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

H. Dereppe¹, M. Verbeke², C. Debruxelles², E. Boucq², L. Ponzoni² and G. Cuvelier²

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.

¹Service de Cardiologie, CHWAPI – Centre d’Onthronutrition, Tournai, Belgium; ²Laboratoire de l’effort et du mouvement, Haute Ecole Provinciale Hainaut-Condrozet, Tournai, Belgium

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 (VO₂peak), maximal heart rate (HR) and maximal cycling power output were measured during a maximal incremental cycling test to assess CRF. Oxygen uptake (VO₂) 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 VO₂ during household activity (VO₂-activity) and resting VO₂, and between VO₂ during household activity and VO₂peak. VO₂ 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 VO₂-activity and resting VO₂ 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 VO₂-activity to VO₂peak. 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 \( \text{VO}_{2\text{peak}} \), which reflects CRF, depends on the expression as an absolute value (mL min\(^{-1}\)) or relative to body mass (mL min\(^{-1}\) kg\(^{-1}\)). While the latter is significantly decreased in subjects with obesity and is pertinent to explain impaired locomotor performance during weight bearing activities, \( \text{VO}_{2\text{peak}} \) 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 [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 \( \text{VO}_2 \) and to \( \text{VO}_{2\text{peak}} \). We hypothesized that the intensity of the three household activities (IR, CLEAN and WCS) would be similar in the two groups since \( \text{VO}_{2\text{peak}} \) in absolute terms has been shown to reflect 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).

<table>
<thead>
<tr>
<th>Table 1 Subject characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (n = 48)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Age, year</td>
</tr>
<tr>
<td>Height, cm</td>
</tr>
<tr>
<td>Weight, kg</td>
</tr>
<tr>
<td>BMI, kg m(^{-2})</td>
</tr>
</tbody>
</table>

BMI, body mass index (weight in kg/[height in m] \( \times \) [height in m]); NO, non-obese; OB, obese; SD, standard deviation.

*Significant difference.

†Extremely significant difference.

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 Orthonutritional Unit of the Centre Hospitalier for consultation specialized in the multidisciplinary management of weight loss (CHWAPI Hospital, Tourinai, 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.

### 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, \( \text{O}_2 \) and \( \text{CO}_2 \) 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. \( \text{VO}_2 \) (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 \( \text{VO}_{2\text{peak}} \) was achieved when at least two of
the following criteria were reached: (i) respiratory gas exchange ratio >1.10; (ii) HRmax >85% of maximal expected HR (12). VO2peak was defined as the highest VO2 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 VO2peak.

To determine whether CRF is normal in women with obesity, we compared their measured VO2 to reference values. VO2peak 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:

$$\text{Predicted VO2peak R} = (48 - 0.37 \times \text{Age}) \times \text{Predicted Weight}$$

with predicted weight = (3.55 \times \text{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:

$$\text{Predicted VO2peak W} = (\frac{22.78 - 0.17 \times \text{Age}}{\text{Predicted Weight} + \text{Measure Weight}}/2)$$

- Women with OB:

$$\text{Predicted VO2peak W} = (\frac{22.78 - 0.17 \times \text{Age}}{\text{Predicted Weight} + 43} + 6 \times (\text{Measure Weight} - \text{Predicted Weight})])$$

With age in year; measured weight in kg; predicted weight = (0.65 \times \text{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 VO2 was determined from the last 2 min of gas exchange measurement while sited.

Following HR and VO2 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 (K4b2, COSMED) was used with Holter mode to record HR and gas exchange variables, such as VO2, during the experimental session. The flowmeter, O2 and CO2 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 K4b2 facemask and turbine. After completion of the experimental session, gas exchange data were downloaded from the K4b2 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 VO2 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 VO2 during household activities to measured resting VO2. Third, VO2 during household activities was also expressed as a ratio to VO2peak, 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 α = 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.
Results

Resting measurements

Resting VO₂ 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.

