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# Physical inactivity, sedentary lifestyle and obesity in the European Union

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**BACKGROUND: Diverging trends of decreasing energy intake and increasing prevalence of obesity suggest that physical inactivity and sedentary lifestyle may be one of the key determinants of the growing rates of overweight/obesity in Western populations. information about the impact of physical inactivity and sedentary lifestyles on the prevalence of obesity among the general adult population in the European Union is sparse.**
**OBJECTIVES: To estimate the association of leisure-time sedentary and non-sedentary activities with body mass index (BMI, kg/m$^2$) and with the prevalence of obesity (BMI $>$ 30 kg/m$^2$) in a sample of the 15 member states of the European Union.**
**METHODS: Professional interviewers administered standardized in-home questionnaires to 15,239 men and women aged 15 years upwards, selected by a multi-stage stratified cluster sampling with quotas applied to ensure national and European representativeness. Energy expenditure during leisure time was calculated based on data on frequency of and amount of time participating in various physical activities, assigning metabolic equivalents (METS) to each activity. Sedentary lifestyle was assessed by means of self-reported hours spent sitting down during leisure time. Multiple linear regression models with BMI as the dependent variable, and logistic regression models with obesity (BMI $>$ 30 kg/m$^2$) as the outcome, were fitted.**
**RESULTS: Independent associations of leisure-time physical activity (inverse) and amount of time spent sitting down (direct) with BMI were found. The adjusted prevalence odds ratio (OR) for obesity was 0.52 [95% confidence interval (CI): 0.43–0.64, *P* $<$ 0.001] for the upper quintile of physical activity ($>$ 30 METS) compared with the most physically inactive quintile ($<$ 1.75 METS). A positive independent association was also evident for the time spent sitting down, with an adjusted OR = 1.61(95% CI: 1.33–1.95, *P* $<$ 0.001) for those who spent more than 35 h of their leisure time sitting down compared with those who spent less than 15 h.**
**Conclusions: Obesity and higher body weight are strongly associated with a sedentary lifestyle and lack of physical activity in the adult population of the European Union. These results, however, need to be interpreted with caution due to the cross-sectional design. Nonetheless, they are consistent with the view that a reduction in energy expenditure during leisure time may be the main determinant of the current epidemic of obesity.**

**Keywords:** obesity; physical activity; survey; exercise; sedentary lifestyle

## Introduction

Obesity is the most prevalent nutrition-related problem in Western societies, and it is associated with an important burden of suffering in terms of mortality,[1,2] morbidity[3–6] and psychological distress.[3] Obesity places a severe burden on health care systems[7] and it is also a condition known to be resistant to intervention. Whereas rates of smoking, mean levels of undesirable lipid profiles, and blood pressure are decreasing in most Western populations, the indices of obesity are increasing.[8–11] All these reasons suggest that obesity could become the leading public health problem in the next century.[12]

The steady increase in the prevalence of obesity over the last two decades in the US,[11,13] the UK[10] and other European countries[14] cannot readily be attributed to genetic factors. Instead, it suggests that behavioural and lifestyle changes in wide sectors of the population are responsible for a sustained imbalance between the total energy intake (food intake) and the energy expenditure through resting metabolism and physical activity.[15] Diverging trends of decreasing energy intake and increasing body weight suggest that reduced physical activity may be the main determinant of the rising prevalence of obesity.[10,16]

Although there is sufficient available evidence from intervention studies supporting the role of physical activity and moderate to vigorous exercise in promoting weight loss,[17] there is little data about the impact of physical inactivity and sedentary lifestyles on the prevalence of obesity among the general adult population. Television viewing has been used in several epidemiological studies as an indicator of sedentary lifestyle. This approach, in a highly selected population of adult male health professionals in the US, has

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been used to elegantly show that the number of hours of television watching is a strong determinant of the risk of becoming overweight.[18,19] Some studies on children and adolescents, mainly performed in the US,[20–22] but also in Europe,[23] have reported important associations between the amount of television viewing and the prevalence of overweight/obesity. Nevertheless, to our knowledge, there has been no previous assessment of the association between physical inactivity or sedentary lifestyle and the prevalence of obesity in the general adult population of the whole European Union.

A pan-European study was carried out to assess this association in representative samples of the 15 member states of the EU.

## Methods

Many of the aspects of the design of this study, including the methods for the selection of participants and for the collection of the information, have been reported elsewhere.[24] These methods were very similar to those of a previous survey ('A pan-EU survey of consumer attitudes to food, nutrition and health') coordinated also by the Institute of European Food Studies (IEFS, Trinity College, Dublin), and these have been already published.[25,26]

Approximately 1000 adults (15 years upward) of each EU member state were selected to participate in the survey. The methods for subject selection were intended to recruit representative samples of each member state. With the exception of Germany ($n=1159$), the UK ($n=1490$) and Luxembourg ($n=518$), the number of participating individuals was very close to 1000 in each country. Multi-stage cluster sampling was used to select the sampling points in each country. In Italy, subjects were selected from each sampling point by random sampling from the electoral register. In all other countries a random route method or random sampling of houses was used at each sampling point to select the subjects, with quotas applied on the samples to ensure national representativeness by various socio-demographic factors based on the most recent official statistics (census data) of each member state. The final total number of participants was 15 239 subjects. The data were weighted to take into account within-country and between-country sampling.

