Overweight, obesity and fat distribution in 50- to 64-year-old participants in the European Prospective Investigation into Cancer and Nutrition (EPIC)

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Abstract

Objective: To describe anthropometric characteristics of participants of the European Prospective Investigation into Cancer and Nutrition (EPIC).

Design: A cross-sectional analysis of baseline data of a European prospective cohort study.

Subjects: This analysis includes study populations from 25 centres in nine European countries. The British populations comprised both a population-based and a 'health-conscious' group. The analysis was restricted to 83 178 men and 163 851 women aged 50–64 years, this group being represented in all centres.

Methods: Anthropometric examinations were undertaken by trained observers using standardised methods and included measurements of weight, height, and waist and hip circumferences. In the 'health-conscious' group (UK), anthropometric measures were predicted from self-reports.

Results: Except in the 'health-conscious' group (UK) and in the French centres, mean body mass index (BMI) exceeded 25.0 kg m^{-2}. The prevalence of obesity (BMI $\geq$ 30 kg m^{-2}) varied from 8% to 40% in men, and from 5% to 53% in women, with high prevalences ($>$25%) in the centres from Spain, Greece, Ragusa and Naples (Italy) and the lowest prevalences ($<$10%) in the French centres and the 'health-conscious' group (UK). The prevalence of a large waist circumference or a high waist-to-hip ratio was high in centres from Spain, Greece, Ragusa and Naples (Italy) and among women from centres in Germany and Bilthoven (The Netherlands).

Conclusions: Anthropometric measures varied considerably within the EPIC population. These data provide a strong base for further investigation of anthropometric measures in relation to the risk of chronic diseases, especially cancer.

Anthropometric measures such as weight, height, and waist and hip circumferences have been shown to be related to risk of many chronic diseases[1,2]. The relationship between body mass index (BMI) and risk of chronic disease is well established for diabetes mellitus[1–4], several cancer types[5–17], coronary heart disease and hypertension[1,3,18] and, in some populations, for total mortality[3,19]. In particular, a high waist-to-hip ratio (WHR)

is associated with elevated total mortality[20,21] and risk for diabetes mellitus[22], coronary heart disease[18,21,23] and hypertension[22].

There is considerable evidence for associations between obesity and increased risk of postmenopausal breast cancer[10–12,15], colon cancer[7,8,13,15], endometrial cancer[9,15] and renal cell cancer[15,16]. Obesity is possibly also associated with increased risk of prostate cancer[5,6,15], adenocarcinoma of the oesophagus[15,17] and thyroid cancer[15]. WHR and waist circumference (WC), as indicators of central adiposity, contribute to breast cancer risk independently of BMI[14].

Further evidence on the role of anthropometric factors in the risk of cancer and other diseases is needed. These studies should preferably be performed in large populations with a high variability of disease risk and a large range of anthropometric values, and should make use of several anthropometric measures. The European Prospective Investigation into Cancer and Nutrition (EPIC) has the potential for comparison of data from large numbers of subjects with high variability in both disease risk and anthropometric characteristics. The EPIC project is a multi-centre prospective cohort study designed to investigate the relation between diet, nutritional and metabolic characteristics, various lifestyle factors and disease risk, particularly cancer. EPIC includes 23 administrative centres in 10 countries with individual national cohorts comprising 28 000–88 000 subjects. Over 500 000 subjects participated in the baseline examination of the EPIC study. The EPIC study was set up by study groups from France, Germany, Greece, Italy, Spain, The Netherlands and the UK; it was subsequently joined by already existing cohorts from Sweden, Denmark and Norway with a similar set of procedures and study variables. Anthropometric measurements at the baseline examination of the EPIC study included weight and height measurements as well as measurements of waist and hip circumferences[24].

The present paper describes baseline data regarding the distribution of weight, height, and waist and hip circumferences over the different EPIC study populations and explores the variability of these anthropometric characteristics between the EPIC study populations. The description is restricted to the age range 50–64 years, which is represented in all EPIC centres.