<table>
<thead>
<tr>
<th></th>
<th>NO Group</th>
<th>OB Group</th>
<th>( P )-values*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured resting VO₂, mL min⁻¹</td>
<td>184.6 ± 70.5</td>
<td>227.2 ± 75.0</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Measured resting HR, bpm</td>
<td>64 ± 9</td>
<td>75 ± 12</td>
<td>&lt;0.001**</td>
</tr>
<tr>
<td>Measured VO₂peak, mL min⁻¹</td>
<td>1612.6 ± 250.9</td>
<td>1845.2 ± 290.5</td>
<td>&lt;0.01‡</td>
</tr>
<tr>
<td>Predicted VO₂peak R, mL min⁻¹</td>
<td>1837.8 ± 245.0</td>
<td>1770.3 ± 193.4</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Predicted VO₂peak W, mL min⁻¹</td>
<td>1627.8 ± 166.0</td>
<td>1786.2 ± 157.7</td>
<td>&lt;0.01‡</td>
</tr>
<tr>
<td>Measured VO₂peak</td>
<td>0.9 ± 0.1</td>
<td>1.0 ± 0.1</td>
<td>&lt;0.001**</td>
</tr>
<tr>
<td>Predicted VO₂peak R</td>
<td>1.0 ± 0.1</td>
<td>1.0 ± 0.1</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Predicted VO₂peak W</td>
<td>172 ± 13</td>
<td>173 ± 9</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Maximal HR, bpm</td>
<td>123 ± 21</td>
<td>133 ± 22</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Maximal power output, watts</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*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:

\[
\text{Predicted VO}_2\text{peak}_R = (48 – 0.37A) \times \text{PW} + (3.55H/2.54 – 106/2.2),
\]

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 VO₂peak_W = \((22.78 – 0.17A) \times ([\text{PW} + \text{MW}/86]/2)\). Equation from Wasserman et al. (W) for women with obesity: Predicted VO₂peak_W = \((22.78 – 0.17A) \times ([\text{PW} + 43] + [0.65(MW – \text{PW})])\), 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.

Maximal oxygen uptake

\( \dot{V}O_2\text{peak} \) 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 \( \dot{V}O_2\text{peak} /\text{predicted } \dot{V}O_2\text{peak} \) was equal to 1.0 ± 0.1 for the two groups using the Wasserman et al. (9) \( \dot{V}O_2\text{peak} \) prediction equation. With the Riddell et al. (9) equation the ratio \( \dot{V}O_2\text{peak} /\text{predicted } \dot{V}O_2\text{peak} \) 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, clearing 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

<table>
<thead>
<tr>
<th>Household activity</th>
<th>NO group</th>
<th>OB group</th>
<th>P-values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>SD</td>
<td>Average</td>
</tr>
<tr>
<td>IR</td>
<td>Measured VO2</td>
<td>471.3</td>
<td>125.6</td>
</tr>
<tr>
<td></td>
<td>Measured VO2peak</td>
<td>2.9</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>Measured Resting VO2peak</td>
<td>91</td>
<td>11</td>
</tr>
<tr>
<td>CLEAN</td>
<td>Measured VO2</td>
<td>748.5</td>
<td>209.5</td>
</tr>
<tr>
<td></td>
<td>Measured VO2peak</td>
<td>0.5</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Measured Resting VO2peak</td>
<td>91</td>
<td>11</td>
</tr>
<tr>
<td>WCS</td>
<td>Measured VO2</td>
<td>916.4</td>
<td>220.4</td>
</tr>
<tr>
<td></td>
<td>Measured VO2peak</td>
<td>0.6</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>Measured VO2peak</td>
<td>6.2</td>
<td>4.9</td>
</tr>
<tr>
<td></td>
<td>Measured Resting VO2peak</td>
<td>114</td>
<td>12</td>
</tr>
</tbody>
</table>

*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.

VO2 and relative energy expenditure of household activities

VO2 during household activities are reported in Table 3. VO2 was significantly higher in the OB group than in the NO group for the 3 household activities investigated. When expressed as percentage, VO2 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 VO2 or relative to VO2peak. VO2, 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 VO2 during household activities, and expressed this VO2 as a ratio to measured resting VO2 (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 VO2 during the three activities in women with obesity.

We considered that resting VO2 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 O2 kg⁻¹ min⁻¹ or 1 kcal kg⁻¹ h⁻¹ (15). However, measured VO2 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 VO2 to express VO2 during household activities as a ratio instead of using the standard 3.5 mL O2 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 VO2peak, of sedentary healthy women with obesity vs. women with normal weight. Interestingly, our results reported no difference in resting VO2 expressed in absolute term between the two groups, confirming what was observed in Gibson’s study (19).

Our results indicate that measured VO2peak was significantly higher in women with obesity than in non-obese (NO) women. When the CRF is expressed as the ratio of measured VO2peak to predicted VO2peak 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 \( V_{O2peak} \) (26, 27), a similar study including the body distribution components for the normalization of \( V_{O2peak} \) 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 \( V_{O2} \) or \( V_{O2peak} \) 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.

**Acknowledgements**

The authors thank all the participants of this investigation, the nursing staff of the 5rd Cardiology Service (CHWAPI, Tournai) and the caregivers of the Orthonutrition Center for their excellent professional contribution in technical support and assistance.

**References**