2 and 3 (BMI ≥ 35 kg/m²; n=51) females. $VO_2\beta$ and VEβ data were calculated in fasting subjects, whereas their $VO_2\alpha$ and VEα values were determined during their postprandial phase. These respiratory values (in L/min) were expressed in terms of BEE (in kcal/day), TDEE (in kcal/day) and Sld (in hours/day) values by using following equations [51]:

$$VO_2\beta = \left[\frac{BEE}{1440}\right] \times H_F \quad (1)$$

$$VO_2\alpha = \left[\frac{(TDEE - BEE)}{(24 - Sld) \times 60} + \frac{BEE}{1440}\right] \times H_P \quad (2)$$

$$VE\beta = \left[\frac{BEE}{1440}\right] \times H_F \times VQ\beta \quad (3)$$

$$VE\alpha = \left[\frac{(TDEE - BEE)}{(24 - Sld) \times 60} + \frac{(BEE)}{1440}\right] \times H_P \times VQ\alpha \quad (4)$$

where, 1440 and 60 are the conversion factors from days to minutes and hours to minutes respectively and 24 is the number of hours in a day.

The H value corresponds to the volume of oxygen consumed at standard temperature and pressure, dry air (STPD) to produce 1 kcal of energy expended. H_F and H_P correspond to H values for subjects during fasting and postprandial phases respectively. The combustion of metabolic fuels (i.e. glycogen, glucose, 3-hydroxybutyric acid, acetoacetic acid, triacylglycerol) in fasting subjects required 0.2057 ± 0.0018 L of O_2 per kcal of energy expended (mean for HF ± S.D.; n=31). A H_P value of 0.2059 ± 0.0019 L of O_2/kcal (n=1245) has been calculated during the postprandial combustion of carbohydrates, proteins and fats. These H_F and H_P data have been determined using published sets of VO_2 and CO_2 production rates (VCO_2) measured by indirect calorimetry at STPD in the same subjects [53]. VQ is the ratio of the VE at body temperature and saturated with water vapour (BTPS) to the VO_2 at STPD. The following published data for non-gravid females aged 18 to 45 years were used in this study: VQβ of 30.1 ± 2.3 (n=307) and VQα of 32.6 ± 3.7 (n=450) for under-/normal-weight females [53], VQβ of 34.2 ± 9.5 (n= 145) and VQα of 31.9 ± 9.2 (n=220) for overweight/obese women [51] and Sld of 8.28 ± 0.61 hours/day (n=1668) [53].

Values for VO_2 and VE (in L/min) were expressed per unit of body surface area (BSA in m²) using the following formula expressed in terms of height (cm) and body weight (Bw in kg) values [96]:

$$BSA = \left[\frac{height \times Bw}{3600}\right]^{0.5} \quad (5)$$

This equation is preferentially recommended for accurate BSA calculations in adults, compared to other algorithms [24,97].

Input data in non-gravid females

Published sets of body weight, height and BEE values (Table 2) that have been systematically measured for the same non-gravid females (n=497) have been used to determine the baseline pre-pregnancy input data for the resting state [98-109]. Published sets of BEE and TDEE values measured in the same non-gravid workers (n=11) by the DLW method were used to calculate an AEE mean of 1242.9 ± 600.0 kcal/day (i.e. AEE=TDEE-BEE) for full-time jobs in hospitals during the postprandial phase, with minimal and maximal values of 389.3 and 2132.9 kcal/day, respectively [98,100-102]. BEE values (in kcal/day) correspond to basal metabolic rates (BMRs in kcal/min) expressed on a 24 hr basis. BMR values are calculated from the respiratory gas-exchange rates of oxygen (O_2) and carbon dioxide (CO_2) monitored by indirect calorimetry in fasting subjects usually 40 minutes immediately after waking-up [110-113]. TDEE values were systematically encompassing voluntary and involuntary energy expended in hospitals workers (i.e. notably for BEE, thermogenesis, physical activities, synthetic cost of growth) during real-life situations and their normal surroundings each minute of the day, 24-hours per day, on a daily basis for 175 days: 60 days in nurses and medical doctors, as well as 14, 15, 15, 31 and 40 days in pharmacy technicians, cleaners, clinical teachers, hospital clerks, and laboratory technicians, respectively [98,100-102,114-116]. TDEE data were calculated by using gas-isotope-ratio mass spectrometric measurements of disappearance rates of oral doses of water isotopes (i.e. ^2H_2O and $H_2^{18}O$) in urine

Weight classifications of pregnant females	n	Progression of the reproductive cycle	Weight gains[a] (kg/week)			MF_{ECP}[b] (unitless)		
			Mean ± S.D.	Min	Max	Mean ± S.D.[c]	Min[d]	Max[d]
Under-weight	17	9th week	2.00 ± 2.69	2.08	8.25	1.027 ± 0.025	0.982	1.086
		22nd week	7.80 ± 4.51	6.16	18.29	1.107 ± 0.024	1.050	1.164
		36th week	13.10 ± 4.62	11.42	23.84	1.310 ± 0.026	1.169	1.371
Normal-weight	34	9th week	0.90 ± 2.73	0.43	7.26	1.020 ± 0.028	0.982	1.086
		22nd week	5.80 ± 4.47	4.03	16.20	1.068 ± 0.041	1.050	1.164
		36th week	12.90 ± 5.19	12.02	24.97	1.265 ± 0.046	1.169	1.371
Overweight/obesity	12	9th week	4.50 ± 4.26	4.29	14.42	1.063 ± 0.010	0.982	1.086
		22nd week	8.50 ± 8.19	5.34	27.55	1.125 ± 0.017	1.050	1.164
		36th week	16.50 ± 6.00	13.49	30.46	1.340 ± 0.014	1.169	1.371

Table 1: Weight gains and energy costs of pregnancy in healthy females aged 18 to 40 years. [a]Weight gains in pregnant females compared to their baseline values before pregnancy measured by Butte *et al.* [106]. [b]MF_{ECP}=multiplying factors for energy costs of pregnancy. MF_{ECP}=(BEEgravid/BEEnon-gravid). BEE=basal energy expenditure measured by Butte *et al.* [106] in females during 24-hour periods, before (BEEnon-gravid) and during their pregnancy (BEEgravid) in a room calorimeter at the 9th, 22nd and 36th week of gestation. [c]Data taken from Butte *et al.* [106]. [d]Values based on data reported in Durnin *et al.*, Forsum *et al.*, Goldberg *et al.*, Spaaij *et al.*, de Groot *et al.* and Butte *et al.* [113,119-123]. n=number of individuals; S.D=standard deviation; Min=minimal value; Max=maximal value.

