Indicators of abdominal adiposity in middle-aged participants of the SU.VI.MAX study: relationships with educational level, smoking status and physical inactivity

S Czernichow¹, ², S Bertrais¹, P Preziosi¹, P Galan¹, S Hercberg¹, JM Oppert²

SUMMARY

Objectives: Abdominal fat accumulation is a risk factor for type 2 diabetes and cardiovascular disease. Identifying the demographic and lifestyle correlates of abdominal adiposity is an important step to target at-risk populations in prevention programs. There are few data of this kind in France.

Methods: Anthropometric indicators of overall (body mass index, BMI) and abdominal (waist hip ratio, WHR; waist circumference, WC) adiposity, educational level, smoking status, and physical activity were assessed in 6,705 middle-aged men and women participating in the SU.VI.MAX study.

Results: The likelihood of being obese was increased more than twice in physically inactive subjects of both genders after adjustment for age, smoking status and educational level (OR = 2.22, CI95%: 1.74-2.83 in men; OR = 2.38, CI95%: 1.84-3.09 in women). Having a high WHR (≥ 0.95 in men, ≥ 0.80 in women) was more likely in subjects ≥ 50 y, in current smokers, and less likely in men with higher education. The likelihood of having a high WHR was also increased in physically inactive subjects of both genders after adjustment for age, BMI, smoking status and educational level (OR = 1.46, CI95%: 1.22-1.74 in women). Having a high WC (≥ 102 cm in men, ≥ 88 cm in women) was positively associated with age and also with physical inactivity (OR = 1.63, CI95%: 1.20-2.22 in women).

Conclusions: These cross-sectional data suggest significant positive associations of physical inactivity with both the WHR and WC, independently of overall adiposity as assessed by the BMI.

Key-words: Epidemiology - Physical activity - Obesity - Body fat distribution - Waist circumference - Waist-to-hip ratio.

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RÉSUMÉ

Indicateurs de l’adiposité abdominale chez des participants de l’étude SU.VI.MAX d’âge moyen : relation avec le niveau d’éducation, le tabagisme et l’inactivité physique

Objectif : L’accumulation de graisse abdominale est un facteur de risque de diabète de type 2 et de pathologies cardiovasculaires. L’identification des facteurs socio-démographiques et environnementaux associés à l’adiposité abdominale est une étape importante pour le dépistage des populations à risque dans les programmes de prévention. Peu de données de ce type sont disponibles en France.

Méthodes : Des données anthropométriques d’adiposité globale (indice de masse corporelle, IMC) et abdominale (rapport taille sur hanche, RTH ; tour de taille, TT), de niveau d’éducation, de statut tabagique et d’activité physique ont été recueillis chez 6 705 hommes et femmes d’âge moyen de l’étude SU.VI.MAX.

Résultats : Le risque d’obésité était deux fois plus élevé chez les sujets inactifs, après ajustement sur l’âge, le statut tabagique et le niveau d’études (OR = 2.22, IC95 % : 1.74-2.83 chez les hommes ; OR = 2.38, IC95 % : 1.84-3.09 chez les femmes). Un RTH élevé (≥ 0,95 chez les hommes, ≥ 0,80 chez les femmes) était plus fréquent chez les sujets de plus de 50 ans, fumeurs, et les hommes de niveau d’éducation primaire. Le risque de RTH élevé était également augmenté chez les sujets inactifs, après ajustement sur l’âge, l’IMC, le statut tabagique et le niveau d’éducation (OR = 1,33, IC95 % : 1,10-1,60 chez les hommes ; OR = 1,46, IC95 % : 1,22-1,74 chez les femmes). Un TT élevé (≥ 102 cm chez les hommes, ≥ 88 cm chez les femmes) était positivement associé à l’âge et l’inactivité physique (OR = 1,63, IC95 % : 1,20-2,22 chez les femmes).

Conclusions : Ces données transversales suggèrent une association significative positive de l’inactivité physique avec le RTH et le TT, indépendante de l’adiposité globale, mesurée par l’IMC.

The worldwide rise in the prevalence of obesity constitutes a serious threat to the health of increasing fractions of the population [1]. Based on the conclusions of a WHO expert consultation [1], obesity is defined in adults of both genders by a body mass index (BMI = weight/height²) over 30 kg/m². Independently of the overall level of adiposity or corpulence, as assessed by the BMI, abdominal fat accumulation is recognised as a potent risk factor for type 2 diabetes and cardiovascular diseases [1].

