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Energy expenditure of household activities and cardiorespiratory fitness in women with obesity

H. Dereppe[1], M. Verbeke[2], C. Debruxelles[2], E. Boucq[2], L. Ponzoni[2] and G. Cuvelier[2]

What is already known about this subject

- Obesity is associated with several cardiovascular and metabolic diseases which ultimately increase mortality.
- Low level of physical activity (PA) is associated with an increased risk of cardiovascular and all cause mortality.
- Household activities contribute to the total PA level.
- Low cardiorespiratory fitness is an independent factor of cardiovascular diseases and mortality.

What this study adds

- The intensity of household activity is not increased in women with obesity and normal cardiorespiratory fitness.
- Obesity is not a barrier to household activities.

[1]Service de Cardiologie, CHWAPI – Centre d'Orthonutrition, Tournai, Belgium;
[2]Laboratoire de l'effort et du mouvement, Haute Ecole Provinciale Hainaut-Condorcet, Tournai, Belgium

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Address for correspondence: Dr H Dereppe, Service de Cardiologie, CHWAPI – Centre d'Orthonutrition, 7500 Tournai, Belgium.
E-mail: hubert.dereppe@chwapi.be

Summary

Patients with obesity experience difficulties in executing household activities. Our purpose was to compare the energy expenditure and exercise intensity of daily household activities and cardiorespiratory fitness (CRF) in women with obesity and normal weight women. Twenty-eight non-obese women (NO, 44.6 ± 7.2 years; body mass index [BMI] 22.1 ± 1.7 kg m^{-2}) and 20 women with obesity (OB, 44.0 ± 7.7 years; BMI 33.4 ± 2.7 kg.m^{-2}). Peak oxygen uptake ($\dot{V}O_{2peak}$), maximal heart rate (HR) and maximal cycling power output were measured during a maximal incremental cycling test to assess CRF. Oxygen uptake ($\dot{V}O_2$) used to assess CRF was measured during a standardized protocol that included ironing, cleaning floor and walking and climbing stairs. The intensity of the three household activities was expressed by the ratio between $\dot{V}O_2$ during household activity ($\dot{V}O_2$-activity) and resting $\dot{V}O_2$, and between $\dot{V}O_2$ during household activity and $\dot{V}O_{2peak}$. $\dot{V}O_2$ peak was higher in OB (1845.2 ± 290.5 mL min^{-1}) than in NO women (1612.6 ± 250.9 mL min^{-1}, $P < 0.01$). There were no significant differences for the ratio between $\dot{V}O_2$-activity and resting $\dot{V}O_2$ between NO and OB women for any of the three household activities. No differences were observed either between the two groups for the ratio of $\dot{V}O_2$-activity to $\dot{V}O_{2peak}$. In healthy women with obesity and normal CRF, physical activity (PA) may not be affected by energy need and intensity of household activities. In this way, these women can be motivated to maintain a high PA level contributing to lessen the cardiovascular risk.

Keywords: Cardiorespiratory fitness, household activities, obesity, physical activity.

Introduction

High energy intake combined with a low daily physical activity (PA) level is a key factor contributing to the development of obesity and related cardiovascular and metabolic diseases (1, 2).

Obesity associated with cardiovascular and metabolic diseases can lead to high risk of premature death (3, 4).

Low PA level and low cardiorespiratory fitness (CRF) are also two independent predictors of the development of cardiovascular diseases and mortality risk; sedentary adults have a higher risk of premature death when compared to physically active adults (5–7).

Increasing PAL of patients with obesity is a major challenge for clinicians despite motivational support, the use of the principles of effective communication or cognitive behavioural strategies (8). Overweight and obesity can also be a barrier to PA. This perceived barrier to PA could limit the participation to household activities.

However, the interpretation of $\dot{V}O_{2peak}$, which reflects CRF, depends on the expression as an absolute value (mL min^{-1}) or relative to body mass (mL min^{-1}). While the latter is significantly decreased in subjects with obesity and is pertinent to explain impaired locomotor performance during weight bearing activities, $\dot{V}O_{2peak}$ in absolute terms has been shown to be similar in subjects with obesity and normal weight subjects (9). This finding is not in line with the belief of a global CRF impairment in patients with obesity. In contrast, there is limited data available regarding energy expenditure and cardiorespiratory responses during household activities (10, 11).