An international expert panel, which included experts in the fields of physical activity/exercise, obesity, nutrition and epidemiology from the 15 European member states, together with market researchers from industry, designed the format, contents and method of administration of a standardized questionnaire on attitudes towards physical activity/exercise, fitness, body weight and health. This expert panel was coordinated by the IEFS. The questionnaire included several closed-ended questions to assess the patterns of sedentary and non-sedentary activities, attitudes and beliefs toward body weight and physical activity, socio-demographic characteristics, as well as self-reported weight and height (questionnaires available from the authors). A translation of the English version of the questionnaire into each relevant European language was verified by the expert panel conducting a pilot survey on 20 subjects in each member state to guarantee that the original meaning was maintained.

Participants were met at their homes and the questionnaires were administered by the in-house face-to-face assisted interview technique with an average duration of 15 min. The field workers who performed the interviews were specifically trained professionals belonging to social research organizations (Taylor-Nelson Ltd and subcontracted organizations in participant states), which were integrated in Eurobus and which conform to the standards of market research set out by ICC/Esomar.[27] Eurobus is an international group of research organizations offering social research in each member state for conducting inter-country surveys. An omnibus approach was used, in which subjects answered questions on different topics from various clients in a single session. The interviews were completed between March and April 1997.

For each participant we calculated the body mass index (BMI) as the weight in kilograms divided by the squared height in meters ($kg/m^2$). Following the criteria of the International Obesity Task Force (Geneva, 3–5 June 1997) sponsored by the World Health Organization,[3] we defined overweight or pre-obesity as a body mass index (BMI) between 25 and $29.99\,kg/m^2$ and obesity as a $BMI > 30\,kg/m^2$. Although obesity can be further subdivided in grade 1, 2 or 3, with cut-off points 35 and 40, in our analysis we merged the three categories of obesity together ($BMI > 30\,kg/m^2$) and considered obesity as a dichotomous variable to represent the overall prevalence of the problem. In addition we performed similar analyses using the BMI as a continuous variable. Participants with a calculated BMI lower than 15 or higher than 50 ($n=26$), and those with implausible or missing values for height, weight or any of the considered variables (see below) were excluded ($n=435$, 2.9% of the sample).

Leisure-time physical activity was appraised by asking the respondents to report the usual participation in the following physical activities, sports or exercises: athletics, cycling, dancing, equestrian sports, fishing, football, gardening, golf, hill-walking, climbing, keep fit, aerobics, jogging, martial arts, racquet sports, rowing, canoeing, skiing, skating, swimming, team sports other than football, walking and water sports. For each activity, participants expressed whether they participated or not and indicated the average amount of time in hours they engaged in each per week.

Work-time physical activity was assessed with the following question: 'Can you describe your typical day's activity (either at work, college, in the office or at home) by telling me the approximate number of hours you spend doing each of the following? (Please do not include your leisure time.) 'Three options were given: (a) sitting down—at work, at home, in a car, etc.; (b) standing or walking around; (c) more physical work than any of the above. Participants were requested to provide an average of the time spent per day for each of these options.

To quantify the volume of activity we computed an activity metabolic equivalent (MET) index by assigning a multiple of resting metabolic rate (MET score) to each activity. Metabolic equivalents thus represent the ratio of energy expended during each specific activity to resting metabolic rate and are independent of body weight.[19] Time spent in each of the activities was multiplied by the MET score specific to each activity, and then summed over all activities obtaining a value of overall weekly MET-hours. The MET scores assigned to specific activities were primarily those recommended in the Paffenbarger questionnaire,[28] although the ratings of other questionnaires[29] and the compendium of physical activities[30] were also taken into account. For simplicity, hereafter the overall weekly MET-hours will be referred to as METS. This measurement represents both the amount and relative intensity of physical exercise during a week for each participant.

We separately computed the overall weekly MET-hours for leisure-time physical activity (hereafter Sport-METS) and for work-time physical activity (Work-METS). Total-METS were calculated by summing Sport-METS and Work-METS. The whole sample was divided in five roughly similar-sized quintiles according to the individual values of Sport-METS and Total-METS (Sport + Work).

Sedentary lifestyle was assessed through the number of hours spent sitting down per week during leisure time. Subjects were asked to indicate the average amount of time they were sitting down with the following question: 'In your leisure time, how many hours on average do you spend sitting down? By that I mean watching TV or videos, playing computer games, reading or listening to music, etc.' Two options were given: (a) on a typical weekday or working day; (b) on a typical weekend day or non-working day. The overall time spent sitting down during a week was computed by multiplying by five the average time on a typical weekday plus twice the average time on a weekend day. The participants were also assigned to quintiles according to the individual values of overall time spent sitting down per week.