Weight classifications of females[a]	n	Progression of the reproductive cycle	Body weight (kg)	Height (cm)	BSA[g] (m^2)	BEE[h] (kcal/day)	TDEE[i] (kcal/day)		
							Full-time hospital jobs[i]		
			Mean ± S.D.	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.	Min	Max
Under-weight females[b]	68	0 week	50.75 ± 2.73	164.5 ± 3.8	1.52 ± 0.06	1256.8 ± 79.3	2358.6 ± 398.8	1527.4	3524.1
		9th week	54.54 ± 3.00		1.58 ± 0.05	1294.4 ± 86.9	2396.9 ± 380.9	1578.4	3582.2
		22nd week	60.42 ± 3.79		1.66 ± 0.06	1393.5 ± 93.2	2496.0 ± 382.3	1624.8	3685.7
		36th week	66.20 ± 4.06		1.74 ± 0.06	1648.5 ± 110.1	2751.1 ± 383.8	1916.0	3945.1
Normal-weight females[c]	268	0 week	59.55 ± 3.81	164.4 ± 3.8	1.65 ± 0.06	1349.8 ± 124.8	2449.7 ± 413.7	1523.6	3834.7
		9th week	61.03 ± 4.06		1.67 ± 0.06	1384.1 ± 129.9	2466.7 ± 395.7	1549.8	3761.3
		22nd week	66.86 ± 4.81		1.75 ± 0.06	1472.5 ± 139.9	2555.0 ± 395.0	1651.2	3850.7
		36th week	75.69 ± 4.86		1.86 ± 0.06	1709.6 ± 167.5	2792.1 ± 398.6	1815.2	3983.9
Overweight females[d]	42	0 week	74.71 ± 6.37	164.3 ± 6.7	1.85 ± 0.11	1484.0 ± 184.1	2596.3 ± 435.6	1689.3	3959.9
		9th week	81.45 ± 6.26		1.92 ± 0.08	1595.0 ± 181.5	2694.3 ± 420.4	1819.7	4010.3
		22nd week	85.32 ± 7.56		1.96 ± 0.09	1687.8 ± 192.1	2787.1 ± 422.1	1904.1	4122.5
		36th week	92.90 ± 6.98		2.05 ± 0.08	2009.7 ± 229.0	3109.0 ± 424.8	2210.0	4408.9
Obese class 1 females[e]	68	0 week	86.49 ± 8.54	164.8 ± 6.6	1.99 ± 0.13	1626.1 ± 271.0	2772.5 ± 453.7	1796.1	4270.6
		9th week	94.42 ± 8.35		2.07 ± 0.10	1778.6 ± 260.6	2892.5 ± 456.9	1880.5	4375.6
		22nd week	98.29 ± 9.50		2.11 ± 0.11	1882.2 ± 276.6	2996.1 ± 459.6	1983.8	4498.6
		36th week	105.87 ± 8.98		2.20 ± 0.10	2240.8 ± 326.6	3354.7 ± 465.2	2277.4	4921.7
Obese classes 2-3 females[f]	51	0 week	124.67 ± 5.71	165.1 ± 1.9	2.38 ± 0.06	2036.4 ± 153.8	3139.1 ± 410.6	2161.5	4341.7
		9th week	131.78 ± 6.16		2.46 ± 0.06	2161.7 ± 162.4	3271.6 ± 406.1	2273.8	4422.5
		22nd week	135.65 ± 7.66		2.49 ± 0.07	2287.5 ± 172.7	3397.4 ± 406.3	2446.6	4547.6
		36th week	143.23 ± 6.89		2.57 ± 0.06	2723.7 ± 204.7	3833.6 ± 409.7	2854.6	4998.5

Table 2: Anthropometric and energetic measurements in healthy non-pregnant and pregnant females aged 18 to 45 years. [a]Based on body mass index (BMI) cut-offs for an ideal pregnancy in females. [b]BMI <19.8 kg/m². [c]BMI from 19.8 to <27 kg/m². [d]BMI from 27 to <30 kg/m². [e]BMI from 30 to <35 kg/m². [f]BMI ≥ 35 kg/m². [g]BSA=body surface area. [h]BEE=basal energy expenditure (i.e. basal metabolic rate expressed on a 24-hour basis) measured by indirect calorimetry. BEE values were taken from the literature [98-104,108,109]. [i]TDEE=BEE+AEE. AEE=Activity energy expenditures based on indirect calorimetric and spectrometric measurements in the same subjects. The gas-isotope-ratio mass spectrometry has been used to measure disappearance rates of oral doses of ^2H_2O and $H_2{}^{18}O$ from urine samples in free-living adults. AEE values are based on published data [98,100-102]. n, S.D. min and max acronyms are defined in Table 1.

samples of each free-living worker over a period of 10 to 31 days [52]. During the DLW method the disappearance rate of deuterium (^2H or D) reflects water output and that of heavy oxygen-18 (^{18}O) corresponds to water output plus CO_2 production rates [52]. The difference between the two disappearance rates represents the CO_2 production rate, which is converted into units of energy (i.e. TDEE in kcal/day) by using the average respiratory quotient of the diet (RQ). The RQ value may be determined by a complete diet record over the duration of the study or respiratory gas-exchange measurements (RQ=CO_2 produced/O_2 consumed). The DLW method is notably described in detail in IDECG (1990) [52].

Input data during pregnancy

Energy costs of pregnancy were calculated by comparing 24-h energy expenditures of females measured in a room calorimeter by Butte *et al.* [106], before their pregnancy and at their 9th, 22nd and 36th week of gestation (Table 1). The latter study has been conducted in under (n=17), normal weight (n=34) and overweight/obese pregnant women (n=12). Resulting energy expenditures have been computed by using continuous measurements of VO_2, VCO_2 and urinary nitrogen excretion in females according to the procedure of Livesey and Elia [117]. The performance of the calorimeter for such measurements is described in Moon *et al.* [118]. The baseline BEE values of under, normal and overweight/obese non-pregnant women were increased by mean multiplying factors (MF_{ECP}) varying from 1.020 ± 0.028 to 1.063 ± 0.010, 1.068 ± 0.041 to 1.125 ± 0.017 and 1.265 ± 0.046 to 1.340 ± 0.014 at the 9th, 22th and 36th week of gestation respectively (Table 1). Minimal and maximal MF_{ECP} values are based on data reported in Durnin *et al.*, Forsum *et al.*, Goldberg *et al.*, Spaaij *et al.*, de Groot *et al.* and Butte *et al.* [101,112,113,119-123]. TDEEs values in pregnant females (TDEE pregnancy) were calculated in terms of MF_{ECP} (Table 1), BEE (Table 2) and AEE values by using the following equation:

$$TDEE_{pregnancy} = [BEE \times MF_{ECP}] + AEE \quad (6)$$

Weight gains varying form 2.00 ± 2.69 to 13.10 ± 4.62, 0.90 ± 2.73 to 12.90 ± 5.19, 4.50 ± 4.26 to 16.50 ± 6.00 kg/week of pregnancy measured by Butte *et al.* [105] in under, normal-weight and overweight/obese gravid females respectively (Table 1) were added to body weights of non-gravid females in order to obtain adequate total weight values at the 9th, 22nd and 36th week of gestation.

Values for Sld of 8.09 ± 1.25 (n=122), 7.83 ± 1.36 (n=1397) and 7.30 ± 1.59 hours/day (n=684) were calculated for pregnant females at the 9th, 22nd and 36th week of gestation respectively (Table 3) by using data reported in Williams *et al.*, Ko *et al.*, Kızılırmak *et al.* and Shiga *et al.* [124-127]. For the same classification of weeks of gestation, VQβ of 39.3 ± 3.3 (n=33), 34.2 ± 1.8 (n=157) and 35.7 ± 1.3 (n=213) were determined (Table 3) according to respiratory data measured in pregnant females at rest by Cugell *et al.*, Knuttgen *et al.*, Pernoll *et al.*, Pivarnik *et al.*, Lotgering *et al.*, Jaque-Fortunato *et al.*, Heenan *et al.* and Jensen *et al.* [27,29,31,32,36,37,128,129].