The primary aim of this study was therefore to assess the energy expenditure and intensities during three daily household activities (ironing [IR], cleaning floor [CLEAN] and walking and climbing stairs [WCS]). To this purpose, we intended to determine the energy expenditure as the ratio of oxygen uptake during household activities to resting $\dot{V}O_2$ and to $\dot{V}O_{2peak}$. We hypothesized that the intensity of the three household activities (IR, CLEAN and WCS) would be similar in the two groups since $\dot{V}O_{2peak}$, which reflects CRF, of healthy women with obesity is known to normal relative to reference values. The validation of our hypothesis was expected to highlight that obesity is unlikely to be a barrier to household activities in healthy patients with obesity.

Materials and methods

Subjects

For this prospective study, 48 healthy Caucasian Belgian women were recruited from the Hainaut area (Belgium). Obesity was determined based on body mass index (BMI = body mass (kg)/height^2 (m)). Twenty women with BMI ranging between 30 and 39.9 kg m^{-2} were included in the group with obesity (OB). Twenty-eight women with BMI ranging between 18.5 and 24.9 kg m^{-2} were included in the non-obese group (NO). Women in the OB group were recruited among patients attending the Orthonutrition Unit of the Centre Hospitalier for consultation specialized in the multidisciplinary management of weight loss (CHWAPI Hospital, Tournai, Belgium).

The NO group consisted of voluntary women. In both groups, all subjects were office workers or unemployed, with minimal work-related PA. Before inclusion, each patient underwent a medical examination and a blood sample in fasted state was drawn for blood glucose and lipid profile analysis to exclude comorbidities. All subjects were free of hypertension, diabetes mellitus, hypertriglyceridemia, and hypercholesterolemia. Subjects were excluded if they were presenting one of the following criteria: (i) history of hypertension with or without medication, diabetes mellitus, cardiovascular or respiratory disease, systemic disease, smoking; (ii) drugs; (iii) 30 years ≤ age ≤60 years; (iv) BMI >40 kg m^{-2}; (v) regular exercise participation.

After a presentation of the purpose of the study, all the subjects signed an informed consent approved by the Academic Ethical Committee Brussels Alliance for Research and Higher Education (acceptance number: B200-20 16-048).

Characteristics of women in the two groups are reported in Table 1.

Table 1 Subject characteristics

Total (n = 48)	NO group (n = 28)		OB group (n = 20)		P-values
	Average	SD	Average	SD	
Age, year	44.6	7.2	44.0	7.7	0.77
Height, cm	167	7	164	5	0.04*
Weight, kg	61.9	6.1	89.4	9.2	<0.001†
BMI, kg m^{-2}	22.1	1.75	33.4	2.72	<0.001†

BMI, body mass index (weight in kg/[height in m] × [height in m]); NO, non-obese; OB, obese; SD, standard deviation.
*Significant difference.
†Extremely significant difference.

Maximal cardiopulmonary exercise testing

The cardiopulmonary exercise testing (CPET) was supervised by the same cardiologist (Cardiology Department, CHWAPI) and performed on a stationary graded cycle ergometer exercise (Schiller CH640/BAR, Ergoline, Switzerland) connected to cardiovascular and respiratory software. Subjects breathed through a facemask in a telemetry system, which collected respiratory and metabolic variables breath-by-breath (MasterScreen CPX, Jaeger, Carefusion, Germany). Before each test, O_2 and CO_2 analyzers (SBx/CPX, Jaeger, Germany) were calibrated. The protocol began with 3 min unloaded cycling in order to record baseline values. Women had to maintain a speed of 60–65 cycling revolutions per minute (rpm) throughout the whole test. An incremental exercise test started at 20 watts with steps of 20 watts min^{-1} up to exhaustion. $\dot{V}O_2$ (mL min^{-1}) was continuously recorded throughout the CPET. Breath by breath gaz exchange data were filtered and averaged into 5-s bins. Continuous heart rate (HR [bpm]) was averaged by an electrocardiogram system (Schiller CS200). We considered that $\dot{V}O_{2peak}$ was achieved when at least two of the following criteria were reached: (i) respiratory gas exchange ratio >1.10; (ii) HR_{max} >85% of maximal expected HR (12). $\dot{V}O_{2peak}$ was defined as the highest $\dot{V}O_2$ values attained in two consecutive 20-s periods (obtained from four averaged 5-s data). The maximal HR and maximal power output corresponded to the mean HR and power output when reaching $\dot{V}O_{2peak}$.