The prevalence of overweight (BMI 25–29.99 $kg/m^2$) and obesity (BMI $> 30\,kg/m^2$) was estimated for each quintile of Total-METS, Sport-METS and time spent sitting down per week. Means of BMI with their respective 95% confidence intervals were computed for each quintile of the three variables. A multiple linear regression model for each gender was fitted to assess the independent association of leisure-time physical activity (Sport-METS) and sedentary lifestyle (time spent sitting down per week) with BMI, adjusting for potential confounders (age, educational level, social class, marital status, smoking habits, recent weight loss and country). Heterogeneity of the associations across levels of other factors was assessed by means of product terms. BMI values were log-transformed to improve normality. Subgroup analyses were also run for three European areas: Northern Scandinavian countries (Denmark, Finland and Sweden), Southern-Mediterranean countries (France, Greece, Italy, Portugal and Spain), and Central European countries (the remaining member states—Austria, Belgium, Luxembourg, Netherlands, Germany, Ireland and the UK).

In a second step, multivariate logistic regression models were fitted with obesity (BMI $> 30\,kg/m^2$) as the outcome or dependent variable to obtain adjusted prevalence odds ratios (OR) with their respective 95% confidence intervals (CI) for quintiles of leisure-time physical activity and for time spent sitting down, adjusting for the same potential confounders. Median values of quintiles were used to test (likelihood ratio test) for linear trend and product terms to test for effect modification. For the data of prevalence and means estimates, weighted samples were used, but for the logistic regression modelling we did not weight the data, given that we were mainly interested in identifying associations. Nevertheless, when we fitted the models using weighted data, the results did not appreciably change.

## Results

Tables 1 and 2 show, for men and women respectively, the mean values of BMI and the prevalence of overweight and obesity for each of the quintiles of total physical activity (Total-METS), leisure-time physical activity (Sport-METS), and time spent sitting down. A trend to lower values of BMI the higher the level of total physical activity was apparent for men but not for women. In both men and women this trend was more apparent for leisure-time physical activity (Sport-METS). A similar pattern was observed with regard to the prevalence of overweight and obesity, with the exception of total physical activity among women (regarding obesity). On the other hand, the longer the time spent sitting down, the higher the BMI, the prevalence of overweight and of obesity among both men and women.

As can be seen in Table 3, participants who were more physically active during leisure time (higher quintiles of Sport-METS) were also those who spent less time sitting down, were younger, more likely to have lost weight in the last 6 months, belonged more

**Table 1** Distribution of body mass index (BMI) and prevalence of overweight and obesity among men in the EU according to total physical activity (Total-METS), leisure-time physical activity (Sport-METS), and sedentary lifestyle (time spent sitting down per week)

| *Limits* | *Median* | *n* | *Mean BMI (95% CI)* | *Percentage overweight (BMI 25–29.99)* | *Percentage obesity (BMI > 30)* |
|---|---|---|---|---|---|
| Total-METS(≈quintiles) | | | | | |
| < 123 | 98 | 1426 | 25.3 (25.1–25.5) | 38.9 | 10.0 |
| 123–161 | 142 | 1462 | 25.1 (24.9–25.3) | 36.2 | 11.0 |
| 161.1–199.5 | 180 | 1393 | 24.8 (24.6–25.0) | 33.7 | 8.7 |
| 199.6–260.5 | 255 | 1402 | 24.9 (24.8–25.1) | 39.7 | 7.3 |
| > 260.5 | 326 | 1414 | 24.8 (24.6–25.0) | 35.1 | 7.4 |
| Sport-METS (≈quintiles) | | | | | |
| < 1.75 | 0 | 1798 | 25.5 (25.2–25.7) | 39.0 | 11.9 |
| 1.75–12 | 8 | 1216 | 25.6 (25.3–25.9) | 39.3 | 9.5 |
| 12.25–21 | 18.5 | 1247 | 25.2 (25.0–25.4) | 38.6 | 10.1 |
| 21.25–37.5 | 29 | 1451 | 24.7 (24.5–24.9) | 33.5 | 5.4 |
| > 37.5 | 52 | 1385 | 24.3 (24.1–24.4) | 31.2 | 6.5 |
| Hours sitting down per week(≈quintiles) | | | | | |
| < 15 | 11 | 1659 | 24.8 (24.6–25.0) | 35.3 | 7.6 |
| 15–20 | 18 | 1140 | 24.8 (24.6–25.0) | 36.3 | 7.3 |
| 21–25 | 23 | 1489 | 25.0 (24.8–25.2) | 37.7 | 8.3 |
| 26–35 | 30 | 1615 | 25.1 (25.0–25.3) | 38.4 | 9.0 |
| > 35 | 44 | 1186 | 25.4 (25.2–25.6) | 35.4 | 13.3 |

CI = confidence intervals.

**Table 2** Distribution of body mass index (BMI) and prevalence of overweight and obesity among women in the EU according to total physical activity (Total-METS), leisure-time physical activity (Sport-METS), and sedentary lifestyle (time spent sitting down per week)