PAL values for 24-hour periods are frequently calculated based on TDEE/BEE ratios [101,104-106,120,123,130-136]. However, PAL values in this study were not calculated for a 24-hour basis, but during the aggregate daytime activities of females (referred to as $PALVO_2$, unit less) as follows:

$$PAL_{VO_2} = \left[\frac{VO_2\alpha}{VO_2\beta}\right] \quad (7)$$

A mean VQα value (referred to as VQα Level) with S.D., minimal and maximal data was determined for each level of $PALVO_2$ (i.e. 1 ≤ 2, 2 ≤ 2.5, 2.5 ≤ 3, 3 ≤ 3.5 and 3.5 ≤ 4.5) that could be performed during daytime activities of females at their 9th, 22nd and 36th week of gestation. These calculations were conducted by using published sets of VO_2 and VE values that have been simultaneously measured in gravid females [27,29,31,32,36,37,128,129]. Distributions of $PALVO_2$ percentiles were then calculated for under, normal, overweight, obese class 1 and obese classes 2-3 females at their 9th, 22nd and 36th week of gestation. Based on these percentiles, percentages of pregnant females (Table 4) performing daytime activities at each VQα Level were determined. Mean VQα values for each category of body weights at the 9th, 22nd and 36th week of gestation (Table 4) were then obtained by multiplying VQαLevel (not reported in Tables) by former percentages.

Statistical analysis

Monte Carlo simulations were necessary to integrate S.D. values of input data into the calculation process of parameters of interest. They were conducted based on random sampling involving 10 000 iterations for each calculation process. A normal distribution for H_F values and lognormal distributions for other input data (i.e. values for H_P, BEE, AEE, TDEE, body weight, body surface area, Sld, VQβ VQα, as well as weight gains and MF_{ECP} during pregnancy) were considered during calculations of mean, S.D. and percentile values for VO_2 and VE. The best fit distribution (i.e. lognormal or normal) per type of values has been determined in our previous studies [49,51,53] notably by carrying out Anderson-Darling goodness-of-fit tests on individual data. Spans of values between 2.5nd and 97.5th VO_2 and VE percentiles were calculated in order to obtain 95% confidence intervals (CI_{95}%).

Accuracy of input data

The accuracy of BEE and TDEE data vary from +1 to +2 and -1.0 to +3.3%, respectively [52,137], whereas the one for H_P and H_F values range from -2 to +2% [53]. In the worst case scenario, simultaneous minimal and maximal mean errors associated with input BEE, TDEE, H_P and H_F data were shown to have a combined effect varying from +1 to +2.6% on the accuracy of $VO_2\beta$, VEβ, $VO_2\alpha$ and VEα values [53]. The possible shorter sleep durations in overweight/obese females compared to their normal-weight counterparts was found to have a negligible influence (less than -0.2%) on the order of magnitude of inhalation rates [53].

Results

VO_2 data in resting and active females increase from 0.180 ± 0.012 to 0.390 ± 0.030 (Table 5) and 0.420 ± 0.083 to 0.616 ± 0.085 L/min (Table 6), respectively as the pregnancy progresses. To support such oxygen demands, VE values in these women raise from 5.43 ± 0.57 to 13.91 ± 1.19 (Table 7) and 13.75 ± 3.17 to 21.68 ± 3.07 L/min, respectively (Table 8). Highest VO_2 and VE absolute means and percentiles (i.e. expressed in L/min) are observed at the 36th week of gestation of obese classes 2-3 women (Tables 5-8). CI_{95}% for VO_2 values in resting and active gravid females vary from 0.160 to 0.450 and 0.278 to 0.801 L/min, respectively (Tables 5 and 6). Those for VE values in the former and the latter groups of females range from 5.81 to 16.37 and 9.27 to 28.19 L/min respectively (Tables 7 and 8). Absolute VE data increase as a function of the increase of BMI values. For instance, lowest and highest mean values of active under-weight and obese classes 2-3 gravid females range from 14.07 ± 2.82 to 15.22 ± 2.71 and 20.19 ± 3.54 to 21.68 ± 3.07 L/min respectively (Table 8). The inverse tendency is observed when data are expressed per unit of body weight (Tables 7 and 9). For instance, lowest and highest VE means are found in active obese classes 2-3 (0.138 ± 0.024 to 0.153 ± 0.028 L/kg-min) and under-weight gravid females (0.231 ± 0.043 to 0.259 ± 0.054 L/kg-min) respectively (Table 9). VE means expressed per unit of body surface area in under-weight (8.28 ± 1.63 to 9.05 ± 2.11 L/m^2-min), normal-weight (8.11 ± 1.67 to 8.77 ± 1.88 L/m^2-min), overweight (7.80 ± 1.57 to 8.38 ± 1.52 L/m^2/min), obese class 1 (7.74 ± 1.53 to 8.48 ± 1.50 L/m^2/min) and obese classes 2-3 active females (7.17 ± 2.38 to 8.46 ± 1.22 L/m^2/min) do not show a clear tendency as a function of BMI values, nor as the pregnancy progresses (Table 10). The same conclusion applies for data expressed in L/m^2-min in females at rest (Table 7).

Discussion

Data of Melzer *et al.* [138] indicate that females aged 20 to 40 years (n=27) perform a low intensity of activity levels in late pregnancy (38.2 ± 1.5 weeks of gestation) during 20.37 h/day (85%) with metabolic equivalents (METs) less than 2. This is consistent with our data. In the present study, the percentage of active females performing low levels of exertions during daytime activities ($PALVO_2$ <2) increases as the pregnancy progresses (Table 4). For instance, 37, 43 and 59% of active normal-weight females (n=268) at the 9th, 22nd and 36th week of gestation respectively have $PALVO_2$ values lower than 2 (Table 4). In accordance with data reported in Brochu *et al.* [51] for non-gravid individuals, most percentages of active gravid females performing low intensity of activity levels ($PALVO_2$ <2) reported in this study increases as a function of the increase of overweight levels based on BMI cutoffs. For instance, 39, 43, 54, 60 and 81% of active under, normal, overweight, obese class 1 and obese classes 2-3 females at 22nd week of gestation respectively have $PALVO_2$ values lower than 2 (Table 4).

Weight classifications, and progression of the reproductive cycle	Sleep duration[a] (hours/day)				VQβ for females at rest[b] (unitless)				VQα for active females[b] (unitless)			
	n	Mean ± S.D.	Min	Max	n	Mean ± S.D.	Min	Max	n	Mean ± S.D.	Min	Max
Under/normal weight NP females[c]	1668	8.28 ± 0.61	5.23	13.56	307	30.1 ± 2.3	18.0	64.0	450	32.6 ± 3.7	15.3	100.5
Overweight/obese NP females[c]					145	34.2 ± 9.5	18.0	100.5	220	31.9 ± 9.2	15.7	100.5
9th week	122	8.09 ± 1.25	4.00	11.00	33	39.3 ± 3.3	23.6	47.1	*see Table 4*			
22nd week	1397	7.83 ± 1.36	4.00	11.00	157	34.2 ± 1.8	23.6	52.0				
36th week	684	7.30 ± 1.59	4.00	11.00	213	35.7 ± 1.3	21.1	63.8				

Table 3. Sleep duration and ventilatory equivalent (VQ) values in healthy non-pregnant and pregnant females aged 18 to 45 years. [a]Values for non-pregnant females have been calculated according to data reported in Brochu *et al.* [50]. Sleep durations of gestating females are based on published values [124-127]. [b]VQ=ratio of the minute ventilation rate (VE in L/min at BTPS) to the oxygen uptake (VO_2 in L/min at STPD). VQβ and VQα=ventilatory equivalent values in females at rest and during their aggregate daytime activities respectively. [b]VQβ and VQα for non-pregnant females have been calculated according to data reported in Brochu *et al.* [50,51]. VQβ for gravid females were based on values reported in the literature [27,29,31,32,36-38,128]. [c]NP=Non-pregnant. n=number of individuals; S.D.=standard deviation; Min=minimal value; Max=maximal value.