To determine whether CRF is normal in women with obesity, we compared their measured $\dot{V}O_2$ to reference values. $\dot{V}O_{2peak}$ was expressed as percentage of predicted values with the Riddle *et al.* and Wasserman *et al.* equations (9).

The equation from Riddle *et al.* (R) Equation for women with or without obesity is a follow:

$$\text{Predicted }\dot{V}O_{2peak}R = (48 - 0.37 \times \text{Age}) \times \text{Predicted Weight}$$

with predicted weight = (3.55 × height/2.54–106/2.2) in kg; age in year; height in cm.

The Equation from Wasserman *et al.* (W) are as follow:

- NO women:

$$\text{Predicted }\dot{V}O_{2peak}W = ([22.78 - 0.17 \times \text{Age}] \times [(\text{Predicted Weight} + \text{Measure Weight})/2])$$

- Women with OB:

$$\text{Predicted }\dot{V}O_{2peak}W = ([22.78 - 0.17 \times \text{Age}] \times [PW + 43] + [6 \times (\text{Measure Weight} - \text{Predicted Weight})])$$

With age in year; measured weight in kg; predicted weight = (0.65 × height − 42.8); height in cm.

Assessment of the relative energy expenditure of household activities

Household activities and gas exchange measurement

Measurements were performed in a standardized room under the supervision of the same operator for all subjects. All subjects had their last meal at least 3 h before testing. At their arrival to the laboratory subjects were asked to lay down on a medical bed for 15 min in dark and quiet in order to record resting HR. (13) HR values were averaged over the last 2 min of measurement (resting HR). Subjects were then asked to sit down for 5 min while measuring gas exchange. Resting $\dot{V}O_2$ was determined from the last 2 min of gas exchange measurement while sited.

Following HR and $\dot{V}O_2$ measurement under resting condition, subjects were asked to complete three household activities: IR with a controlled and standardized motion pattern with the same iron and table for all subjects, CLEAN a standardized room floor with a controlled and standardized motion pattern, WCS with a controlled rate motion. The activities were performed in a randomized order for each subject. IR and CLEAN were performed in the same room and lasted 3 and 4 min, respectively. WCS consisted of a self-paced walking and stair climbing exercise over a distance of 256.8 m followed by 66 stairs (height: 0.18 m; depth: 0.23 m). Tasks were interspersed by a 5-min rest period. A portable indirect calorimetry system ($K4b^2$, COSMED) was used with Holter mode to record HR and gas exchange variables, such as $\dot{V}O_2$, during the experimental session. The flowmeter, O_2 and CO_2 cells were calibrated before each test. HR was measured before and during activities with a Polar T34 HR belt. Subjects had to breathe through the $K4b^2$ facemask and turbine. After completion of the experimental session, gas exchange data were downloaded from the $K4b^2$ unit to a computer for latter analysis. Gas exchange data analyses were performed with the Cosmed software (Roma, Italy).

Energy expenditure and intensity of household activities

First, the energy expenditure of household intensity was first expressed as absolute $\dot{V}O_2$ values (mL min^{-1}). Second, the energy expenditure of each task was expressed as metabolic equivalent of task (METs), defined as the ratio between measured $\dot{V}O_2$ during household activities to measured resting $\dot{V}O_2$. Third, $\dot{V}O_2$ during household activities was also expressed as a ratio to $\dot{V}O_{2peak}$, which provides an estimate of exercise capacity relative to CRF.