Various indicators of abdominal fat accumulation have been described during the last 25 years or so [2]. Following the work of Swedish investigators in Göteborg [3, 4], the waist-hip circumference ratio (WHR) is the best known of these indicators. More recently, because of its simplicity and also its correlation with visceral fat, the measurement of waist girth alone (waist circumference, WC) was put forward as a valuable clinical tool to screen subjects at risk for metabolic and cardiovascular diseases [5-8]. Consensus conferences on the diagnosis and management of obesity [1, 9] and the metabolic syndrome [10] have defined WC cut-offs for increased risk as ≥102 cm in men and ≥88 cm in women. No such consensus exists for WHR thresholds [2]. Whereas more and more obesity prevalence data are collected in all regions of the world, there is less information on the current status regarding abdominal fat accumulation in large samples of adults, especially in France [11-16].

Identifying the demographic and lifestyle factors associated with abdominal fat accumulation is an important step in understanding the determinants of this condition and may help to target at-risk populations in preventive programs. Using the WHR as indicator of abdominal fat accumulation, associations with age, gender, and smoking status are well documented [17-20]. A more limited number of studies have investigated these relationships using WC [20, 21]. An inactive lifestyle is now considered as a major factor in body weight gain over time [1, 22]. Many cross-sectional studies reported negative relationships between BMI, or obesity prevalence, and self-reported physical activity [1, 22]. However, there are few recent data about the associations of indicators of abdominal adiposity with habitual physical activity/inactivity levels in adults [18, 23, 24], especially in France [25]. Therefore, the aim of the present work was to investigate the relationships of abdominal fat accumulation, as assessed by both the WHR and WC, with educational level, smoking and physical inactivity in middle-aged French subjects participating in the SU.VI.MAX study.

**Subject and methods**

**Study population**

Subjects were participants of the SU.VI.MAX. (“SUpplémentation en VItamines et Minéraux Anti-oXydants”) study, a randomised double-blind placebo-controlled primary-prevention trial designed to evaluate the impact of a daily antioxidant supplementation at nutritional doses on the incidence of cancers and ischemic heart disease [26]. Another objective of the study is to contribute to a better understanding of the relationships between nutrition and health, by constituting a database on indicators of nutritional status and health events in a large French sample of adults. In total 12,735 subjects (men 45-60 y, women 35-60 y), from all over France, were included in 1994-1995 with a planned follow-up of 8 y. All subjects gave their informed written consent to the study which was approved by ethical committees, i.e. the “Comité consultatif de Protection des Personnes dans la Recherche biomédicale” (CCPPRB n° 706 Paris-Cochin Hospital, France) and the “Commission Nationale de l’Informatique et des Libertés” (CNIL n° 334641). Details on recruitment, study design, and baseline characteristics of the subjects have been previously reported [26]. Participants undergo a clinical examination every two years (from 1996 onward) with anthropometric measurements. For the present study only those subjects with available anthropometric data in 1996 were included. In order to have a similar age range in both sexes, the sample was further restricted to subjects aged 45 y or more in 1996. Analyses in the present report were thus based on data from 3,483 men and 3,222 women.

**Body weight, height, waist and hip measurements**

Weight was measured with an electronic scale (Seca®, Germany) with subjects in indoor clothing and no shoes. Height was measured in the same conditions to the nearest 0.5 cm with a wall-mounted stadiometer. BMI was calculated as weight divided by height squared (kg/m²). Obesity was defined as a BMI ≥ 30 kg/m² [1]. WC was measured as the circumference midway between lower ribs and iliac crests, and hip circumference was measured as the largest circumference between waist and thighs, both in standing position [1]. Cut-offs for an increased WHR were ≥ 0.95 in men and ≥ 0.80 in women, and for an increased WC ≥ 102 cm in men and ≥ 88 cm in women [7].

**Assessment of physical activity, smoking status and educational level variables**

Level of education, as an indicator of socio-economic status, was obtained from a questionnaire at baseline and was coded in three categories according to the highest certification obtained (primary school, high school, university or equivalent). Data on smoking status (current smokers, previous smokers, non smokers) were collected through the same questionnaire. The overall level of habitual physical activity was assessed using the following question: “Do you have a regular physical activity (transportation, work, leisure): yes/no?” , and was coded in two categories: regular activity or inactivity.
Statistical analyses

Analyses were performed separately by sex. Multivariate logistic regression analyses were used to determine the odds ratios (OR) for being obese and for having an increased WHR or WC, according to educational level, smoking status and physical inactivity. ORs for having an increased WHR or WC were adjusted for BMI, in addition to other factors. Multivariate-adjusted ORs are reported with 95% confidence intervals. Data were compiled on an Alpha-VMS system and all statistical analyses were performed using SAS software (SAS Institute, Cary, NC).