Methods

Subjects

This study presents baseline data from the EPIC study, which were collected between 1992 and 2000. The selection of study populations in each study centre was largely influenced by practical considerations of obtaining adequate participation and ensuring long-term follow-up, and, as such, study populations were not intended to be representative of entire regions. The study populations were either population-based (Bilthoven, The Netherlands,

describing population-based samples from the towns of Amsterdam, Doetinchem and Maastricht; Greece; Germany; Sweden; Denmark; Norway; part of the study population from the UK, Spain and Italy) or included special groups such as participants in breast cancer screening (Utrecht, The Netherlands; Florence, Italy), blood donors (part of the study populations from Spain and Italy), teachers and school workers (France) or vegetarians, vegans and other health-conscious individuals (part of the study population from the UK). In France, Norway, Utrecht (The Netherlands) and Naples (Italy), only women were examined. The age range differed substantially between centres. To reduce the heterogeneity between centres due to these age differences, the present analysis was restricted to the age group 50–64 years, which was represented in all centres. A total of 84 515 men and 166 065 women were 50–64 years old. Anthropometric data were available for 83 178 men and 163 851 women in this age group. Study populations, sample sizes and sources of populations are described in more detail elsewhere[25]. At the time of the analysis, no anthropometric data were available for Norway.

Anthropometric measurements

Details of the anthropometry core protocols in each EPIC centre are described in Table 1. In Umeå (Sweden), anthropometric data collection was restricted to measurement of weight and height. In the 'health-conscious' group (UK), in addition to self-reports of weight, height and circumferences of waist and hip for all participants, measurements of weight, height and circumferences were available in a sub-group. In the French centres, weight and height were requested by questionnaire, and subsequently weight, height and waist and hip circumferences were measured in a sub-group. In each centre, hip circumference (HC) was measured either at the widest point or over the buttocks. These two measurement methods used to assess HC are generally in agreement[26]. WC was measured either at the narrowest torso circumference (France; Italy; Spain; UK; Utrecht, The Netherlands; Heidelberg, Germany; Greece; Denmark) or midway between the lower ribs and the iliac crest (Spain; Bilthoven, The Netherlands; Greece; Germany; Malmö, Sweden). In Spain, Greece and Heidelberg (Germany), a combination of methods was used, whereby the majority of participants were measured at the narrowest circumference. If the narrowest circumference could not be identified, WC was measured midway between the lower ribs and the iliac crest.

Overall, the proportion of missing values for anthropometric measures was less than 5%. However, in the British cohort representing the general population, anthropometric measurements were missing in 12% of all participants. In 18% of the men from Florence (Italy) and in 13% of the British men representing the 'health-

Table 1 Procedures for anthropometric measurements in the regional European Prospective Investigation into Cancer and Nutrition (EPIC) centres