Progression of the reproductive cycle	Weight classifications of females[a]	Percentage[b] of cohorts performing daytime activities at various $PALVO_2$[c]						Ventilatory equivalents[d] (VQα) (unitless)			
		$PALVO_2$ from 1 to less than 4.5						n	Mean ± S.D.	Min	Max
		n	*1 < 2*	*2 < 2.5*	*2.5 < 3*	*3 < 3.5*	*3.5 <4.5*				
9th week	Under-weight	68	33%	37%	22%	5%	3%	333	33.28 ± 1.24	22.10	47.06
	Normal-weight	268	37%	35%	20%	6%	2%		33.63 ± 1.33	22.10	47.06
	Overweight	42	47%	33%	15%	4%	1%		34.45 ± 1.60	22.10	47.06
	Obese class 1	68	56%	28%	12%	3%	1%		35.26 ± 1.85	22.10	47.06
	Obese classes 2-3	51	76%	21%	2%	1%	0%		36.96 ± 2.44	22.10	47.06
22nd week	Under-weight	68	39%	39%	17%	4%	1%	457	31.70 ± 0.93	22.10	51.97
	Normal-weight	268	43%	35%	17%	4%	1%		31.90 ± 0.96	22.10	51.97
	Overweight	42	54%	29%	14%	2%	1%		32.33 ± 1.08	22.10	51.97
	Obese class 1	68	60%	29%	8%	2%	1%		32.47 ± 1.15	22.10	51.97
	Obese classes 2-3	51	81%	17%	1%	1%	0%		33.30 ± 1.47	22.10	51.97
36th week	Under-weight	68	59%	32%	8%	1%	0%	510	32.94 ± 1.26	21.11	63.81
	Normal-weight	268	59%	32%	8%	1%	0%		32.94 ± 1.26	21.11	63.81
	Overweight	42	70%	26%	3%	1%	0%		33.59 ± 1.20	21.11	63.81
	Obese class 1	68	76%	20%	3%	1%	0%		34.03 ± 1.14	21.11	63.81
	Obese classes 2-3	51	93%	6%	1%	0%	0%		35.18 ± 1.16	21.11	63.81

Table 4: Physical activity levels and ventilatory equivalents during daytime activities of pregnant females with full-time hospital jobs. [a]Defined in Table 2. [b]Based on percentiles of $PALVO_2$. [c]$PALVO_2=VO_2\alpha/VO_2\beta$ ratio. $VO_2\beta=(BEE/1440) \times H_F$. $VO_2\alpha=[(TDEE-BEE)/((24-Sld) \times 60)+(BEE)/1440] \times H_P$, where, H_F and H_P=oxygen uptake factor during fasting and postprandial phases respectively. H_F (0.2057 ± 0.0018 L of O_2/kcal) and H_P (0.2059 ± 0.0019 L of O_2/kcal) are reported in Brochu *et al.* [53]. TDEE and BEE are defined in Table 2. Sld=Sleep duration (in hours/day). Sld values appear in Table 3. [d]VQα=ratio of the minute ventilation rate (VEα in L/min at BTPS) to the oxygen uptake ($VO_2\alpha$ in L/min at STPD) during the aggregate daytime activities of pregnant females. The simultaneous VEα and $VO_2\alpha$ measurements used for VQα calculations were taken from the literature [27,29,31,32,36-38,128]. n=number of individuals; S.D.=standard deviation; Min=minimal value; Max=maximal value.

Weight classifications of females	Progression of the reproductive cycle	Oxygen consumption rates[a]											
		(L/min)				(L/kg-min)[b]				(L/m^2-min)[b]			
		Mean ± S.D.	Percentiles			Mean ± S.D.	Percentiles			Mean ± S.D.	Percentiles		
			2.5nd	97.5th	99th		2.5nd	97.5th	99th		2.5nd	97.5th	99th
Under-weight females	0 week	0.180 ± 0.012	0.157	0.205	0.210	0.0036 ± 0.0003	0.0030	0.0042	0.0043	0.118 ± 0.009	0.101	0.137	0.141
	9th week	0.185 ± 0.013	0.160	0.214	0.218	0.0034 ± 0.0003	0.0028	0.0040	0.0042	0.117 ± 0.009	0.101	0.136	0.139
	22nd week	0.199 ± 0.014	0.172	0.228	0.234	0.0033 ± 0.0003	0.0027	0.0040	0.0041	0.120 ± 0.009	0.102	0.139	0.143
	36th week	0.236 ± 0.017	0.205	0.270	0.277	0.0036 ± 0.0003	0.0030	0.0043	0.0044	0.136 ± 0.010	0.116	0.157	0.161
Normal-weight females	0 week	0.193 ± 0.018	0.160	0.233	0.241	0.0033 ± 0.0004	0.0026	0.0040	0.0042	0.117 ± 0.012	0.096	0.143	0.148
	9th week	0.198 ± 0.019	0.163	0.240	0.248	0.0033 ± 0.0004	0.0026	0.0041	0.0042	0.119 ± 0.012	0.097	0.144	0.150
	22nd week	0.211 ± 0.021	0.172	0.257	0.264	0.0032 ± 0.0004	0.0024	0.0039	0.0041	0.121 ± 0.012	0.098	0.147	0.152
	36th week	0.245 ± 0.025	0.200	0.300	0.313	0.0032 ± 0.0004	0.0025	0.0041	0.0042	0.132 ± 0.014	0.107	0.161	0.167
Overweight females	0 week	0.215 ± 0.025	0.175	0.272	0.283	0.0029 ± 0.0004	0.0022	0.0038	0.0040	0.118 ± 0.015	0.093	0.150	0.157
	9th week	0.228 ± 0.026	0.187	0.288	0.301	0.0028 ± 0.0004	0.0022	0.0037	0.0038	0.119 ± 0.015	0.095	0.152	0.160
	22nd week	0.241 ± 0.028	0.198	0.306	0.321	0.0029 ± 0.0004	0.0021	0.0037	0.0039	0.123 ± 0.015	0.098	0.158	0.166
	36th week	0.287 ± 0.033	0.234	0.363	0.380	0.0031 ± 0.0004	0.0024	0.0041	0.0043	0.140 ± 0.017	0.112	0.179	0.188

Obese class 1 females	0 week	0.239 ± 0.035	0.186	0.317	0.345	0.0028 ± 0.0005	0.0020	0.0039	0.0041	0.120 ± 0.019	0.091	0.162	0.173
	9th week	0.254 ± 0.038	0.198	0.338	0.368	0.0027 ± 0.0005	0.0020	0.0038	0.0040	0.123 ± 0.019	0.094	0.166	0.177
	22nd week	0.269 ± 0.040	0.210	0.360	0.389	0.0028 ± 0.0005	0.0020	0.0038	0.0042	0.127 ± 0.020	0.097	0.172	0.184
	36th week	0.320 ± 0.047	0.250	0.426	0.458	0.0030 ± 0.0005	0.0022	0.0042	0.0046	0.146 ± 0.022	0.112	0.196	0.209
Obese classes 2-3 females	0 week	0.291 ± 0.022	0.250	0.337	0.346	0.0023 ± 0.0002	0.0020	0.0028	0.0029	0.122 ± 0.010	0.104	0.143	0.148
	9th week	0.309 ± 0.024	0.265	0.358	0.367	0.0024 ± 0.0002	0.0020	0.0028	0.0029	0.126 ± 0.010	0.107	0.148	0.152
	22nd week	0.327 ± 0.026	0.280	0.378	0.392	0.0024 ± 0.0002	0.0020	0.0029	0.0030	0.131 ± 0.011	0.111	0.155	0.160
	36th week	0.390 ± 0.030	0.335	0.450	0.464	0.0027 ± 0.0003	0.0023	0.0032	0.0034	0.152 ± 0.013	0.129	0.179	0.184

Table 5: Means and percentiles of oxygen consumption rates in fasting females at rest aged 18 to 45 years during pregnancy. [a]$VO_2\beta$=(BEE/1440) x H_F. BEE values are given in Table 2. H_F=oxygen uptake factor during fasting phase. H_F of 0.2057 ± 0.0018 L of O_2/kcal is defined in Table 4. [b]Oxygen consumption rates in L/min were divided by body weight and body surface area values reported in Table 2 in order to obtain values expressed in L/kg-min and L/m²-min respectively. S.D=standard deviation.