Results

The unadjusted overall prevalence of obesity was 8.7% and 8.3%, in men and women respectively. The likelihood of being obese increased with age in women and decreased with educational level in both genders (Tab I). In men, former smokers were more likely to be obese than never smokers. Physical inactivity was strongly associated with obesity in both men and women. The unadjusted overall prevalence of increased WHR was 33.3% and 34.0%, in men and women respectively. In both genders, the likelihood of having a high WHR increased with age, current smoking, and physical inactivity (Tab II). Educational level was inversely associated with increased WHR in men. The unadjusted overall prevalence of increased WC was 13.6% and 15.4%, in men and women respectively. The likelihood of having a high WC increased with age in both genders and with physical inactivity in women (Tab III). Odds-ratios (95% CI) for having a high WHR when physically inactive with adjustment on age, smoking status and educational level, but not BMI, were 1.81 (1.55-2.13) in men and 1.79 (1.53-2.10) in women. For WC, these ORs were 2.13 (1.74-2.62) in men and 2.28 (1.86-2.78) in women.

Discussion

In this study, we investigated the relationships of indicators of abdominal obesity with educational level, smoking status, and physical inactivity in middle-aged participants of the SU.VI.MAX study. We found that several of these associations differed when considering WHR or WC. However, physical inactivity had a significant negative effect on the likelihood of having either an increased WHR or an increased WC, independently of age, BMI, smoking status and educational level.

The overall prevalence of obesity in the present study appears lower than that found in the OBEPI study [13, 14] a survey on obesity performed repeatedly in large representative samples of about 20,000 French households. In that study, in men and women in the age range of 45-54 y, the prevalence of obesity in 1997, assessed by self-reported weight and height, was 11.4% and 10.0% respectively [13]. Over 55 y of age, the obesity prevalence was 14.8% and 11.5% in men and women respectively, whereas in our study it ranged between 9-11%. Our figures seem more comparable.
to data from the professional GAZEL cohort where the prevalence of obesity, also assessed with self-reported data, was 10.8% and 7.0%, in men over 45 y and women over 40 y respectively [27]. In women (50-64 y) from the French cohort of the EPIC study, the prevalence of obesity based on measured data, ranged from 5.0 to 7.6% [15]. The prevalence of

### Table II

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a Odds-ratios [95% confidence interval]; b adjusted for age and BMI; c adjusted for age, BMI, smoking status and educational level.

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a Odds-ratios [95% confidence interval]; b adjusted for age and BMI; c adjusted for age, BMI, smoking status and educational level.
increased WHR and WC in these same women, was 35.1% and 12.7%, which is comparable to our data in that gender. In the DESIR study, the prevalence of a high WC (≥ 102/88 cm) ranged from 6.5 to 20.4% in men, and from 11.2 to 24.2% in women, which is in close to our data [16]. A comparison of our results for WHR and WC with the data of the OBEPI study is more difficult because of differences in the cut-offs used. For a WHR ≥ 1 in men and ≥ 0.85 in women, the prevalence was 15.0% and 24.5% respectively. For a waist circumference ≥ 100 cm in men and ≥ 90 cm in women, the prevalence was 27.3% and 19.4% respectively [28].

One strength of the present study is that weight, height, and circumferences were all measured data in a relatively large sample of adults. It has been shown that self-reported vs. measured weight and height may lead to misclassification for body weight status [27]. On the other hand, a concern is that our subjects were enrolled in a nutritional intervention study. Although a previous report on baseline characteristics of the participants of the SU.VI.MAX study showed that the study sample was close to the national population with regard to geographic density and socio-economic status [26], these subjects may have a healthier lifestyle. This may explain why the prevalence of obesity was lower than in the OBEPI study [13], conducted in a representative sample from the general population.

In this study, as in many previous reports, obesity was positively associated with age and physical inactivity in both genders, and with former smoking (in men) [1, 22, 29]. Former male smokers were more likely to be obese than non smokers. Prospective studies have shown that smoking cessation was related to the risk of overweight or obesity [30]. Moreover, obesity was negatively associated with educational level in both genders [18, 19, 31], suggesting a strong influence of socio-economic status on body weight control. Noticeably, the likelihood of being obese was 2 to 2.5 higher in inactive men and women compared to active subjects. This relationship was the strongest observed in our study and was found after taking into account age, smoking status and educational level.

An important finding in this study is that there was a difference in the relationships of educational level, smoking and physical activity with WHR and with WC. Except for smoking, the pattern of associations with an increased WHR was similar to the one observed for obesity. As in most studies, age was positively associated with an increased WHR in both genders [17, 19, 20]. Whereas former smoking was associated with obesity, the likelihood of an increased WHR was higher in current smokers as compared to non smokers, in agreement with other reports [18]. We also found that a higher educational attainment was associated with a lower WHR (in men), as previously shown in different settings [18, 19]. According to Bjorntorp, adverse socio-economic conditions coupled with psychosocial stress may lead to increased WHR through chronic activation of the hypothalamo-pituitary-adrenocortical axis [32]. In middle-aged men, it was shown that a low socio-economic status was associated with a perturbed cortisol secretion [32], possibly due to frequent exposure to perceived chronic stress.