| *Limits* | *Median* | *n* | *Mean BMI (95% CI)* | *Percentage overweight (BMI 25–29.99)* | *Percentage obesity (BMI > 30)* |
|---|---|---|---|---|---|
| Total-METS(≈quintiles) | | | | | |
| < 119.75 | 98 | 1594 | 24.2 (24.0–24.4) | 26.7 | 10.8 |
| 119.75–156 | 140 | 1582 | 24.1 (23.9–24.3) | 27.2 | 9.0 |
| 156.5–192.25 | 175 | 1587 | 23.9 (23.7–24.1) | 26.7 | 7.6 |
| 192.3–245 | 214 | 1589 | 24.2 (24.0–24.4) | 23.4 | 11.1 |
| > 245 | 300 | 1585 | 24.3 (24.1–24.6) | 23.7 | 12.7 |
| Sport-METS (≈quintiles) | | | | | |
| < 2 | 0 | 2372 | 24.6 (24.4–24.7) | 28.0 | 12.1 |
| 2–8 | 6 | 1020 | 24.7 (24.4–25.0) | 28.7 | 13.0 |
| 8.25–18.75 | 13 | 1373 | 24.2 (23.9–24.4) | 22.0 | 7.8 |
| 19–30 | 22 | 1642 | 23.9 (23.6–24.1) | 27.1 | 8.3 |
| > 30 | 42 | 1529 | 23.0 (22.8–23.2) | 19.7 | 8.0 |
| Hours sitting down/week (≈quintiles) | | | | | |
| < 15 | 11 | 2171 | 23.8 (23.6–24.0) | 22.9 | 9.2 |
| 15–20 | 18 | 1304 | 23.5 (23.3–23.7) | 24.7 | 6.5 |
| 21–25 | 22 | 1555 | 24.2 (24.0–24.4) | 26.7 | 10.3 |
| 26–35 | 30 | 1706 | 24.4 (24.1–24.6) | 23.8 | 11.8 |
| > 35 | 43 | 1190 | 24.9 (24.7–25.2) | 31.9 | 12.4 |

often to a higher social status and educational level, and were less likely to be smokers or to be married. Conversely those who spent more time sitting down also exercised less in leisure time, were older, more likely to have gained weight in the last 6 months, had lower social and educational achievements, and a greater proportion of them were current smokers.

In order to take into account the unequal distribution of all these variables associated both with obesity and with leisure-time physical activity (Sport-METS) and time spent sitting down (Table 3) we fitted a multiple linear regression model with BMI as the dependent variable. Sport-METS and the time spent sitting down were introduced as continuous independent variables in the model, together with the potential confounders (Table 3). Separate models were fitted for men and women (Table 4). A quadratic term for age was introduced to account for non-linearity. We repeated the analysis using log-transformed BMI. As the results were very similar, we present here the fitted coefficients without transformation for ease of interpretation (Table 4).

The multiple linear regression model showed an independent inverse association between leisure-time physical activity (Sport-METS) and BMI. In contrast, a direct association with the amount of time spent sitting down in leisure time was also statistically significant *independently* of the level of physical activity (Sport-METS) and of the other variables included in the model. A quadratic term was

**Table 3** Distribution of potential confounders across quintiles (Q1–Q5) of leisure-time physical activity (Sport-METS) and time spent sitting down

| | Quintiles of leisure-time physical activity (Sport-METS) | | | | |
|---|---|---|---|---|---|
| | *Q1* | *Q2* | *Q3* | *Q4* | *Q5* |
| | | | *Men* | | |
| Median time sitting down (h) | 26 | 25 | 25 | 24 | 23 |
| Mean age (y) | 45 | 45 | 44 | 40 | 39 |
| Percentage losing weight (last 6 months) | 12 | 14 | 14 | 14 | 15 |
| Percentage high social class | 13 | 19 | 17 | 19 | 22 |
| Percentage university level education | 13 | 19 | 19 | 22 | 23 |
| Percentage current smokers | 49 | 41 | 39 | 34 | 31 |
| Percentage married | 64 | 61 | 61 | 54 | 50 |
| | | | *Women* | | |
| Median time sitting down (h) | 25 | 22 | 23 | 23 | 23 |
| Mean age (y) | 46 | 44 | 41 | 41 | 41 |
| Percentage losing weight (last 6 months) | 17 | 18 | 18 | 20 | 20 |
| Percentage high social class | 12 | 17 | 18 | 16 | 20 |
| Percentage university level education | 11 | 16 | 19 | 18 | 20 |
| Percentage current smokers | 31 | 30 | 30 | 31 | 26 |
| Percentage married | 60 | 61 | 59 | 53 | 54 |
| | *Quintiles of hours/week sitting down in leisure-time* | | | | |
| | *Q1* | *Q2* | *Q3* | *Q4* | *Q5* |
| | | | *Men* | | |
| Median of Sport-METS | 22 | 25 | 23 | 22 | 18 |
| Mean age (y) | 41 | 38 | 43 | 44 | 46 |
| Percentage gaining weight (last 6 months) | 18 | 18 | 21 | 20 | 20 |
| Percentage high social class | 22 | 20 | 15 | 14 | 18 |
| Percentage university level education | 20 | 22 | 17 | 16 | 20 |
| Percentage current smokers | 34 | 37 | 41 | 41 | 42 |
| Percentage married | 58 | 50 | 60 | 57 | 55 |
| | | | *Women* | | |
| Median of Sport-METS | 16 | 19 | 19 | 17 | 15 |
| Mean age (y) | 41 | 39 | 43 | 46 | 45 |
| Percentage gaining weight (last 6 months) | 25 | 28 | 24 | 24 | 28 |
| Percentage high social class | 20 | 16 | 16 | 14 | 14 |
| Percentage university level education | 19 | 18 | 17 | 13 | 14 |
| Percentage current smokers | 26 | 28 | 31 | 32 | 34 |
| Percentage married | 64 | 60 | 58 | 54 | 47 |

significant for age, describing an inverted U-shaped relationship between age and the prevalence of obesity. Independent associations with smoking status, educational levels and marital status were present for both men and women, whereas the association with social class was apparent only among women. Both people losing weight and gaining weight in the last 6 months had higher values of BMI than those who stayed the same weight, adjusting for all other factors included in the model.