Weight classifications of females	Progression of the reproductive cycle	Oxygen consumption rates[a]											
		(L/min)				(L/kg-min)[b]				(L/m²-min)[b]			
		Mean ± S.D.	Percentiles			Mean ± S.D.	Percentiles			Mean ± S.D.	Percentiles		
			2.5nd	97.5th	99th		2.5nd	97.5th	99th		2.5nd	97.5th	99th
Under-weight females	0 week	0.420 ± 0.083	0.276	0.599	0.633	0.0083 ± 0.0017	0.0054	0.0120	0.0128	0.277 ± 0.056	0.181	0.397	0.420
	9th week	0.422 ± 0.084	0.278	0.605	0.637	0.0078 ± 0.0016	0.0050	0.0113	0.0120	0.268 ± 0.054	0.177	0.384	0.408
	22nd week	0.432 ± 0.083	0.293	0.614	0.647	0.0072 ± 0.0015	0.0047	0.0104	0.0111	0.261 ± 0.051	0.175	0.374	0.394
	36th week	0.461 ± 0.081	0.324	0.641	0.672	0.0070 ± 0.0013	0.0048	0.0099	0.0104	0.266 ± 0.047	0.186	0.371	0.392
Normal-weight females	0 week	0.434 ± 0.089	0.279	0.633	0.670	0.0073 ± 0.0016	0.0046	0.0108	0.0115	0.263 ± 0.055	0.170	0.385	0.412
	9th week	0.436 ± 0.089	0.281	0.631	0.668	0.0072 ± 0.0016	0.0046	0.0106	0.0113	0.261 ± 0.055	0.168	0.384	0.409
	22nd week	0.445 ± 0.088	0.293	0.640	0.681	0.0067 ± 0.0014	0.0043	0.0099	0.0105	0.254 ± 0.052	0.167	0.370	0.396
	36th week	0.471 ± 0.086	0.323	0.662	0.700	0.0063 ± 0.0012	0.0042	0.0090	0.0096	0.254 ± 0.048	0.174	0.362	0.385
Overweight females	0 week	0.455 ± 0.093	0.296	0.658	0.697	0.0062 ± 0.0013	0.0039	0.0091	0.0097	0.247 ± 0.052	0.158	0.362	0.385
	9th week	0.466 ± 0.092	0.307	0.666	0.709	0.0058 ± 0.0012	0.0037	0.0084	0.0090	0.241 ± 0.049	0.157	0.352	0.369
	22nd week	0.475 ± 0.091	0.320	0.677	0.713	0.0056 ± 0.0012	0.0036	0.0082	0.0088	0.241 ± 0.048	0.160	0.348	0.369
	36th week	0.514 ± 0.089	0.365	0.708	0.751	0.0056 ± 0.0010	0.0038	0.0079	0.0084	0.249 ± 0.045	0.174	0.348	0.366
Obese class 1 females	0 week	0.480 ± 0.098	0.308	0.698	0.738	0.0056 ± 0.0012	0.0035	0.0084	0.0090	0.242 ± 0.051	0.153	0.351	0.375
	9th week	0.492 ± 0.098	0.323	0.711	0.754	0.0053 ± 0.0011	0.0033	0.0079	0.0084	0.238 ± 0.048	0.156	0.342	0.366
	22nd week	0.503 ± 0.097	0.337	0.720	0.767	0.0052 ± 0.0011	0.0033	0.0077	0.0083	0.238 ± 0.046	0.160	0.337	0.362
	36th week	0.547 ± 0.093	0.389	0.756	0.797	0.0052 ± 0.0010	0.0036	0.0074	0.0079	0.249 ± 0.043	0.176	0.344	0.368
Obese classes 2-3 females	0 week	0.531 ± 0.089	0.372	0.717	0.750	0.0043 ± 0.0007	0.0030	0.0058	0.0062	0.223 ± 0.038	0.156	0.302	0.318
	9th week	0.546 ± 0.089	0.389	0.736	0.775	0.0042 ± 0.0007	0.0029	0.0057	0.0060	0.222 ± 0.036	0.159	0.301	0.316
	22nd week	0.561 ± 0.087	0.405	0.747	0.783	0.0042 ± 0.0007	0.0029	0.0057	0.0059	0.225 ± 0.036	0.163	0.302	0.319
	36th week	0.616 ± 0.085	0.468	0.801	0.836	0.0043 ± 0.0006	0.0032	0.0057	0.0060	0.240 ± 0.034	0.182	0.312	0.325

Table 6: Means and percentiles of oxygen consumption rates during the aggregate daytime activities of females aged 18 to 45 years. [a]$VO_2\alpha$=[(TDEE-BEE)/((24-Sld) x 60)+(BEE)/1440] x H_P. BEEs and TDEEs appear in Table 2. Sld=sleep duration (hours/day). Sld values are presented in Table 3. H_P of 0.2059 ± 0.0019 L of O_2/kcal is defined in Table 4. [b]Oxygen consumption rates in L/min were divided by body weight and body surface area values reported in Table 2 in order to obtain values expressed in L/kg-min and L/m²-min respectively. S.D=standard deviation.

