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# Prevalence of normal weight obesity in Switzerland: effect of various definitions

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**Abstract** *Background* Normal weight obesity (NWO) is defined as an excessive body fat associated with a normal body mass index (BMI $< 25$ kg/m$^2$), but its prevalence in the general population is unknown. *Aim of the study* To assess the prevalence of NWO in Switzerland according to different cut points used to define excess body fat. *Methods* Cross-sectional study including 3,213 women and 2,912 men aged 35–75 years. Body fat was assessed by bioelectrical impedance analysis and prevalence of NWO was assessed using four previously published definitions for excess body fat. *Results* Percent body fat increased with age: in men, the values (mean ± SD) were 20.2 ± 5.4, 23.0 ± 5.4, 26.3 ± 5.2 and 28.2 ± 4.6 for age groups 35–44, 45–54, 55–64 and 65–75 years, respectively; the corresponding values for women were 29.9 ± 7.8, 33.1 ± 7.4, 36.7 ± 7.5 and 39.6 ± 6.9. In men, prevalence of NWO was <1% irrespective of the definition used. Conversely, in women, a 1- to 20-fold difference (from 1.4 to 27.8%) in NWO prevalence was found. The prevalence of NWO increased with age when age-independent cut points were used in women, but not in men. *Conclusions* Prevalence of NWO is low in the general population and higher in women than in men. The prevalence is highly dependent on the criteria used to define excess body fat, namely in women. The use of gender- and age-specific cut points to define excess body fat is better than fixed or gender-specific only cut points.

**Key words** cross-sectional study – normal weight obesity – prevalence – Switzerland

## Introduction

Obesity is defined by an excess body fat [1], but in the absence of a simple technique to measure body fat in the general population, increased body mass index (BMI) has been widely used as a surrogate marker for excess body fat [1]. Recently, a new entity named normal weight obesity (NWO) has been described; NWO is defined as a normal BMI associated with increased body fat [6] and has been associated with an unfavorable lipid [6] and inflammatory [5] profile. Still, the exact prevalence of NWO in the general population has been seldom studied. Another difficulty arises as there is no established validated cut point to define excess body fat. Body fat levels vary according to gender and age [6, 11], and several cut points have been proposed to define excess body fat. For instance, the initial description of NWO used a single cut point of 30% to define excess body fat [5, 6], whereas other authors have proposed gender-specific, age-independent [27], or gender- and age-specific [11, 16] cut points. Further, there is no information regarding the potential effect of those different cut points on NWO prevalence rates.

Thus, the aim of the present study was to assess the prevalence of NWO according to those different cut points in the city of Lausanne, Switzerland.

## Subjects and methods

### Sampling

The sampling procedure of the CoLaus (Cohorte Lausannoise) study has been described previously [8]. Briefly, the complete list of the Lausanne inhabitants aged 35–75 years ($n$ = 56,694) was provided by the population registry of the city. A simple, nonstratified random selection of the subjects was performed and a random sample of 35% of the overall population was drawn. An invitation letter with a quick description of the study and a formulary in a pre-stamped envelope was sent to all randomized subjects. Subjects interested in participating returned the formulary and were contacted telephonically within 14 days by one of the staff members who provided more information about the study and arranged for an appointment.

Since the CoLaus study aimed at including only Caucasians to avoid population stratification and to increase genetic homogeneity for association studies, the following inclusion criteria were applied: (a) written informed consent; (b) aged 35–75 years; (c) willingness to take part in the examination and to have blood sample drawn and (d) Caucasian origin. Caucasian origin was defined as having both parents and grandparents Caucasian.

Of the initial 19,830 subjects sampled, 54 subjects were considered as noneligible before contact and 15,109 (76%) responses were obtained. A total of 4,667 subjects who did not respond were considered as nonresponders. Among responders, 6,189 (41%) subjects refused to participate in the study and 799 (5%) were considered as noneligible. Subjects who refused were older (52.6 ± 11.7 vs. 51.2 ± 10.9 years, $P < 0.01$) and included more women (61 vs. 52%, $P < 0.01$) than subjects who accepted to participate. The sample of 8,121 subjects who agreed to participate represented 41% of the initially sampled population, 54% of all responders and 57% of all eligible responders. Among these subjects, the first 6,738 were invited to attend the clinic and completed the examination. About 6,189 participants met the inclusion criteria (including ethnicity) and were included in the CoLaus study. The other 549 participants (8.1%) were not of Caucasian ethnicity and were excluded. As the number of subjects who agreed to participate (8,121) was higher than the number of subjects initially planned for the CoLaus study (6,000), 1,383 could not be included into the study although they were willing to participate. One subject withdrew after consent due to personal reasons. Therefore, the final CoLaus sample ($n$ = 6,188) represents 43% of the eligible responders, 41% of all the responders and 31% of the initially sampled population.