Data analysis

Data are presented as mean ± standard deviation (SD). Statistical inferences were made by comparisons between NO group and OB group. For every variable, the normality of data distribution was verified with the Kolmogorov–Smirnov (KS) test. When normality was verified, variables were presented with *P*-value of the Student's *t*-test and when normality test failed, SD was not listed. The Mann–Whitney (M-W) *U* test was used when normality was not verified. Homoscedasticity was verified with the Levene test. If it was confirmed, T-Student tests were used. In case of heteroscedasticity, the M-W was used. Statistical significance was established as $\alpha = 0.05$. All statistical analyses were performed with STATISTICA software (Statsoft 2012). Statistical significance was set at $P < 0.05$.

All variables were compared between groups with the Student's *t*-test.

Table 2 Evaluation of cardiorespiratory fitness in women without obesity and women with obesity

	NO Group		OB Group		*P*-values*
	Average	SD	Average	SD	
Measured resting $\dot{V}O2$, mL min^{-1}	184.6	70.5	227.2	75.0	>0.05
Measured resting HR, bpm	64	9	75	12	<0.001**
Measured $\dot{V}O_{2peak}$, mL min^{-1}	1612.6	250.9	1845.2	290.5	<0.01‡
Predicted $\dot{V}O_{2peak}$ R†, mL min^{-1}	1837.8	245.0	1770.3	193.4	>0.05
Predicted $\dot{V}O_{2peak}$ W‡, mL min^{-1}	1627.8	166.0	1786.2	157.7	<0.01‡
$\frac{\text{Measured } \dot{V}O_{2peak}}{\text{Predicted } \dot{V}O_{2peak} R}$	0.9	0.1	1.0	0.1	<0.001**
$\frac{\text{Measured } \dot{V}O_{2peak}}{\text{Predicted } \dot{V}O_{2peak} W}$	1.0	0.1	1.0	0.1	>0.05
Maximal HR, bpm	172	13	173	9	>0.05
Maximal power output, watts	123	21	133	22	>0.05

*All the variables were analysed with the Student's *t*-test.

†Equation from Riddle *et al.* (R) for women with obesity and women with normal weight: Predicted $\dot{V}O_{2peak}R = (48 - 0.37A) \times PW(PW = 3.55H/2.54 - 106/2.2)$, where A, age in years; PW, predicted weight in kg; H, height in cm.

‡Equation from Wasserman *et al.* (W) for non-obese women: Predicted $\dot{V}O_{2peak}W = ([22.78 - 0.17A] \times [(PW + MW/86)/2])$. Equation from Wasserman *et al.* (W) for women with obesity: Predicted $\dot{V}O_{2peak}W = ([22.78 - 0.17A] \times [PW + 43] + [6X(MW - PW)])$, where A, age in years; MW, measured weight in kg; PW, (0.65H − 42.8).

**Very significant difference.

***Extremely significant difference.

HR, heart rate; NO, non-obese; OB, obese; SD, standard deviation.

Results

Resting measurements

Resting $\dot{V}O_2$ was not significantly different in the OB group (227.2 ± 75.0 mL min^{-1}) and NO group (184.6 ± 70.5 mL min^{-1}) (Table 2). Resting HR was significantly higher in the OB group (75 ± 12 bpm) than in the NO group (64 ± 9 bpm, $P < 0.001$). Results are reported in Fig. 1.

Maximal oxygen uptake

$\dot{V}O_{2peak}$ was significantly higher in the OB group (1845.2 ± 290.5 mL min^{-1}) than in the NO (1612.6 ± 250.9 mL min^{-1}, $P = 0.01$) (Table 2). The ratio $\dot{V}O_{2peak}$ /predicted $\dot{V}O_{2peak}$ was equal to 1.0 ± 0.1 for the two groups using the Wasserman *et al.* (9) $\dot{V}O_{2peak}$ prediction equation. With the Riddell *et al.* (9) equation the ratio $\dot{V}O_{2peak}$ /predicted $\dot{V}O_{2peak}$ was, respectively, of 0.9±0.1 and of 1.0±0.1 in NO and OB (Table 2 and Fig. 1).