Weight classifications of females	Progression of the reproductive cycle	Minute ventilation rates[a]											
		Mean ± S.D.	(L/min) Percentiles			Mean ± S.D.	(L/kg-min)[b] Percentiles			Mean ± S.D.	(L/m²-min)[b] Percentiles		
			2.5nd	97.5th	99th		2.5nd	97.5th	99th		2.5nd	97.5th	99th
Under-weight females	0 week	5.43 ± 0.57	4.47	6.63	6.92	0.107 ± 0.013	0.085	0.133	0.139	3.56 ± 0.39	2.86	4.37	4.51
	9th week	7.30 ± 0.82	5.81	9.08	9.28	0.134 ± 0.017	0.103	0.171	0.177	4.60 ± 0.51	3.67	5.65	5.83
	22nd week	6.83 ± 0.61	5.71	8.09	8.35	0.113 ± 0.013	0.09	0.138	0.145	4.10 ± 0.39	3.39	4.89	5.08
	36th week	8.42 ± 0.66	7.20	9.72	9.97	0.128 ± 0.013	0.105	0.153	0.158	4.83 ± 0.41	4.07	5.69	5.85
Normal-weight females	0 week	5.84 ± 0.69	4.59	7.33	7.69	0.098 ± 0.014	0.075	0.128	0.132	3.53 ± 0.45	2.73	4.49	4.70
	9th week	7.80 ± 1.02	5.94	9.97	10.60	0.128 ± 0.019	0.095	0.171	0.179	4.65 ± 0.61	3.55	5.94	6.23
	22nd week	7.22 ± 0.83	5.72	8.95	9.38	0.108 ± 0.015	0.082	0.141	0.145	4.13 ± 0.48	3.28	5.15	5.40
	36th week	8.73 ± 0.92	7.13	10.78	11.26	0.116 ± 0.014	0.092	0.147	0.154	4.70 ± 0.52	3.77	5.80	6.04
Overweight females	0 week	7.35 ± 2.14	4.12	12.37	13.43	0.100 ± 0.030	0.053	0.170	0.193	4.05 ± 1.23	2.25	7.04	7.78
	9th week	8.99 ± 1.28	6.81	11.78	12.64	0.111 ± 0.018	0.080	0.149	0.157	4.67 ± 0.68	3.53	6.15	6.51
	22nd week	8.27 ± 1.09	6.51	10.55	11.32	0.098 ± 0.016	0.072	0.131	0.139	4.22 ± 0.57	3.27	5.50	5.76
	36th week	10.27 ± 1.25	8.26	13.13	13.69	0.111 ± 0.016	0.084	0.146	0.155	5.00 ± 0.64	3.96	6.44	6.76
Obese class 1 females	0 week	8.21 ± 2.53	4.46	14.07	15.41	0.095 ± 0.031	0.050	0.172	0.186	4.14 ± 1.31	2.23	7.31	8.16
	9th week	10.02 ± 1.71	7.33	14.05	14.80	0.107 ± 0.021	0.075	0.156	0.168	4.81 ± 0.83	3.50	6.68	7.10
	22nd week	9.22 ± 1.45	7.03	12.51	13.27	0.095 ± 0.018	0.068	0.134	0.147	4.36 ± 0.71	3.26	5.99	6.37
	36th week	11.45 ± 1.73	8.81	15.42	16.50	0.109 ± 0.019	0.079	0.151	0.164	5.19 ± 0.81	3.95	7.05	7.49

Obese classes 2-3 females	0 week	9.98 ± 2.84	5.64	16.26	18.79	0.080 ± 0.023	0.045	0.133	0.152	4.21 ± 1.21	2.41	7.12	7.88
	9th week	12.19 ± 1.41	9.63	15.07	15.74	0.093 ± 0.012	0.072	0.117	0.122	4.93 ± 0.57	3.91	6.12	6.38
	22nd week	11.21 ± 1.07	9.24	13.52	13.96	0.083 ± 0.009	0.066	0.103	0.106	4.50 ± 0.44	3.70	5.43	5.61
	36th week	13.91 ± 1.19	11.69	16.37	16.76	0.097 ± 0.010	0.08	0.117	0.122	5.42 ± 0.49	4.53	6.44	6.65

Table 7: Means and percentiles of minute ventilation rates in fasting females at rest aged 18 to 45 years during pregnancy. [a]VEβ=(BEE/1440) x H_F x VQβ. BEE and VQβ values are given in Tables 2 and 3 respectively. H_F of 0.2057 ± 0.0018 L of O_2/kcal is defined in Table 4. [b]Minute ventilation rates in L/min were divided by body weight and body surface area values reported in Table 2 in order to obtain values expressed in L/kg-min and L/m²-min respectively. S.D=standard deviation. Min.=minimum, Max.=maximum.

Such data are also consistent with the fact that overstrain and overwork in pregnant females are usually avoided by reducing physical activity, increasing work efficiency and adjusting daily physical activities [101,105,110,122,134-136,139,140-146]. Values for VQβ (based on respiratory measurements in pregnant females at rest) and VQα (based on percentages of gravid females per cohort performing daytime activities at various PALVO$_2$) are consistent with VQ as well as sets of VE and VO$_2$ measurements reported in the literature for gravid women [27,29,31,32,36-38,128].

The pregnancy requires absolute oxygen demands (in L/min) with VO$_2$ mean values increasing by 2.4 to 6.3, 8.8 to 12.5 and 26.4 to 33.9% at the 9th, 22nd and 36th week of gestation respectively compared to baseline values for non-gravid females (Table 5). To support such oxygenation rates VE means increase by 22.1 to 34.3, 12.2 to 25.6 and 39.4 to 55.0% for the same classification of weeks of gestation respectively (Table 6). Moreover, absolute VE means during aggregate daytime activities of non-pregnant and pregnant females at rest (Table 7: 5.43 ± 0.57 to 13.91 ± 1.19 L/min) increase by 1.6 to 2.5 folds when they have full-time hospital jobs (Table 8: 13.75 ± 3.17 to 21.68 ± 3.07 L/min). These working females inhale 7.77 to 8.32 L of additional volumes of air per minute in order to be adequately oxygenated during their aggregate daytime activities compared to baseline values at rest (Tables 7 and 8). Based on our percentiles (Table 8), about 2.5% of under and normal weight women as well as 10, 15 and 50% of overweight, obese class 1 and classes 2-3 females of our cohorts at the 36th week of gestation respectively inhale more air (thus more air pollutants) than the default VE value of 20.83 L/min (i.e. 10 m³ in an 8-hour workday) that can be used for conducting occupational exposure assessments and/or hygienic standards for airborne toxic chemicals [147-150].

All adults are expected to have residues of organic chemicals and/or metals stored in their tissues resulting from sporadic exposures to environmental pollutants since their childhood: mainly by the ingestion of food, drinking water, dust and/or soil; and/or the inhalation of indoor and/or outdoor air [149,151-188]. For instance, cadmium and lead are stored in kidneys and bones respectively [189] and an impressive number of fat soluble environmental xenobiotics are stored in the adipose tissue including notably organochlorine pesticides and organic solvents [168,190-201].

As observed with organic environmental pollutants [195,199,202], drugs tend to dissolve into lipid-rich spaces [203] as shown by their lipophilic octanol-water partition coefficients [204-207]. Consequently, workers in hospitals inhaled concentrations of organic lipophilic toxic chemicals that are absorbed into their body and stored in their adipose tissue, including notably pharmaceutical aerosolized medications, volatile anesthetic gases, aromatic components of chirurgical smokes