### Assessment process

All participants were asked to attend the outpatient clinic at the Centre Hospitalier Universitaire Vaudois (CHUV) in the morning after an overnight fast. Data were collected by trained field interviewers in an single visit lasting about 60 min. Informed consent was obtained from participants upon their arrival at the study clinic. The first questionnaire mailed with the appointment's letter and completed by the participant prior to the morning visit was then quickly reviewed and a second questionnaire was applied by interview prior to clinical measurements and blood collection.

Data on smoking included the previous and current smoking status. Data on alcohol consumption included the past and current drinking status as well as the number of alcoholic beverage units (wine, beer and spirits) consumed over the week preceding the interview. Data on physical activity assessed whether the participant practiced leisure time physical activity at least twice per week. Whenever necessary (difficulty in understanding the questionnaire, irrespective of the reason), staff members helped the participants.

## Clinical data

All staff members were trained and certified before participating in the study. Certification included ability to conduct all interviews, to perform phlebotomy and blood sample processing, anthropometric and blood pressure measurements, and data entry. The data was monitored by an external quality control organism (PRN, North Hampshire, UK). This external organism checked the integrity of the data by comparing the paper and the electronic information but had no access to the identification of the participants. The Ethics Committee was aware of this external data checking and the letter of consent also included the information that the data would be checked by an external organism.

Body weight and height were measured with participants standing without shoes in light indoor clothes. Body weight was measured in kilograms to the nearest 100 g using a Seca® electronic scale (Hamburg, Germany), which was calibrated yearly. Height was measured to the nearest 5 mm using a Seca® height gauge (Hamburg, Germany). BMI was defined as weight/height$^2$. Waist and hip circumferences were measured as recommended [18].

Body composition was assessed by electrical bioelectrical impedance analysis [13, 14] using the Bodystat® 1500 analyzer (Isle of Man, British Isles). This device has been validated against reference methods [9, 12] and its results have been shown to be more accurate than those obtained using a dual frequency bioelectrical impedance analysis device [21]. The correlation between the bioelectrical impedance analysis device and the coefficient of variation for repeated measurements of electrical impedance is 0.7% [12]; the reproducibility has been shown to be between 1% [12] and 5% [19]; the intraclass correlation coefficient has been estimated at 0.987 [22] and its correlation with reference methods such as isotope dilution is between 0.855 [19] and 0.96 [21]. Subjects had to fast for at least 5 h, not engage into strenuous physical activity the previous 12 h and abstain from consuming caffeine or alcohol-containing beverages 24 h before the analysis. All metallic adornments were removed, and measurement was performed after a 10-min rest in the supine position in an air-conditioned room with a constant temperature of 20°C. Care was taken that the subject did not touch any metallic component of the bed and that the inner part of the thighs did not touch each other. The electrodes were positioned in the right side of the body according to the manufacturer's recommendations: injecting leads were connected to the electrodes behind the finger and toe, whereas measuring leads were connected to the electrodes on the wrist and ankle. Measurement was conducted with a test current of 400 μA (root mean square) at a frequency of 50 kHz, with an impedance measuring range of 30–1,000 Ω (accuracy 3 Ω). Conversely, no information was available regarding the equation used (proprietary). Body fat was expressed as percentage of total body weight (%BF) or as fat mass index, defined as body fat (in kg) divided by height (m) squared (kg/m$^2$) [17].

**Table 1** Cut points used to define excess % of body fat

| Age group (years) | De Lorenzo (%) | NHANES (%) | Other[a] (%) | Switzerland[b] (%) |
|---|---|---|---|---|
| Men | | | | |
| 35–44 | 30 | 29.1 | 26 | 28.1 |
| 45–54 | 30 | 29.1 | 29 | 28.7 |
| 55–64 | 30 | 29.1 | 31 | 30.6 |
| 65–74 | 30 | 29.1 | | 32.6 |
| Women | | | | |
| 35–44 | 30 | 37.2 | 39 | 35.9 |
| 45–54 | 30 | 37.2 | 41 | 36.5 |
| 55–64 | 30 | 37.2 | 43 | 40.5 |
| 65–74 | 30 | 37.2 | | 44.4 |

The table presents the different cut-points used to define excess body fat by gender and age group. According to De Lorenzo [5], NHANES [27], other [11] and Switzerland [16]

[a]For white subjects and BMI > 30 kg/m$^2$; age groups are 20–39, 40–59 and 60–79 years