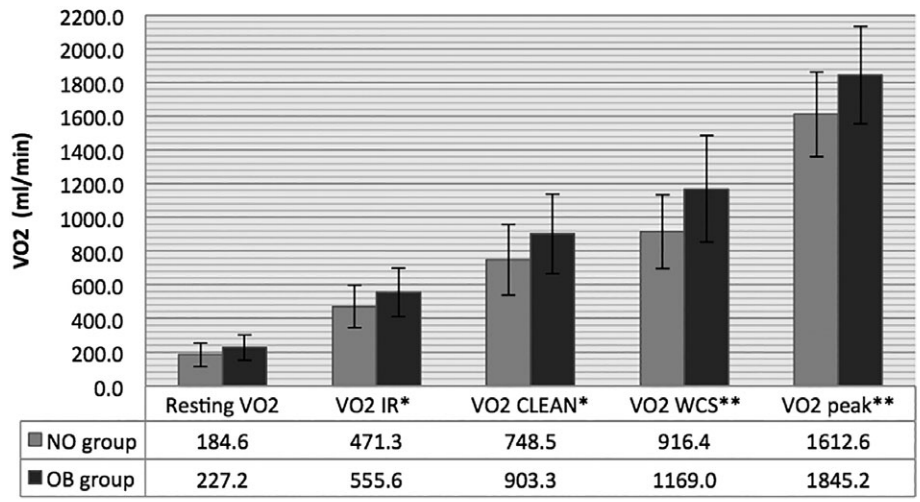

Figure 1 Oxygen uptake's comparison between obese and non-obese women. CLEAN, cleaning floor; IR, ironing; NO, non-obese; OB, obese; WCS, walking and climbing stairs; *0.05 > P > 0.01 = significant difference; **0.01 > P > 0.001 = very significant difference; ***P < 0.001 = extremely significant difference.

Table 3 Household activities

	NO group		OB group		*P*-values
	Average	SD	Average	SD	
IR					
Measured $\dot{V}O2$	471.3	125.6	555.6	145.5	<0.05
$\frac{\text{Measured } \dot{V}O_2}{\text{Measured } \dot{V}O_{2peak}}$	0.3	0.1	0.3	0.1	>0.05
$\frac{\text{Measured} O_2}{\text{Measured Resting } \dot{V}O_{2peak}}$	2.9	1.2	2.9	1.7	>0.05
HR	91	11	100	14	<0.05
CLEAN					
Measured $\dot{V}O2$	748.5	209.5	903.3	236.4	<0.05
$\frac{\text{Measured} O_2}{\text{Measured } \dot{V}O_{2peak}}$	0.5	0.1	0.5	0.1	>0.05
$\frac{\text{Measured } \dot{V}O_2}{\text{Measured Resting } \dot{V}O_{2peak}}$	4.9	3.4	4.6	2.2	>0.05
HR	106		117		<0.05
WCS					
Measured $\dot{V}O2$	916.4	220.4	1169.0	316.2	<0.01
$\frac{\text{Measured } \dot{V}O_2}{\text{Measured } \dot{V}O_{2peak}}$	0.6	0.2	0.6	0.2	>0.05
$\frac{\text{Measured } \dot{V}O_2}{\text{Measured Resting} O_{2peak}}$	6.2	4.9	6.1	3.5	>0.05
HR	114	12	128	13	<0.001

*0.05 > *P* > 0.01 = significant difference.
**0.01 > *P* > 0.001 = very significant difference.
****P* < 0.001 = extremely significant difference.
CLEAN, cleaning floor; HR, heart rate; IR, ironing; NO, non-obese; OB, obese; SD, standard deviation; WCS, walking and climbing stairs.