Each 10-MET increase in the leisure-time physical activity (equivalent to 2.5 h walking, or 50 min of competition running) was associated with having a lower BMI ($-0.074\,kg/m^2$) among men (equivalent to 225 g for a typical man 175 cm tall) and $-0.097\,kg/m^2$ among women (equivalent to 265 g for a typical woman 165 cm tall). Each 10 h per week increase in the time spent sitting down during leisure time was associated with a BMI $0.086\,kg/m^2$ higher among men, and $0.24\,kg/m^2$ higher among women. This is equivalent to +260 g for a typical man and +650 g for a typical woman.

Although the magnitude of these differences might be thought of as small, when the coefficients were applied to the values of the median for the two extreme quintiles of Sport-3 METS, the model predicted a difference of 1.2 kg for a typical man and 1.1 kg for a typical woman. When the median of extreme quintiles of time spent sitting down were compared using the same procedure, the predicted adjusted differences were 0.87 kg among men and 2.0 kg among women. These differences were in general in a greater range than the adjusted observed differences for most of the variables in the model, with the exception of age, and having gained weight in the last 6 months. There was no statistical evidence of a modification of the association between leisure-time physical activity (Sport-METS) and BMI by the time spent sitting down ($P=0.37$ and $P=0.57$ for the product term for men and women, respectively). Other regression approaches (introducing quadratic terms or polynomic splines) did not appreciably change the estimates nor the linear shape of the association.

In order to assess the association of leisure-time activity levels with the prevalence of obesity in the EU, a multivariable logistic regression model (Table 5) was fitted with obesity ($BMI > 30\,kg/m^2$ as the outcome.

**Table 4** Variables associated with BMI among men and women. Multiple linear regression model with BMI as the dependent variable

| | Men Coefficients | (standard error) | P | Women Coefficients | (standard error) | P |
|---|---|---|---|---|---|---|
| Constant | 18.00 | (0.32) | < 0.001 | 15.81 | (0.38) | < 0.001 |
| Sport-METS | − 0.0074 | (0.0019) | 0.001 | − 0.0097 | (0.0027) | < 0.001 |
| Hours sitting down per week | 0.0086 | (0.0031) | 0.006 | 0.024 | (0.0036) | < 0.001 |
| Age (y) | 0.24 | (0.014) | < 0.001 | 0.24 | (0.017) | < 0.001 |
| Age$^2$ (y$^2$) | − 0.0022 | (0.00015) | < 0.001 | − 0.0019 | (0.00018) | < 0.001 |
| Smoking | | | | | | |
| never smokers | 0 (ref.) | | | 0 (ref.) | | |
| current smokers | − 0.52 | (0.086) | < 0.001 | − 0.83 | (0.11) | < 0.001 |
| former smokers ( < 1 y) | 0.12 | (0.24) | 0.62 | − 1.13 | (0.33) | < 0.001 |
| former smokers ( ≥ 1 y) | 0.35 | (0.12) | 0.005 | − 0.067 | (0.18) | 0.70 |
| Education level | | | | | | |
| university | 0 (ref.) | | | 0 (ref.) | | |
| secondary | 0.50 | (0.10) | < 0.001 | 0.65 | (0.13) | < 0.001 |
| primary | 0.87 | (0.12) | < 0.001 | 1.65 | (0.16) | < 0.001 |
| Social class | | | | | | |
| high | 0 (ref.) | | | 0 (ref.) | | |
| mid–high | − 0.16 | (0.11) | 0.14 | 0.16 | (0.13) | 0.23 |
| mid–low | − 0.06 | (0.11) | 0.59 | 0.72 | (0.13) | < 0.001 |
| low | 0.14 | (0.14) | 0.32 | 0.96 | (0.16) | < 0.001 |
| Marital status | | | | | | |
| single | 0 (ref.) | | | 0 (ref.) | | |
| married/cohabiting | 0.60 | (0.09) | < 0.001 | 0.30 | (0.12) | 0.01 |
| widowed/divorced/separated | − 0.11 | (0.17) | 0.50 | − 0.36 | (0.16) | 0.02 |
| Weight change (last 6 months) | | | | | | |
| stayed the same | 0 (ref.) | | | 0 (ref.) | | |
| lost weight | 0.95 | (0.12) | < 0.001 | 1.02 | (0.12) | < 0.001 |
| gained weight | 1.81 | (0.10) | < 0.001 | 1.61 | (0.11) | < 0.001 |

The logistic regression analyses showed that participants whose energy expenditure in leisure time (Sport-METS) was higher than 30 METS/week (upper quintile) had a 57% lower chance of being obese compared with those in the lower quintile. The adjustment for hours/week spent sitting down during leisure time had little impact on the estimates of the OR. Further adjustment for age, sex and other sociodemographic and behavioural characteristics only slightly attenuated the magnitude of the association. In the fully multivariate adjusted model the predicted chance of obesity was almost half for those more physically active compared with the most physically inactive. Moreover, every higher quintile of Sport-METS was associated with a lower odds of being obese, with the exception of the comparison between the second and third quintile.