The likelihood for both increased WHR and increased WC was higher in inactive compared to regularly active subjects. Odds-ratios were about 1.8 for high WHR and 2.3 for high WC in the multivariate analyses where BMI was not controlled for. Taking into account BMI reduced these same ORs to about 1.5, a marked reduction for the likelihood for an increased WC. This may be due in part to the stronger correlation found between BMI and WC, compared to BMI and WHR (data not shown). Fully adjusted-ORs in our study are in agreement with recent data reported by Han et al. in Dutch adults, using the same cut-offs for increased WHR and WC [20]. In that study, adjusted odds-ratios for increased WC were close to ours, respectively 1.47 (1.30-1.66) and 1.72 (1.48-2.00) in inactive women and men compared to their active counterparts [20]. A limitation to such findings, including ours, is that physical activity was assessed by a single question classifying subjects into the broad categories of “inactive” and “active”. This allows to emphasise the potentially deleterious effects of inactivity. However, a more detailed assessment of the various dimensions and levels of physical activity and inactivity would be needed for a better understanding of the relationship between physical activity and abdominal adiposity. There is some evidence that WHR and WC are related negatively with leisure-time (or sports) activity and positively [33] or non significantly [18] with occupational (work) activity. Interestingly, a recent report from the franco-irish PRIME study showed that daily living activities such as walking or cycling to work were inversely associated with WC in middle-aged men [24].

In this study, except for age and physical inactivity (in women), no other factor was significantly associated with an increased WC. It is likely that the cut-offs chosen to define a high WC influence such results. Moreover, these thresholds might be population-specific. For WC, the cut-offs we used were those proposed in 1995 by Lean et al. (≥ 102 cm in men and ≥ 88 cm in women) [7]. These cut-offs have now been endorsed by consensus conferences on obesity and the metabolic syndrome [9, 10]. They were initially defined on their relationship with WHR (data not shown). Fully adjusted-ORs in our study are in agreement with recent data reported by Han et al. (≥ 102 cm in men and ≥ 88 cm in women) [7]. These cut-offs have now been endorsed by consensus conferences on obesity and the metabolic syndrome [9, 10]. They were initially defined on their relationship with WHR (data not shown). Fully adjusted-ORs in our study are in agreement with recent data reported by Han et al. (≥ 102 cm in men and ≥ 88 cm in women) [7].
For WHR, the cut-offs we used were the same as Lean et al. [7] in their first study about WC thresholds (WHR ≥ 0.95 in men and ≥ 0.80 in women). These cut-offs were those from the 1990 US dietary guidelines [35]. There is a number of other WHR thresholds available in the literature, and, in contrast with WC, no consensus exists in this area. In men and women respectively, proposed cut-offs were 1.0 and 0.80 for Swedish investigators [3, 4], 1.0 and 0.85 for the World Health Organisation [1], 1.0 and 0.90 for Bray [36] and 0.94 and 0.88 for Lemieux et al. [8].

A critical point to consider when examining the differential associations found in this study with WC and WHR is that each of these indicators conveys different types of information about the regional distribution of adiposity. WHR is usually taken as an indicator of upper vs lower adiposity. However, as a ratio, WHR is difficult to interpret biologically [2]. An increased WHR may reflect decreased muscle mass in the lower part of the body as much as increased abdominal adiposity [37]. This may explain in part the relationship with physical inactivity. Although more strongly correlated with the BMI, WC was shown to correlate better than WHR with the abdominal visceral fat depot assessed by imaging techniques such as computer tomography or MRI [5, 38]. It is widely accepted that the high lipolytic activity of visceral adipocytes, drained by the portal vein to the liver, is a key factor to understand why an accumulation of fat in the visceral area is associated with the metabolic complications of obesity [39].

In conclusion, data from this study show a consistent association of physical inactivity with indicators of overall and abdominal obesity. This association was found with both the WHR, an indicator of upper versus lower body fat or mass, and with the WC (in women), a more specific indicator of visceral fat accumulation in the abdominal region, independent of overall adiposity (as assessed by the BMI), age, smoking and socio-economic status (as assessed by educational level). Since our study has a cross-sectional design, it is not possible to conclude on causality. However, the correlates of abdominal adiposity shown here may be of importance for health-promotion policies designed to reduce the risk for type 2 diabetes and cardiovascular diseases. A more detailed investigation of the longitudinal relationships of the various dimensions and levels of physical activity as well as sedentary behaviour (TV viewing) with indicators of abdominal fatness is ongoing in these subjects.

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