Country and centre	Weight: Self-report	Weight: In light underwear	Weight: In light clothing*	Weight: Normally dressed without shoes	Weight: Balance	Weight: Precision (kg)	Weight: Bladder empty	Height: Self-report	Height: Fixed on wall	Height: Free standing	Height: Without shoes	Height: Precision (cm)	Clothing: None	Clothing: Over underwear	Clothing: Over normal clothing	Waist: Natural waist	Waist: Midway†	Waist: Self-report	Hip: Widest circumference	Hip: Over the buttocks	Hip: Self-report
Greece																					
Greece	−	−	+	−	Digital^r	0.1	−	−	+	−	+	0.1	−	+	−	+	+	−	+	−	−
Spain																					
Granada	−	+	−	−	Digital^r	0.1	+	−	+	−	+	1.0	−	+	−	+	+	−	+	−	−
Murcia	−	+	−	−	Digital^r	0.1	+	−	+	−	+	1.0	−	+	−	+	+	−	+	−	−
Navarra	−	+	−	−	Digital^r	0.1	+	−	+	−	+	1.0	−	+	−	+	+	−	+	−	−
San Sebastian	−	+	−	−	Digital^r	0.1	+	−	+	−	+	1.0	−	+	−	+	+	−	+	−	−
Asturias	−	+	−	−	Digital^r	0.1	+	−	+	−	+	1.0	−	+	−	+	+	−	+	−	−
Italy																					
Ragusa	−	+	−	−	Digital^r	0.1	−	−	+	−	+	0.1	+	−	−	+	−	−	+	−	−
Naples	−	+	−	−	Beam^r	0.1	−	−	+	−	+	0.1	+	−	−	+	−	−	+	−	−
Florence	−	+	−	−	Beam^r	0.1	−	−	+	−	+	0.5	−	−	−	+	−	−	+	−	−
Turin	−	−	−	+	Beam^r	0.1	−	−	+	−	+	0.1	+	−	+	+	−	−	+	−	−
Varese	−	+	−	−	Beam^r	0.1	−	−	+	−	+	0.5	+	−	−	+	−	−	+	−	−
France																					
All centres	+	−	−	+	Digital^r	0.1	−	+	+	−	+	0.5	+	−	−	+	−	−	+	−	−
Germany																					
Heidelberg	−	+	−	−	Beam^r	0.1	+	−	+	−	+	0.1	+	−	−	+	+	−	−	+	−
Potsdam	−	+	−	−	Digital^r	0.1	−	−	−	+	+	0.1	+	−	−	−	+	−	−	+	−
The Netherlands																					
Bilthoven	−	−	+	−	Beam^n	0.1	−	−	+	−	+	0.5	−	−	+	−	+	−	+	−	−
Utrecht	−	−	−	+	Digital^r	0.5	−	−	+	−	+	0.5	−	−	+	+	−	−	−	+	−
United Kingdom																					
General population	−	−	−	+	Beam^r	0.1	−	−	+	−	+	0.5	−	−	+	+	−	−	−	−	−
'Health-conscious'	+	−	+	−	Digital^r	0.1	−	+	+	−	+	0.5	−	+	−	+	−	+	−	+	+
Denmark																					
Copenhagen	−	+	−	−	Digital^o	0.1	−	−	+	−	+	1.0	+	−	−	+	−	−	−	+	−
Aarhus	−	+	−	−	Digital^o	0.1	−	−	+	−	+	1.0	+	−	−	+	−	−	−	+	−
Sweden																					
Malmö	−	+	−	−	Beam^n	0.1	−	−	+	−	+	1.0	+	−	−	−	+	−	+	−	−
Umeå	−	−	−	+	Digital^r	0.1	−	−	+	−	+	1.0	−	−	−	−	−	−	−	−	−
Norway																					
Norway	+	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−

r – regularly calibrated; n – not calibrated; o – calibrated once.
* After removal of shoes, heavier sweaters, indoor jackets and heavier objects from pockets.
† Measured midway between the iliac crest and the lower ribs.

conscious' group, data on waist and hip circumferences were missing.

The anthropometric data were adjusted to reduce heterogeneity due to protocol differences in clothing worn during measurement. In most Italian centres, as well as in Spain, Germany and Denmark, weight was measured on subjects in light underwear. In the centres of France, Turin (Italy), the general population of the UK, Umeå (Sweden) and Utrecht (The Netherlands), subjects wore normal clothing without shoes, while in the remaining centres (the 'health-conscious' group (UK); Bilthoven, The Netherlands; Greece; Malmö, Sweden) weighing was undertaken with subjects in light clothing after the removal of shoes, heavier sweaters or indoor jackets and emptying heavy objects from pockets. For subjects who were normally dressed and without shoes, correction factors of -1.5 kg for weight and -2.0 cm for circumferences were adopted from an earlier multi-centre study[27]. In centres where weight was measured with subjects in light clothing only (the 'health-conscious' group (UK); Bilthoven, The Netherlands; Greece; Malmö, Sweden), the adjustment for weight was -1.0 kg.