Conversely, a positive association with obesity prevalence was evident for the time spent sitting down, with a crude odds of obesity 68% higher for those who spent more than 35 h of their leisure time sitting down compared with those who spent less than

**Table 5** Association of leisure-time physical activity (quintiles of Sport-METS) and time spent sitting down (quintiles of hours sitting down per week) with the prevalence of obesity among men and women (considered together) in the EU ($n = 15{,}239$). Multiple logistic regression model with obesity (BMI > 30 kg/m$^2$) as the dependent variable

| | Prevalence odds ratios (95% confidence intervals) Leisure-time physical activity (Sport-METS) | | | | |
|---|---|---|---|---|---|
| *Quintiles (Limits of quintiles)* | *Q1 ( < 1.75)* | *Q2 (1.75–8.00)* | *Q3 (8.25–18.75)* | *Q4 (19.00–30.00)* | *Q5 ( > 30.00)* |
| Crude OR | 1 (ref.) | 0.85 (0.72–1.01) | 0.79 (0.68–0.92) | 0.59 (0.50–0.70) | 0.43 (0.36–0.51) |
| Adjusted for time sitting down | 1 (ref.) | 0.87 (0.73–1.04) | 0.82 (0.70–0.95) | 0.61 (0.52–0.72) | 0.44 (0.37–0.53) |
| Age, sex and time sitting down adjusted | 1 (ref.) | 0.89 (0.74–1.05) | 0.86 (0.74–1.00) | 0.68 (0.58–0.81) | 0.55 (0.45–0.66) |
| Multivariate adjusted[a] | 1 (ref.) | 0.81 (0.67–0.99) | 0.85 (0.72–1.01) | 0.69 (0.57–0.82) | 0.52 (0.43–0.64) |
| | *Leisure time spent sitting down (hours/week)* | | | | |
| *Quintiles (Limits of quintiles)* | *Q1 ( < 15)* | *Q2 (15–20)* | *Q3 (21–25)* | *Q4 (26–35)* | *Q5 ( > 35)* |
| Crude OR | 1 (ref.) | 1.12 (0.94–1.34) | 1.11 (0.91–1.34) | 1.39 (1.17–1.65) | 1.68 (1.41–1.99) |
| Adjusted for Sport METS | 1 (ref.) | 1.15 (0.96–1.37 | 1.13 (0.93–1.37) | 1.38 (1.17–1.64 | 1.60 (1.35–1.90) |
| Age, sex and Sport METS adjusted | 1 (ref.) | 1.14 (0.96–1.36) | 1.15 (0.95–1.40) | 1.34 (1.13–1.60) | 1.60 (1.34–1.92) |
| Multivariate adjusted[b] | 1 (ref.) | 1.13 (0.93–1.36) | 1.15 (0.94–1.20) | 1.40 (1.16–1.69) | 1.61 (1.33–1.95) |

[a]Hours sitting down, age, sex education, recent weight change, social class, marital status, country and smoking.
[b] Sport-METS, age, sex, education, recent weight change, social class, marital status, country and smoking.

15 h. Odds ratios (OR) for each quintile changed little when we adjusted for leisure-time physical activity (Sport-METS), gender, age and other covariables. A clear monotonic trend from each quintile to the next was apparent in the fully adjusted model.

For both leisure-time physical activity (Sport-METS) and time spent sitting down the test for linear trend was highly significant ($P < 0.001$) in the multivariate adjusted models. The interaction product term to assess heterogeneity between men and women was not significant ($P = 0.46$ and 0.49, respectively), and also when we fitted separated models for men and women the results were very similar. In the fully adjusted models, the OR for the four upper quintiles of leisure-time physical activity (Sport-METS) were 0.81, 0.79, 0.65 and 0.56 for men, and 0.81, 0.91, 0.73 and 0.45 for women; and for time spent sitting down, they were 1.19, 1.14, 1.36 and 1.51 for men, and 1.07, 1.14, 1.42 and 1.68 for women. The linear trend test was highly significant ($P < 0.01$) for all these associations (results not shown).

When we excluded individuals with overweight (BMI 25−29.99 kg/m$^2$) the associations were stronger (OR = 0.47 for the highest quintile of Sport-METS, and OR = 1.70 for the highest quintile of time spent sitting down). We also fitted separated models for men and women with 25 kg/m$^2$ as the cut-off point for BMI, that is considering together obesity and overweight as the dependent variable. The results were similar, albeit the strength of the associations was attenuated (OR = 0.74 and 0.70, $P < 0.001$, for the fifth quintile of leisure-time physical activity, among men and women, respectively), and eventually disappeared for time spent sitting down among men (OR = 1.01, $P = 0.91$), although it remained highly significant among women (OR = 1.49, $P < 0.001$).