$\dot{V}O_2$ and relative energy expenditure of household activities

$\dot{V}O_2$ during household activities are reported in Table 3. $\dot{V}O_2$ was significantly higher in the OB group than in the NO group for the 3 household activities investigated. When expressed as percentage, $\dot{V}O_2$ was higher by +17.9% during IR ($P < 0.05$), +20.7% during CLEAN ($P < 0.05$), and +27.6% during WCS ($P < 0.01$) in the OB group than in the NO group.

However, the energy expenditure of the three activities was not significantly different between the OB and NO groups, whether it was expressed relative to resting $\dot{V}O_2$ or relative to $\dot{V}O_{2peak}$. $\dot{V}O_2$, the relative energy expenditure of household activities and HR data are reported in Table 3.

Discussion

We aimed to compare the intensity of daily household activities in women with obesity and normal weight women. To this purpose, we measured $\dot{V}O_2$ during household activities, and expressed this $\dot{V}O_2$ as a ratio to measured resting $\dot{V}O_2$ (14). The main finding of the present study was that the relative energy expenditure of the three household activities that we studied was similar in normal weight women and women with obesity. This is despite a significantly higher $\dot{V}O_2$ during the three activities in women with obesity.

We considered that resting $\dot{V}O_2$ in the present study would provide an estimate of METs in healthy women with obesity. Indeed, a value of 1 MET is commonly accepted as 3.5 mL O_2 kg^{-1} min^{-1} or 1 kcal kg^{-1} h^{-1} (15). However, measured $\dot{V}O_2$ under resting condition was previously shown to be lower than the standard MET value in subjects with obesity (16). A strength of our study is that we measured resting $\dot{V}O_2$ to express $\dot{V}O_2$ during household activities as a ratio instead of using the standard 3.5 mL O_2 kg^{-1} min^{-1} METs.

These three activities that we chose, IR, CLEAN and WCS range from low to vigorous intensity according to the Compendium of Physical Activity (10). We found the same intensity in the two groups for each activity compared to recent literature (14): the ratio that we obtained indicates that household activities can be recommended to patients with obesity to increase their PA level to reach the recommendation (17). PA guidelines that take into account mortality risk and CRF have been established by Leitzmann *et al.* (18). According to these guidelines, a subject is considered as active if at least 30 min of moderate-intense exercise are completed each day, or at least 20 min of vigorous-intensity exercise are performed at least three times per week (17).

A second aim of this study was to evaluate and compare the CRF, as assessed by $\dot{V}O_{2peak}$, of sedentary healthy women with obesity vs. women with normal weight. Interestingly, our results reported no difference in resting $\dot{V}O_2$ expressed in absolute term between the two groups, confirming what was observed in Gibson's study (19).

Our results indicate that measured $\dot{V}O_{2peak}$ was significantly higher in women with obesity than in non-obese (NO) women. When the CRF is expressed as the ratio of measured $\dot{V}O_{2peak}$ to predicted $\dot{V}O_{2peak}$ by the equations of Riddle *et al.* and Wasserman *et al.* (9), this ratio reaches 100% of the predicted values in subjects with obesity. In the NO women, the ratio reaches 90% of the predicted values with the equation of Wasserman *et al.* and 100% with the equation of Riddle *et al.* (9). This observation convinced us that Riddle's equation seems to be more reliable to compare women individuals with obesity to women individuals without obesity (9). Cohen-Solal *et al.* (20) considered a normal CRF between 90 and 110% of the predicted values for sedentary subject. Hence the women with obesity that we studied do not appear to have impaired cardiorespiratory function.

Although our subjects presented a normal CRF, it is important to convince them to, at least, maintain their CRF at this level. Notably, with this study, subjects with obesity may become aware of their capacity and be encouraged to continue and progress. Secondly, it is worth mentioning that subjects may increase their PA level per week in order to improve the CRF, leading to a proportionally decrease in the relative risk of death (21). Moreover, Jakicic (22) reported that increasing the PA level positively influences the weight, which represents an additional benefit.

Our study has reported that resting HR is higher in subjects with obesity vs. NO subjects. This result corroborated the recent study of Rossi *et al.* (23) in which it was demonstrated that parasympathetic function is decreased and that sympathetic nervous tone is relatively increased in individuals with obesity.