In 965 men (33% of all men) and 1464 women (16% of all women) aged 50–64 years old from the 'health-conscious' group (UK), self-reported and measured anthropometric measures were determined within 3 weeks. These data showed discrepancies between measurements and self-reports. Self-reported weight, waist and hip circumferences were underestimated and self-reported height was overestimated. The degree of the over- or underestimation was dependent on the level of the anthropometric measure and age: a higher level of underestimation of weight was observed in heavier subjects. Overestimation of height was more common among shorter subjects. Waist and hip circumferences were underestimated to greater extents by heavier subjects. The accuracy of anthropometric measures in subjects with only self-reports was improved by using prediction equations (shown in the Appendix). Sex-specific predictions were derived from subjects with both measured and self-reported measures by linear regression models, with the measured parameter as the dependent variable and the self-reported variable and age as the independent variables.

In the French centres, weight and height were measured in 31% of all women, while self-reports were available for all women. For the French women with both self-reported and measured data, the time interval between self-reports and measurements varied between less than 1 month and 6 years. The maximum time interval between measurements and self-reports, considered necessary to allow for a reasonable comparison of self-reported and measured values, was 3 months. Due to the insufficient number of eligible women within this time interval ($n = 115$), prediction equations from self-reports were not determined. Instead, we present the self-reported and the measured values for the French women. In statistical questions and data comparison, the measured values were used. A study of the validity of self-measured anthropometric measures among 152 French women showed reasonable agreement between self-measured weight and height and those measured directly by a technician (B. Tehard, personal communication).

BMI was calculated as weight (kg) divided by height (m) squared. Subjects were classified into different BMI categories according to the World Health Organization guidelines as follows: subjects with a BMI below 18.5 kg m^{-2} were considered underweight, subjects with a BMI between 18.5 and 24.9 kg m^{-2} had normal weight, subjects with a BMI between 25.0 and 29.9 kg m^{-2} were considered overweight and subjects with a BMI of 30.0 kg m^{-2} or higher were classified as obese[1].

WHR was calculated as waist circumference (cm) divided by hip circumference (cm). Both WC and WHR are used as indicators of central obesity. Cut-off points used to identify subjects with a large WC were 102 cm in males and 88 cm in females. These values have been used previously to identify subjects with increased relative risk for the development of obesity-related risk factors[1]. Cut-off points to categorise subjects with a high WHR were 0.95 in men and 0.80 in women[28].

Statistical analysis

Statistical analyses were carried out using the SAS statistical package, version 8.0. The centres or geographical regions were redefined, as described elsewhere[29], resulting in a total of 27 analytical centres. The redefined centres include both centres and geographical regions. In the present analysis, both centres and geographical regions are described in terms of centres. At the time of the analysis, no data were available for the two centres from Norway. Therefore, results from 25 EPIC centres are described in this paper. All data analyses were stratified by gender. The arithmetic mean, standard error, and 10th, 50th (median) and 90th percentiles for weight, height, BMI, WC, HC and WHR are presented for each centre. The percentiles were used to describe the distribution of each body measure by centre. Both mean and median (50th percentile) are statistical parameters describing the central tendency of the data. We examined the shape of the distributions and the extent of skewness of the body measures. In addition, the prevalences of overweight, obesity and abdominal body fat accumulation were determined, by applying commonly used cut-off points indicating a high level of adiposity.

Due to the association between anthropometric measures and age[30], all statistical measures were adjusted for age, using the residuals of linear regression with age as the independent variable and the anthropometric measure as the dependent variable. Since differences between crude and adjusted values were small ($<1\%$), only the age-adjusted values are presented here.

To describe the association between BMI and WC or WHR as indicators of fat distribution, Pearson correlation coefficients were calculated both on an individual level for each centre and on the level of the centres. In addition, the association between prevalence of obesity and prevalence of a large WC or a high WHR is described.