When we fitted separated models with obesity as the outcome for the three defined European regions, the associations remained fairly consistent across regions. For the extreme quintiles of Sport-METS the ORs were 0.54 in Northern Scandinavian countries, 0.55 in Central Europe, and 0.50 in Southern Mediterranean countries. For time spent sitting down, the OR for the upper quintile was 1.82 in Scandinavian countries, 1.59 in Central Europe and 1.58 in the Mediterranean region. The linear trend tests were also highly significant in all these subgroups.

When we excluded some groups of individuals (those with higher values of BMI, higher than 40, higher than 38, higher than 35; or with lower values of BMI, lower than 20) or restricted the analysis to several subgroups (older or younger individuals, those with less than university educational level, never smokers, married individuals) the results did not substantially change (range of point estimates of the OR for the upper quintile of Sport-METS, 0.52−0.60; range of estimates of the OR for the upper quintile of hours spent sitting down 1.49−1.89).

Although no statistically significant interaction between leisure-time physical activity (Sport-METS) and obesity was observed across the levels of time spent sitting down, we described the joint association with obesity of both non-sedentary and sedentary activities during leisure time. Each participant was assigned to one of 25 possible categories made with the cross-classification of quintiles of Sport-METS and quintiles of hours per week spent sitting down. This classification is presented graphically in Figure 1. The multivariate-adjusted odds ratios for each of the categories were estimated by a logistic regression model, with the most active subjects as the reference (those in the upper quintile of leisure-time physical activity and in the lowest quintile of time spent sitting down). Those who were more sedentary in leisure time (two lower quintiles of physical activity and two upper quintiles of hours per week spent sitting down) had on average three to four times higher odds of being obese (OR = 2.5, 4.2, 3.9 and 3.8). A trend towards higher ORs the longer the time spent sitting down can be seen in Figure 1 within each Sport-METS category, with the exception of those who were more physically active (fifth quintile of Sport METS), and a tendency to lower ORs with higher energy expenditure is also seen within each category of time spent sitting down.

## Discussion

This pan-EU survey found a strong, independent and consistent inverse association between non-sedentary activity levels in leisure time and the prevalence of obesity in a representative sample of the 15 member states. Exercise levels were measured as energy expenditure in non-sedentary activities (METS). An indicator of sedentary lifestyle (hours spent sitting down per week) was also found to be positively correlated with obesity. These associations were present both for obesity (BMI > 30 kg/m$^2$) and linearly for BMI. The high prevalence of overweight/obesity affecting almost half of the EU adult population[31] underlines the importance of these findings.

Although we did not conduct a previous formal validation study for some of the items in the questionnaire, our methods can be considered externally validated for their consistence with the results of previous reports which studied different populations.[10,16,18,19,31−37] Many of the referenced studies assessed US populations, but some of them also included particular European countries.[10,36,37]

Individuals were contacted at their homes by interviewers who were professionals with specific training, to ensure good quality in the gathering of information. Nevertheless, BMI values were not directly measured, but they were calculated from self-reported data, which may tend to misclassify the participants.[38] Information on the amount of time and frequency of participation in leisure-time physical activities was