HR was significantly higher in women with obesity than in normal weight women, whatever the household activity. These observations have already been discussed by others. In fact, during submaximal exercise the increase in sympathetic tone is preceded by the inhibition of parasympathetic function (24). Although we previously indicated that the relative energy expenditure of household activities was unaffected by obesity, women with obesity could have perceived the activities as more strenuous than did normal weight women since HR is closely associated to the rate of perceived exertion (25).

There are a number of limitations to the present study. First, we studied middle-aged Caucasian women without associated comorbidities. It would be interesting to investigate other groups including older patients of both sexes, other ethnicities or patients with severe obesity. By the way, there is a limitation because of the lack of information about differences between the two groups in daily PA level, social factors, etc. Second, although CRF may not prevent women with obesity from performing household activity, this may not be the case in patients with higher risks of comorbidities, metabolic and cardiovascular systems. Third, there is a need to assess the perceived exertion of household activities.

Finally, as there is growing literature regarding the impact of body composition on $\dot{V}O_{2peak}$ (26, 27), a similar study including the body distribution components for the normalization of $\dot{V}O_{2peak}$ could provide more information.

Our study has several strengths. The first one is that we evaluated the intensity of household activities by direct measurements. The second one is that we evaluated CRF by a CPET to exhaustion in order to reach maximal values. Finally, in order to limit the heterogeneity, we selected the enrolled population with strict inclusion criteria.

Conclusion

The present study points out that the energy expenditure of household activities expressed relative to resting $\dot{V}O_2$ or $\dot{V}O_{2peak}$ is not increased in healthy middle-aged women with obesity relative to normal weight women. This result is attributable to CRF that remain within the normal range according to the predicted reference values. Therefore, excess body fat does not represent a barrier to household PA, at least with regard to its energy demand. These results are of importance since household activities can contribute significantly to the increase of total PA level and thereby participate to reduce the risk of cardiovascular and all-cause mortality.

Conflict of Interest Statement

No conflict of interest was declared.

Author contributions

HD, GC, MV, LP and CD conceived and carried out experiments. They analysed data with Boucq E, the statistician. All authors were involved in writing the paper and had final approval of the submitted version.

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References

1. Archer E, Shook RP, Thomas DM *et al.* 45-Year trends in women's use of time and household management energy expenditure. *PLoS One* 2013; **8**: e56620. https://doi.org/10.1371/journal.pone.0056620.
2. Lavie CJ, Lee DC, Sui X *et al.* Effects of running on chronic diseases and cardiovascular and all-cause mortality. *Mayo Clin Proc* 2015; **90**: 1541–1552. https://doi.org/10.1016/j.mayocp.2015.08.001.
3. Britton KA, Massaro JM, Murabito JM *et al.* Body fat distribution, incident cardiovascular disease, cancer, and all-cause mortality. *J Am Coll Cardiol* 2013; **62**: 921–925.
4. U.S. Department of Health. Managing overweight and obesity in adults. *Obesity Expert Panel* 2013; **1**: 3–4.
5. Staiano AE, Reeder BA, Elliott S *et al.* Physical activity level, waist circumference, and mortality. *Appl Physiol Nutr Metab* 2012; **37**: 1008–1013.
6. Lee D, Artero EG, Sui X, Blair SN. Mortality trends in the general population: the importance of cardiorespiratory fitness. *J Psychopharmacol* 2010; **24**(4 Suppl.): 27–35.
7. Kodama S, Saito K, Tanaka S *et al.* Cardiorespiratory fitness as a quantitative predictor of all-cause mortality and cardiovascular events in healthy men and women. *JAMA* 2009; **301**: 2024–2035.
8. Rubak S, Sandbaek A, Lauritzen T, Christensen B. Motivational interviewing: a systematic review and meta-analysis. *Br J Gen Pract* 2005; **55**: 305–312.