Results

The age-adjusted mean, standard error, and 10th, 50th and 90th percentiles of weight, height and BMI are presented in Tables 2 and 3 for men and women, respectively. The difference between mean and median was consistently less than $\pm 3.5\%$ for each centre, indicating that the distribution of the data was symmetrical. Examination of the skewness of the sex-stratified distributions using pooled data of all centres indicated the following values for skewness: weight, 0.73; height, -0.12; and BMI, 0.89 in men; and weight, 0.98; height, -0.07; and BMI, 1.09 in women. Mean weight varied from 77.0 kg (Turin, Italy) to 83.6 kg (Heidelberg, Germany) in men and from 60.2 kg (South of France) to 73.3 kg (Granada, Spain) in women. Mean height varied between 166.6 cm (Murcia, Spain) and 176.8 cm (Malmö, Sweden; Copenhagen, Denmark) in men and between 154.4 cm (Granada, Spain) and 164.5 cm (Utrecht, The Netherlands) in women. Mean BMI ranged from 25.2 kg m^{-2} (the 'health-conscious' group, UK) to 29.3 kg m^{-2} (Granada and Navarra, Spain) in men and from 23.5 kg m^{-2} (South and South coast of France) to 30.8 kg m^{-2} (Granada, Spain) in women. Mean BMI exceeded 27.5 kg m^{-2} in the Greek and Spanish centres and in the centres of Ragusa and Naples (Italy). In the women from the French centres and the 'health-conscious' group (UK), mean BMI was less than 25.0 kg m^{-2}.

Prevalence of underweight was less than 1% in men and 4% or less in women. In the total EPIC cohort of 50- to 64-year-olds with measured anthropometric data ($n = 245\,153$), 32% of men and 49% of women had normal weight. Large variations were observed in the distribution of normal weight, overweight and obesity across EPIC centres. Over 50% of women from centres in France, Turin (Italy), Utrecht (The Netherlands), Malmö (Sweden) and Denmark, and men and women from the 'health-conscious' group (UK), had normal weight. Prevalence of obesity was 25% or more in the Spanish and Greek centres, as well as in the Italian centres of Ragusa and Naples (Table 4).

Overweight and obesity were observed less frequently when using self-reports of weight and height in the total cohort of French women, compared with measured data in the sub-group. In each French centre, the mean of the individual differences of BMI between self-reported and measured data was significantly negative (data not shown). Table 3 shows that the self-reported weight of all French

Table 2 Age-adjusted mean, standard error (SE), and 10th, 50th and 90th percentiles (P$_{10}$, P$_{50}$ and P$_{90}$) of weight (kg), height (cm) and body mass index (BMI; kg m^{-2}) in men aged 50–64 years in the European Prospective Investigation into Cancer and Nutrition (EPIC) centres