Weight classifications of females	Progression of the reproductive cycle	Minute ventilation rates[a] (L/min)													
		Mean ± S.D.	Percentiles												
			1st	2.5nd	5th	10th	25th	50th	65th	75th	85th	90th	95th	97.5th	99th
Under-weight females	0 week	13.75 ± 3.17	7.91	8.52	9.13	9.95	11.47	13.42	14.69	15.69	17.04	17.99	19.52	21.01	22.47
	9th week	14.07 ± 2.82	8.67	9.27	9.85	10.62	12.02	13.82	14.96	15.87	17.06	17.91	19.17	20.28	21.56
	22nd week	13.74 ± 2.66	8.69	9.21	9.79	10.50	11.79	13.48	14.56	15.44	16.57	17.36	18.55	19.62	20.77
	36th week	15.22 ± 2.71	10.07	10.60	11.21	11.89	13.24	14.95	16.05	16.91	18.07	18.92	20.14	21.18	22.44
Normal-weight females	0 week	14.14 ± 3.34	7.86	8.53	9.27	10.11	11.76	13.82	15.11	16.16	17.55	18.58	20.15	21.55	23.35
	9th week	14.62 ± 3.09	8.73	9.38	10.04	10.86	12.43	14.34	15.52	16.52	17.81	18.76	20.17	21.59	23.20
	22nd week	14.14 ± 2.85	8.67	9.34	9.95	10.67	12.08	13.89	15.00	15.89	17.09	17.95	19.25	20.51	21.95
	36th week	15.49 ± 2.91	9.95	10.60	11.19	11.91	13.42	15.22	16.35	17.26	18.45	19.40	20.78	22.05	23.45
Overweight females	0 week	14.55 ± 5.15	6.20	7.08	7.78	8.78	10.86	13.62	15.69	17.34	19.65	21.46	24.21	26.90	30.11
	9th week	15.94 ± 3.28	9.67	10.37	11.05	11.93	13.56	15.65	16.95	17.97	19.40	20.35	21.90	23.26	24.65
	22nd week	15.28 ± 2.98	9.59	10.13	10.80	11.64	13.11	15.04	16.19	17.14	18.44	19.31	20.63	21.89	23.10
	36th week	17.18 ± 3.03	11.47	12.02	12.66	13.45	15.00	16.89	18.12	19.08	20.36	21.26	22.68	23.82	25.23
Obese class 1 females	0 week	15.40 ± 5.41	6.72	7.48	8.28	9.35	11.45	14.53	16.62	18.35	20.74	22.49	25.44	28.17	32.07
	9th week	17.31 ± 3.52	10.54	11.40	12.07	12.98	14.74	17.03	18.43	19.53	20.96	22.00	23.65	25.04	26.74
	22nd week	16.31 ± 3.13	10.36	11.05	11.62	12.46	14.03	16.03	17.33	18.30	19.61	20.52	21.96	23.14	24.62
	36th week	18.59 ± 3.20	12.57	13.23	13.87	14.66	16.25	18.3	19.59	20.60	21.92	22.82	24.32	25.64	27.01
Obese classes 2-3 females	0 week	17.08 ± 5.64	7.77	8.66	9.53	10.77	12.98	16.24	18.36	20.21	22.71	24.55	27.60	30.53	34.28
	9th week	20.19 ± 3.54	13.26	13.99	14.82	15.90	17.65	19.90	21.33	22.46	23.86	24.91	26.56	27.84	29.27
	22nd week	18.67 ± 3.00	12.64	13.39	14.09	14.96	16.51	18.47	19.66	20.60	21.79	22.67	23.89	25.02	26.49
	36th week	21.68 ± 3.07	15.57	16.30	17.04	17.89	19.51	21.47	22.66	23.59	24.93	25.84	27.20	28.19	29.52

Table 8: Distribution of minute ventilation rate (L/min) percentiles during the aggregate daytime activities of females aged 18 to 45 years. [a]VEα=[(TDEE-BEE)/((24-Sld) x 60)+(BEE)/1440] x H_P x VQα. BEEs and TDEEs are reported in Table 2. Sld data appear in Table 3. H_P of 0.2059 ± 0.0019 L of O_2/kcal is defined in Table 4. S.D.=standard deviation.

Weight classifications of females	Progression of the reproductive cycle	Minute ventilation rates[a] (L/kg-min)[b]													
		Mean ± S.D.	Percentiles												
			1st	2.5nd	5th	10th	25th	50th	65th	75th	85th	90th	95th	97.5th	99th
Under-weight females	0 week	0.272 ± 0.064	0.155	0.166	0.177	0.195	0.226	0.265	0.290	0.310	0.338	0.358	0.389	0.417	0.451
	9th week	0.259 ± 0.054	0.158	0.167	0.179	0.193	0.220	0.254	0.276	0.293	0.316	0.331	0.356	0.377	0.403
	22nd week	0.228 ± 0.047	0.140	0.150	0.160	0.172	0.195	0.223	0.242	0.257	0.278	0.291	0.311	0.332	0.352
	36th week	0.231 ± 0.043	0.150	0.159	0.168	0.179	0.199	0.227	0.244	0.258	0.277	0.289	0.311	0.328	0.348
Normal-weight females	0 week	0.238 ± 0.058	0.129	0.141	0.154	0.168	0.197	0.233	0.255	0.273	0.298	0.316	0.343	0.370	0.403
	9th week	0.240 ± 0.053	0.141	0.151	0.162	0.175	0.203	0.235	0.256	0.273	0.295	0.312	0.337	0.361	0.389
	22nd week	0.213 ± 0.046	0.126	0.137	0.146	0.158	0.180	0.208	0.226	0.240	0.260	0.272	0.294	0.317	0.340
	36th week	0.206 ± 0.041	0.129	0.138	0.146	0.156	0.177	0.202	0.218	0.231	0.247	0.260	0.281	0.300	0.320
Overweight females	0 week	0.197 ± 0.071	0.083	0.093	0.104	0.118	0.146	0.184	0.213	0.236	0.267	0.292	0.331	0.367	0.418
	9th week	0.197 ± 0.044	0.116	0.124	0.134	0.145	0.166	0.193	0.210	0.224	0.242	0.256	0.276	0.295	0.317
	22nd week	0.181 ± 0.039	0.108	0.116	0.123	0.134	0.153	0.177	0.193	0.205	0.221	0.233	0.251	0.268	0.285
	36th week	0.185 ± 0.036	0.119	0.126	0.133	0.142	0.160	0.182	0.196	0.207	0.223	0.234	0.250	0.266	0.281
Obese class 1 females	0 week	0.179 ± 0.065	0.076	0.085	0.094	0.107	0.131	0.168	0.193	0.214	0.242	0.265	0.300	0.333	0.380
	9th week	0.186 ± 0.041	0.109	0.118	0.126	0.136	0.156	0.182	0.198	0.211	0.228	0.239	0.258	0.274	0.295
	22nd week	0.168 ± 0.036	0.100	0.109	0.116	0.125	0.143	0.165	0.179	0.190	0.205	0.216	0.232	0.246	0.264
	36th week	0.177 ± 0.033	0.113	0.121	0.127	0.136	0.153	0.174	0.187	0.198	0.212	0.222	0.237	0.250	0.267
Obese classes 2-3 females	0 week	0.137 ± 0.046	0.062	0.069	0.076	0.086	0.104	0.130	0.148	0.163	0.183	0.198	0.223	0.245	0.275
	9th week	0.153 ± 0.028	0.099	0.105	0.112	0.119	0.133	0.151	0.162	0.171	0.183	0.190	0.203	0.214	0.226
	22nd week	0.138 ± 0.024	0.091	0.097	0.103	0.109	0.121	0.136	0.146	0.153	0.162	0.169	0.179	0.189	0.200
	36th week	0.151 ± 0.023	0.107	0.112	0.117	0.123	0.135	0.150	0.158	0.166	0.175	0.182	0.192	0.200	0.211

Table 9: Distribution of minute ventilation rate (L/kg-min) percentiles during the aggregate daytime activities of females aged 18 to 45 years. [a]VEα=[(TDEE-BEE)/((24-Sld) x 60)+(BEE)/1440] x H_P x VQα. BEEs and TDEEs are reported in Table 2. Sld data appear in Table 3. H_P of 0.2059 ± 0.0019 L of O_2/kcal is defined in Table 4. [b]Values expressed in L/kg-min were obtained by dividing VEα in L/min of Table 7 by body weight values presented in Table 2. S.D=standard deviation.