9. Lorenzo S, Babb TG. Quantification of cardiorespiratory fitness in healthy nonobese and obese men and women. *Chest* 2012; **141**: 1031–1039.
10. Ainsworth BE, Haskell WL, Whitt MC *et al*. Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc* 2000; **32**(9 Suppl.): S498–S504.
11. Gunn SM, Brooks AG, Withers RT *et al*. Determining energy expenditure during some household and garden tasks. *Med Sci Sports Exerc* 2002; **34**: 895–902.
12. Mezzani A, Hamm LF, Jones AM *et al*. Aerobic exercise intensity assessment and prescription in cardiac rehabilitation: a joint position statement of the European Association for Cardiovascular Prevention and Rehabilitation, the American Association of Cardiovascular and Pulmonary Rehabilitation and the Canadian Association of Cardiac Rehabilitation. *Eur J Prev Cardiol* 2013; **20**: 442–467.
13. Nauman J, Aspenes ST, Nilsen TIL, Vatten LJ, Wisløff U. A prospective population study of resting heart rate and peak oxygen uptake (the HUNT study, Norway). *PLoS One* 2012; **7**: 1–9.
14. Graham I, Atar D, Borch-Johnsen K *et al*. European guidelines on cardiovascular disease prevention in clinical practice. *Eur Heart J* 2016, 2016; **28**: 2375–2414.
15. Jetté M, Sidney K, Blümchen G. Metabolic equivalents (METS) in exercise testing, exercise prescription, and evaluation of functional capacity. *Clin Cardiol* 1990; **13**: 555–565. https://doi.org/10.1002/clc.4960130809.
16. Byrne NM, Hills AP, Hunter GR, Weinsier RL, Schutz Y. Metabolic equivalent: one size does not fit. *J Appl Physiol* 2005; **99**: 1112–1119.
17. Kahlmeier S, Wijnhoven TM, Alpiger P *et al*. National physical activity recommendations: systematic overview and analysis of the situation in European countries. *BMC Public Health* 2015; **15**: 133.
18. Leitzmann MF, Park Y, Blair A *et al*. Physical activity recommendations and decreased risk of mortality. *Arch Intern Med* 2007; **167**: 2453–2460.
19. Gibson GJ. Obesity, respiratory function and breathlessness. *Thorax* 2000; **55**(Suppl. 1): S41–S44.
20. Cohen-Solal A, François C. Réalisation pratique et analyse d'une épreuve d'effort cardiorespiratoire. In: Elsevier Masson - France (ed). *Guide pratique des épreuves d'effort cardiorespiratoires*. Mediguides, 2009, pp. 35–69.
21. Kokkinos P. Physical activity, health benefits, and mortality risk. *ISRN Cardiol* 2012; **2012**: 718789.
22. Bouchard C, Katzmarzyk PT (eds). *Physical Activity and Obesity*, 2010, pp. 104–106.
23. Rossi RC, Vanderlei LCM, Gonçalves ACCR *et al*. Impact of obesity on autonomic modulation, heart rate and blood pressure in obese young people. *Auton Neurosci* 2015; **193**: 138–141.
24. Gondoni LA. Exercise physiology in obese subjects: cardiovascular function. In: Hansen D (ed). *Exercise Therapy in Adult Individuals with Obesity*. Nova Sciences Publisher: NY, USA, 2013, pp. 73–86.
25. Jakicic JM, Donnelly JE, Pronk NP, Jawad AF, Jacobsen DJ. Prescription of exercise intensity for the obese patient: the relationship between heart rate, VO2 and perceived exertion. *Int J Obes Relat Metab Disord* 1995; **19**: 382–387.
26. Arterburn DE, Maciejewski ML, Tsevat J. Impact of morbid obesity on medical expenditures in adults. *Int J Obes (Lond)* 2005; **29**: 334–339.
27. Terada T, Johnson JA, Norris C *et al*. Severe obesity is associated with increased risk of early complications and extended length of stay following coronary artery bypass grafting surgery. *J Am Heart Assoc* 2016; **5**: e003282. https://doi.org/10.1161/JAHA.116.003282.