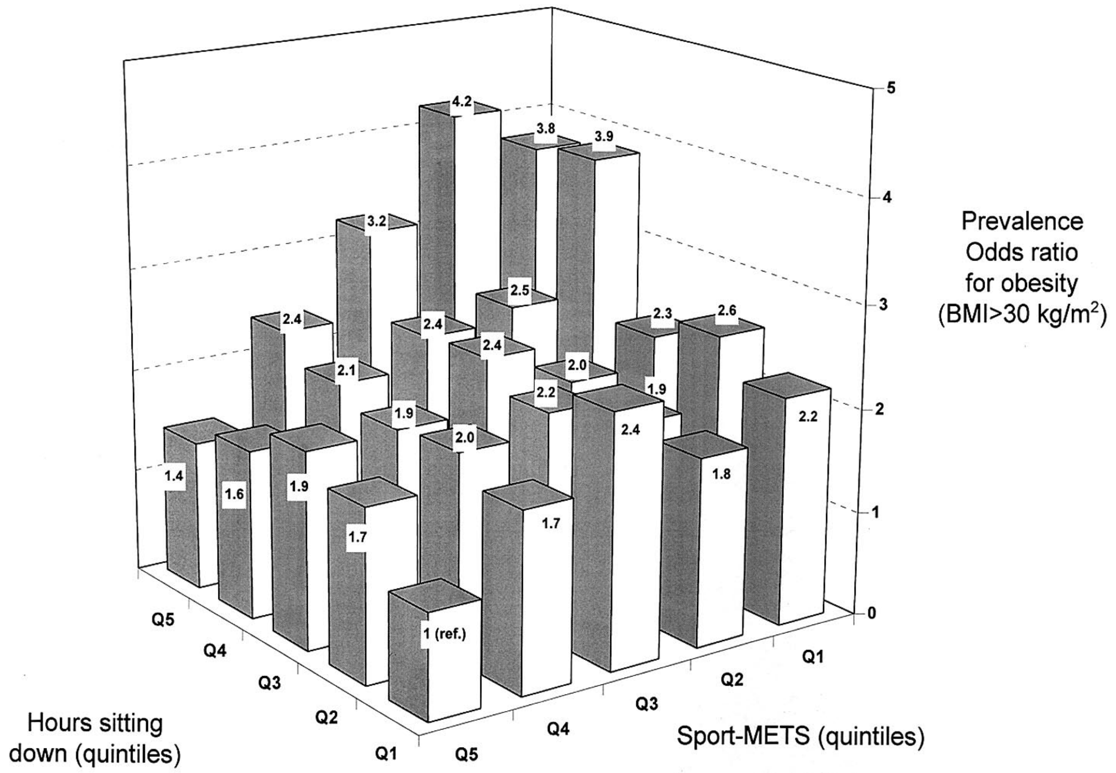


**Figure 1** Joint classification of the sample according to quintiles of hours spent sitting during leisure time. (h/week: Q1 < 15, Q2 = 15–20, Q3 = 21–25, Q4 = 26–35, Q5 > 35) in the left axis, and leisure-time physical activity (Sport-METS: Q1 < 1.75, Q2 = 1.75–8.00, Q3 = 8.25–18.75, Q4 = 19.00–30.00, Q5 > 30.00) on the right axis. For each combination of time sitting down and Sport-METS the adjusted prevalence odds ratio for obesity (BMI > 30 kg/m$^2$) is presented with reference to the category with the highest energy expenditure (Sport-METS Q5 > 30) and shortest time spent sitting down (Q1 < 15 h/week).

collected from participants, but information on the intensity of practising each specific activity was not collected. Instead, an average of relative energy expenditure was assigned to each specific activity. Consequently, some degree of misclassification may exist in both variables (physical activity and BMI). If this misclassification bias is taken into account, our results are probably a conservative estimate of the true inverse association between leisure-time activity and obesity. If no misclassification occurred, the association would probably be stronger.

Low physical activity may be both a cause and a consequence of weight gain. The cross-sectional approach of the study does not allow us to distinguish between causes and consequences. Even in a longitudinal prospective study some sources of intractable confounding can lead to a biased association between obesity and physical inactivity, because, for example, general health consciousness is associated with both an attitude of awareness and watching over one's own weight and a favourable attitude toward physical activity and exercise.[6] Only randomized trials could give the right causal answer, but, in addition to important ethical issues, usually they are not feasible to conduct at a population level on representative samples. In a previous report[31] we found that a passive attitude toward starting physical activity, i.e. precontemplation stage of change according to the Prochaska model[39] was strongly associated with a higher prevalence of obesity. Nevertheless, when we further adjusted our results for this variable, they did not substantially change.

Taking into account the growing prevalence of overweight and obesity in Europe[8–10,16,31,40–43] and the decreasing trends in energy intake,[6,8] our findings are consistent with the view that physical activity either reduces body weight or help to maintain it, and with the explanation that a reduction in energy expenditure must be the main determinant of the current epidemic of obesity.[6,44,45] Among men, even a small move away from a sedentary lifestyle (from quintile 5th to 4th) was associated with substantially lower prevalence of obesity (Table 1). This finding is consistent with the view that even a modest level of activity may confer health benefits.[46,47]

Even with the unlikely interpretation that all the association was due to reverse causality (physical inactivity as a consequence of obesity), the clustering of both risk factors (sedentary lifestyle and overweight/obesity) in the EU that our data shows provides evidence for concern. Both overweight[1] and sedentary activity during leisure time[48] are likely to be causally related to higher risk of total mortality, and represent a very serious burden of suffering and premature death.

The major strengths of this study are its comprehensiveness and representativeness of the European adult population and the assessment of physical activity through a quantitative measure that allows a better classification of subjects than other simpler approaches, together with an assessment of sedentary lifestyle, which is not restricted to time devoted to watching television or video-cassettes but considers all the leisure time spent sitting down.

The direction of the association was similar, although its strength was attenuated, when we used total energy expenditure (leisure time plus work time) to fit the regression model, instead of leisure-time physical activity (Sport-METS) as the independent variable (data not shown). When we used only work-time energy expenditure the association disappeared. This fact could be explained by a greater misclassification bias regarding work-time physical activity, and also by a greater heterogeneity in exposure to leisure-time physical activity. The degree of between-subjects variability in the exposure to a particular factor in the population under study is a strong determinant of the ability that a study possesses to detect an association between that exposure and the outcome of interest, and, in fact the coefficient of variation was 2.4 times higher in our sample for Sport-METS than for Work-METS. Consequently, it can be inferred that, within an homogenous social environment, requiring very limited energy expenditure to earn a living and obtain food and water, as well as for transportation and other aspects of ordinary life,[44] those individuals who in addition are less active during leisure time are exposed to a high risk of developing obesity. Leisure-time physical activity, which exhibited a greater between-subject variability, can be what makes the difference. However, caution must be taken regarding causal inferences from a cross-sectional survey, as we have already indicated above.

The epidemic of obesity is growing at a fast pace in Europe. The American experience and alarming data from the UK[10] provide no grounds for optimism. Obesity being refractory to treatment, prevention becomes essential. A population strategy to prevent overweight/obesity is urgently needed in Europe. Our findings provide support for approaching the prevention of overweight/obesity in the European Union through promoting increased leisure-time physical activity, which appears also to be the most effective physiologic alternative.[6]

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