Weight classifications of females	Progression of the reproductive cycle	Minute ventilation rates[a] (L/m²-min)[b]													
		Mean ± S.D.	Percentiles												
			1st	2.5nd	5th	10th	25th	50th	65th	75th	85th	90th	95th	97.5th	99th
Under-weight females	0 week	9.05 ± 2.11	5.16	5.61	5.98	6.53	7.52	8.81	9.67	10.34	11.23	11.87	12.96	13.84	14.88
	9th week	8.93 ± 1.81	5.48	5.86	6.23	6.72	7.62	8.75	9.51	10.07	10.86	11.37	12.19	12.90	13.66
	22nd week	8.28 ± 1.63	5.20	5.52	5.87	6.31	7.10	8.12	8.79	9.30	10.00	10.48	11.22	11.89	12.57
	36th week	8.77 ± 1.59	5.79	6.09	6.44	6.84	7.62	8.62	9.26	9.76	10.44	10.91	11.65	12.30	12.99
Normal-weight females	0 week	8.59 ± 2.05	4.75	5.14	5.56	6.14	7.12	8.38	9.19	9.82	10.69	11.29	12.27	13.22	14.23
	9th week	8.77 ± 1.88	5.23	5.58	6.00	6.48	7.43	8.59	9.31	9.94	10.70	11.28	12.12	13.02	14.07
	22nd week	8.11 ± 1.67	4.94	5.32	5.67	6.09	6.90	7.96	8.62	9.13	9.83	10.31	11.12	11.85	12.72
	36th week	8.35 ± 1.60	5.35	5.69	6.00	6.41	7.20	8.21	8.83	9.31	9.98	10.48	11.26	12.02	12.75
Overweight females	0 week	7.96 ± 2.86	3.36	3.80	4.22	4.79	5.92	7.45	8.58	9.50	10.77	11.78	13.24	14.78	16.79
	9th week	8.32 ± 1.75	4.98	5.37	5.72	6.18	7.06	8.15	8.85	9.41	10.14	10.66	11.48	12.25	13.06
	22nd week	7.80 ± 1.57	4.83	5.13	5.44	5.88	6.67	7.65	8.28	8.78	9.44	9.90	10.63	11.25	11.97
	36th week	8.38 ± 1.52	5.55	5.82	6.11	6.51	7.28	8.24	8.84	9.32	9.96	10.44	11.18	11.73	12.37
Obese class 1 females	0 week	7.76 ± 2.78	3.32	3.71	4.10	4.66	5.76	7.31	8.37	9.26	10.48	11.40	12.96	14.36	16.53
	9th week	8.38 ± 1.74	5.06	5.44	5.79	6.24	7.13	8.23	8.93	9.46	10.18	10.68	11.47	12.19	13.05
	22nd week	7.74 ± 1.53	4.81	5.16	5.47	5.85	6.64	7.59	8.22	8.71	9.34	9.80	10.47	11.05	11.78
	36th week	8.48 ± 1.50	5.65	5.95	6.26	6.64	7.39	8.35	8.94	9.43	10.03	10.47	11.15	11.79	12.53
Obese classes 2-3 females	0 week	7.17 ± 2.38	3.26	3.63	4.01	4.50	5.44	6.82	7.71	8.50	9.53	10.32	11.62	12.87	14.33
	9th week	8.22 ± 1.45	5.37	5.68	6.02	6.44	7.17	8.10	8.68	9.15	9.74	10.15	10.82	11.39	11.98
	22nd week	7.49 ± 1.22	5.06	5.33	5.63	5.99	6.61	7.40	7.90	8.28	8.77	9.12	9.62	10.11	10.72
	36th week	8.46 ± 1.22	6.06	6.33	6.62	6.95	7.58	8.38	8.85	9.21	9.74	10.10	10.60	11.05	11.57

Table 10: Distribution of minute ventilation rate (L/m²-min) percentiles during the aggregate daytime activities of females aged 18 to 45 years. [a]VEα=[(TDEE-BEE)/((24-Sld) x 60)+(BEE)/1440] x H_P x VQα. BEEs and TDEEs are reported in Table 2. Sld data appear in Table 3. H_P of 0.2059 ± 0.0019 L of O_2/kcal is defined in Table 4. [b]Values expressed in L/m²-min were obtained by dividing VEα in L/min of Table 7 by body surface area values presented in Table 2. S.D=standard deviation.

(including notably benzene, toluene, ethyl benzene, xylene, styrene and aromatic polycyclic hydrocarbons) and organic solvents of cleaning products [203,208-213]. These chemicals and fat soluble environmental xenobiotics sequestered in adipose tissues as well as lead stored in bones are released into the bloodstream of female workers during their pregnancy, lactation and menopause and workers of both genders during weight loss resulting from an energy-restricted diet [168,174,214]. The mobilization of lead from bone tissues increases during calcium-deficient diets [215-220].

The adipose tissue may act as a reservoir for the accumulation of fat soluble drugs and toxicants. Large fat storage sites in obese women could increase their body's capacity for the accumulation of lipophilic xenobiotics, compared to those in under and normal weight females [221-223]. Moreover, published plasma levels of organochlorines suggest that high circulating concentrations of fat soluble pollutants mobilized from the adipose tissue could be related to high BMI values [221]. Therefore, obese female workers are at risk to have higher blood concentrations of total toxicants during their pregnancy, compared to their thinner counterparts, considering their high intakes and uptakes of air pollutants resulting from their high minute ventilation rates and blood concentrations of xenobiotics released from their adipose tissue. These blood concentrations of chemicals may generate adverse effects in gravid females, their embryo or fetus and even their newborns [224,225]. This is explained by the fact that most of these chemicals may be transferred to the embryos or fetus by the umbilical cord after crossing the placenta, or transferred to newborns during the breastfeeding [168,225]. Prenatal exposure to carcinogens could results in differentially higher levels of procarcinogenic DNA damage in the fetus [226]. This may disproportionately increase the probability of the latter to develop a cancer over his lifetime. The inhalation and absorption of teratogenic chemicals by pregnant female workers, after the implantation of their blastocyst may lead to genetic damages, structural defects, malformation of systems or growth retardations in newborns [182,223,227-229]. Diseases and developmental disorders could also occur in children, during their life course and in future generations [228]. The embryonic death occurs when future mothers absorb in their bloodstream teratogenic chemicals mainly by the inhalation process, before the implantation of their blastocyst [223]. For instance, the exposure to anesthetic gases, antineoplastic drugs and sterilizing agents were associated to high risks of spontaneous abortions in exposed working females in hospitals, compared to those that were not exposed [68,226,230-234]. Significantly more congenital abnormalities were also found in children of some exposed female workers [232,233,235]. These high risks of spontaneous abortions are enhanced by the fact that working women in hospitals cannot know exactly when their pregnancy begins: the human chorionic gonadotropin (hCG) being only detected in the blood or urine samples after the implantation of the blastocyst, which occurs six to twelve days after the fertilization [222,223].

Conclusion

The present study provides a complete and original set of $PALVO_2$, VQβ, VQα, VO_2 and VE values during the aggregate daytime activity of under (n=68), normal (n=268), overweight (n=42), obese class 1 (n=68) and obese classes 2-3 (n=51) females with full-time hospital jobs, before their pregnancy, and at their 9th, 22nd and 36th week of gestation. The integration into the calculation process of BEE, TDEE and H data has assured mean low potential errors on VE data varying from +1 to +2.6%. The use of published BEE, TDEE, body weight and height values that have been systematically measured in the same females has allowed accurate calculations of VE data per unit of body weight or body surface area. Therefore, VE percentiles reported in this study are recommended for conducting occupational health risk assessment and management of potential toxic air pollutants in non-pregnant and pregnant females working in hospitals. However, the non-exposure of female workers to teratogenic and carcinogenic agents in hospitals is recommended before and during their pregnancy.

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Declaration of Interest

The authors report no declarations of interest.

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