[b]95$^{th}$ Percentile

Normal weight obesity was defined as a BMI < 25 kg/m$^2$ and a % body fat superior to several established cut points: gender- and age-independent as reported initially (30% for both men and women) [5, 6]; fixed sex-specific values (29.1% in men and 37.2% in women) as proposed in NHANES [27]; age- and gender-specific values derived from an international study (for instance, %BF >26% among white men aged 20–39 or %BF >43% for white women aged 60–79) [11], and age- and gender-specific 95th percentiles for the Swiss population (%BF >28.1, 28.7, 30.6 and 32.6% for men aged 35–44, 45–54, 55–64 and 65–74, respectively; the corresponding values for women being 35.9, 36.5, 40.5 and 44.4%) [16] (Table 1). Alternatively, normal weight obesity was also defined as a BMI < 25 kg/m$^2$ and a fat mass index ≥8.3 kg/m$^2$ (men) or ≥11.8 kg/m$^2$ (women) [17].

## Statistical analysis

Statistical analyzes were performed using Stata 9.2 (Stata Corp, College Station, USA). Results were expressed as mean ± standard deviation (SD) or as number of subjects and (percentage). Comparisons

**Table 2** Sample characteristics, overall and by gender

| | Overall ($n$ = 6,125) | Women ($n$ = 3,213) | Men ($n$ = 2,912) | $P$ value |
|---|---|---|---|---|
| Age (years) | 53.1 ± 10.8 | 53.5 ± 10.7 | 52.6 ± 10.8 | 0.005 |
| Born in Switzerland (%) | 3,961 (64.7) | 2,107 (65.6) | 1,854 (63.7) | 0.12 |
| Education (%) | | | | |
| Basic | 1,273 (20.8) | 777 (23.9) | 510 (17.4) | |
| Apprenticeship | 2,267 (37.0) | 1,159 (36.1) | 1,108 (38.1) | <0.001 |
| High school/college | 1,450 (23.7) | 792 (24.7) | 658 (22.6) | |
| University | 1,130 (18.5) | 489 (15.2) | 641 (22.0) | |
| Smoking status (%) | | | | |
| Current | 1,660 (27.1) | 804 (25.0) | 856 (29.3) | |
| Former | 2,015 (32.9) | 895 (27.9) | 1,130 (38.5) | <0.001 |
| Never | 2,450 (40.0) | 1,514 (47.1) | 936 (32.1) | |
| Physical activity (%) | 3,400 (55.5) | 1,842 (57.3) | 1,558 (53.5) | 0.005 |
| Alcohol drinking (%) | 4,466 (72.9) | 2,017 (62.8) | 2,449 (84.1) | <0.001 |
| Height (cm) | 168.6 ± 9.3 | 162.7 ± 6.7 | 175.0 ± 7.3 | <0.001 |
| Weight (kg) | 73.6 ± 15.0 | 66.4 ± 12.7 | 81.5 ± 13.1 | <0.001 |
| BMI (kg/m$^2$) | 25.8 ± 4.5 | 25.1 ± 4.8 | 26.6 ± 4.0 | <0.001 |
| % Body fat | 29.3 ± 8.0 | 34.3 ± 8.2 | 23.8 ± 6.0 | <0.001 |
| Fat mass index (kg/m$^2$) | 7.8 ± 3.4 | 8.9 ± 3.7 | 6.5 ± 2.5 | <0.001 |
| Waist (cm) | 89.3 ± 13.2 | 83.4 ± 12.2 | 95.7 ± 11.1 | <0.001 |
| Hip (cm) | 101.7 ± 9.2 | 100.6 ± 10.1 | 102.9 ± 7.8 | <0.001 |

Results are expressed as number of subjects and (percentage) or as mean ± standard deviation. Between gender comparisons by $\chi^2$ or Student's $t$ test
*BMI* body mass index

were performed using Student's $t$ test and analysis of variance for quantitative variables, and using $\chi^2$ for qualitative variables. Statistical significance was assessed for $P < 0.05$.

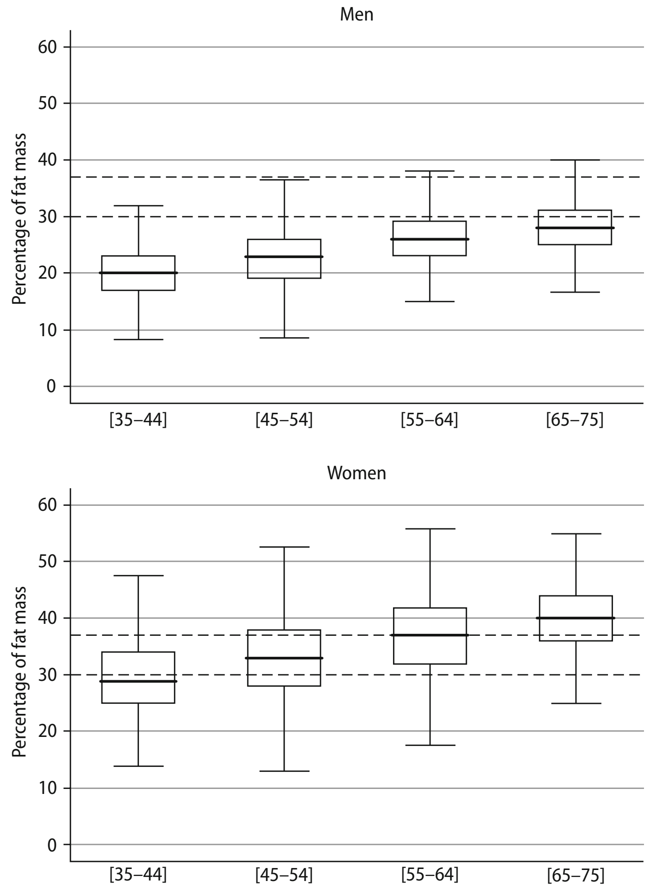


**Fig. 1** Distribution of body fat (expressed as percentage of total body weight) according to gender and age group. The 30 and 37% thresholds to define obesity are indicated by the dashed lines

## Results

### Sample characteristics

Of the 6,188 subjects from the initial sample, 6,125 had data on body fat that allowed their classification. The other 63 were excluded from the analysis as no data on body fat was available. Their main clinical characteristics according to gender are summarized in Table 2.

Swiss nationals represented circa two thirds of the sample, and no differences were found between genders. Six out of 10 subjects reported a current or previous history of smoking, and slightly more than half reported engaging in leisure physical activity at least twice per week. Also, almost three quarters of the subjects reported some type of alcohol consumption.

Between-gender comparisons showed that women were older, had a lower educational level, smoked and drank less and were more physically active than men. Women also had lower BMI, waist and hip but a higher % body fat and a higher fat mass index than men. Finally, in both genders, body fat levels (expressed in % of body weight) increased with age (Fig. 1).

### Prevalence of normal weight obesity

The prevalence rates of NWO according to gender, age group and the cut point used to define excess BF are summarized in Table 3. In men, prevalence of NWO was below 1% irrespective of the definition used, whereas in women a 1- to 20-fold difference in the prevalence of NWO was found when % body fat thresholds were used. Conversely, the fat mass index-based definition led to a very low prevalence of NWO for both genders (Table 3). In women, the prevalence of NWO also increased with age when age-independent cut points were used, whereas no such increase with age was found in men. Finally, irrespective of the definition used, prevalence of NWO was considerably higher in women than in men, with the exception of the definition based on fat mass index (Table 3).

**Table 3** Prevalence of normal weight obesity by gender and age group according to the cut-point used to define excess body fat

| Age group | n | De Lorenzo[a] | NHANES[b] | Other[c] | Switzerland[d] | Fat mass index[e] |
|---|---|---|---|---|---|---|
| Men | | | | | | |
| All | 2,912 | 21 (0.7) | 29 (1.0) | 24 (0.8) | 17 (0.6) | 1 (0.1) |
| 35–44 | 873 | 2 (0.2) | 3 (0.3) | 3 (0.3) | 3 (0.3) | 0 (0.0) |
| 45–54 | 840 | 4 (0.5) | 5 (0.6) | 6 (0.7) | 6 (0.7) | 0 (0.0) |
| 55–64 | 760 | 4 (0.5) | 5 (0.7) | 6 (0.8) | 3 (0.4) | 0 (0.0) |
| 65-75 | 439 | 11 (2.5) | 16 (3.6) | 9 (2.1) | 5 (1.1) | 1 (0.2) |
| Women | | | | | | |
| All | 3,213 | 892 (27.8) | 222 (6.9) | 44 (1.4) | 80 (2.5) | 2 (0.1) |
| 35–44 | 857 | 128 (14.9) | 9 (1.1) | 6 (0.7) | 17 (2.0) | 0 (0.0) |
| 45–54 | 906 | 229 (25.3) | 29 (3.2) | 6 (0.7) | 35 (3.9) | 1 (0.1) |
| 55–64 | 932 | 322 (34.6) | 75 (8.1) | 11 (1.2) | 18 (1.9) | 0 (0.0) |
| 65-75 | 518 | 213 (41.1) | 109 (21.0) | 21 (4.1) | 10 (1.9) | 1 (0.2) |

Results are expressed as number of subjects and (percentage). Definitions used: BMI < 25 kg/m$^2$

[a] Gender- and age-independent (30% for both men and women) [5, 6]

[b] Fixed sex-specific values (29.1% in men and 37.2% in women) [27]

[c] Age- and gender-specific values (%BF >26% among white men aged 20–39 years or %BF >43% for white women aged 60–79 years) [11]

[d] Age- and gender-specific 95th percentiles for the Swiss population (%BF >28.1, 28.7, 30.6 and 32.6% for men aged 35–44, 45–54, 55–64 and 65–74 years, respectively; the corresponding values for women being 35.9, 36.5, 40.5 and 44.4%) [16]

[e] Fat mass index ≥8.3 kg/m$^2$ (men) or ≥11.8 kg/m$^2$ (women) [17]

## Discussion

There is little if no information regarding the prevalence of NWO in the general population. In this study, we tried to assess the prevalence of this entity using several cut points for excess body fat as proposed in the literature. Since in this study body fat was assessed by bioelectrical impedance analysis, we chose to use age- and gender-specific bioimpedance-derived cut points which had been proposed for the Swiss population [16]; alternatively, other bioimpedance-derived cut points from an international study [11] or the USA [27], and the >30% cut-off obtained by DXA [5] were also used. Overall, our results indicate that in men the prevalence of NWO was below 1% for all thresholds used, but that in women the prevalence of NWO varied considerably from 1.4 to 27.8% according to the cut-off used. Interestingly, using age- and gender-specific cut points [11, 16] led to more similar results than using a single cut-off [5, 27]. As it has been shown that body fat increases with age [3, 11, 16], the use of a single cut-off value might overestimate the prevalence of excess fat in the elderly groups and, inversely, underestimate this condition in the younger groups. The increase of body fat with age might also explain the higher prevalence of NWO when using a single cut-off [5, 27] (see Fig. 1). Finally, the use of increased fat mass index to define NWO led to a very low prevalence in both genders; a possible explanation is the fact that fat mass index is dependent both on the percentage of body fat but also on the value of BMI (as fat mass index can be derived as %BF × BMI), and for subjects with a BMI below 25 kg/m$^2$ values of %BF as high as 33% (for men) and 47% (for women) would be needed to reach the published thresholds [17]; those values are considerably higher than the thresholds used by the other authors (see Table 1). Hence, it is possible that the thresholds of fat mass index to define NWO might be excessive, and further studies are needed to better assess this point.

This study has some limitations that should be taken into account. First, only Caucasians were included, and it might be necessary to use ethnic-specific cut-points as proposed by others [3, 7, 27]. Second, the assessment of body fat was performed using bioelectrical impedance analysis, which might underestimate the values relative to DXA [20, 25], although this statement has been challenged [2, 4], namely among normal weight subjects [23]. Thus, it is rather unlikely that the high prevalence of women with NWO observed in this study using cut points obtained by DXA [5, 6] was due to an underestimation of body fat by bioelectrical impedance analysis. Third, our study did not include subjects aged over 75 years, and it would have been interesting to assess the prevalence of NWO in this age group. Still, the results obtained among participants aged 65–75 years indicate that the prevalence of NWO varies considerably depending on the definition used, and that age-specific cut-points to define excess body fat might be necessary, although further studies are needed to better assess this point. Fourth, the participation rate was rather low (41%), which might limit the generalization of our findings. However, low participation is typical of surveys in Western countries and is comparable with the MONICA surveys conducted in Switzerland and in other countries [26]. The magnitude of the nonparticipation bias is not proportional to the percentage of nonparticipants [10] and a study on representativeness observed that people with risky behaviors participated in the same proportions as people without risk factors [24]. Finally, it has been shown that the NHANES and Geneva bioelectrical impedance analysis equations estimate body composition equally well in men but showed some discrepancies in women [15]; thus, it is likely that the differences in the prevalence of NWO women as derived from the Swiss or the USA cut points might partly be due to differences in estimation methods.

In summary, our data indicate that prevalence of NWO is low in the Caucasian population of Lausanne and higher in women than in men. Our results also indicate that the prevalence of NWO in women is highly dependent on the cut point used to define excess body fat, and efforts are needed to establish appropriate body fat cut points if the prevalences are to be compared between surveys.

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**Conflict of interest** Vincent Mooser is a full-time employee of GlaxoSmithKline. The other authors report no possible conflict of interest.

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