	Weight (kg)						Height (cm)						BMI (kg m^{-2})					
Country and centre	n	Mean	SE	P$_{10}$	P$_{50}$	P$_{90}$	n	Mean	SE	P$_{10}$	P$_{50}$	P$_{90}$	n	Mean	SE	P$_{10}$	P$_{50}$	P$_{90}$
Greece																		
Greece	3664	80.4	0.2	65.6	79.6	95.7	3669	168.5	0.1	160.9	168.3	176.6	3662	28.3	0.1	23.7	28.0	33.2
Spain																		
Granada	880	81.6	0.4	67.8	80.8	96.9	888	166.9	0.2	159.0	167.0	174.8	879	29.3	0.1	24.8	29.2	34.1
Murcia	1265	79.8	0.3	66.9	79.1	93.4	1285	166.6	0.2	159.0	166.4	174.6	1264	28.7	0.1	24.7	28.4	33.0
Navarra	1908	82.5	0.2	70.6	81.6	95.9	1915	167.8	0.1	160.6	168.0	175.3	1907	29.3	0.1	25.4	29.0	33.5
San Sebastian	2144	81.0	0.2	68.6	80.1	94.8	2145	169.2	0.1	161.5	169.0	177.5	2143	28.3	0.1	24.7	28.0	32.4
Asturias	1355	80.6	0.3	67.5	79.9	94.3	1354	167.7	0.2	160.1	167.6	175.2	1352	28.7	0.1	24.6	28.3	33.0
Italy																		
Ragusa	1057	78.5	0.3	65.3	77.4	93.3	1057	167.4	0.2	159.5	167.4	175.6	1057	28.0	0.1	23.7	27.8	32.5
Florence	1711	78.9	0.3	65.3	77.9	93.0	1708	172.1	0.2	164.1	172.1	180.0	1708	26.6	0.1	22.7	26.3	30.8
Turin	2844	77.0	0.2	64.1	76.2	90.6	2846	171.2	0.2	162.9	171.0	179.8	2841	26.3	0.1	22.4	26.0	30.4
Varese	1587	77.7	0.3	65.1	76.6	91.6	1588	170.7	0.2	162.9	170.5	178.8	1587	26.7	0.1	22.9	26.3	30.9
Germany																		
Heidelberg	7110	83.6	0.1	69.6	82.5	98.9	7184	175.0	0.1	167.0	175.0	183.2	7100	27.3	0.0	23.2	26.9	31.9
Potsdam	6115	82.6	0.2	68.6	81.6	97.8	6098	174.1	0.1	165.9	174.0	182.4	6086	27.2	0.0	23.2	26.9	31.8
The Netherlands																		
Bilthoven	3232	81.9	0.2	67.8	80.8	96.9	3232	175.1	0.1	166.2	175.1	183.6	3232	26.7	0.1	22.6	26.4	31.0
United Kingdom																		
General population	6477	80.0	0.1	66.3	78.9	95.0	6475	174.9	0.1	166.6	175.1	183.3	6473	26.1	0.0	22.3	25.7	30.3
'Health-conscious'*	2423	77.9	0.2	64.7	76.8	92.4	2444	175.6	0.1	168.1	176.0	183.2	2415	25.2	0.1	21.5	24.9	29.3
Denmark																		
Copenhagen	18 511	83.1	0.1	68.6	81.8	99.2	18 511	176.8	0.0	168.7	176.7	185.1	18 511	26.6	0.0	22.4	26.1	31.2
Aarhus	8320	82.8	0.1	68.8	81.7	98.3	8320	176.3	0.1	168.4	176.1	184.4	8320	26.6	0.0	22.6	26.2	31.0
Sweden																		
Malmö	7299	81.1	0.1	66.8	80.0	96.9	7299	176.8	0.1	168.4	176.8	185.2	7299	25.9	0.0	21.8	25.7	30.4
Umeå	5155	80.2	0.2	66.8	78.8	94.8	5160	176.2	0.1	168.6	175.8	184.5	5154	25.8	0.0	21.9	25.5	29.8

*Weight and height predicted from self-reports.

Table 3 Age-adjusted mean, standard error (SE), and 10th, 50th and 90th percentiles (P_{10}, P_{50} and P_{90}) of weight (kg), height (cm) and body mass index (BMI; kg m^{-2}) in women aged 50–64 years in the European Prospective Investigation into Cancer and Nutrition (EPIC) centres

Country and centre		Weight (kg)						Height (cm)						BMI (kg m^{-2})					
		n	Mean	SE	P_{10}	P_{50}	P_{90}	n	Mean	SE	P_{10}	P_{50}	P_{90}	n	Mean	SE	P_{10}	P_{50}	P_{90}
Greece																			
Greece		5985	71.5	0.2	56.9	70.4	87.4	5984	155.5	0.1	148.6	155.4	162.9	5980	29.6	0.1	23.6	29.2	36.1
Spain																			
Granada		2569	73.3	0.2	60.0	72.2	88.2	2584	154.4	0.1	147.6	154.2	161.6	2566	30.8	0.1	25.2	30.4	37.0
Murcia		2306	72.2	0.2	59.0	71.1	86.4	2328	154.6	0.1	147.9	154.3	161.6	2303	30.2	0.1	25.0	29.8	35.8
Navarra		1730	70.9	0.3	58.6	69.3	85.2	1745	156.0	0.1	149.1	155.9	163.0	1730	29.2	0.1	24.1	28.6	34.7
San Sebastian		1637	69.5	0.3	57.3	67.9	84.5	1637	157.1	0.1	149.7	157.0	164.4	1637	28.2	0.1	23.3	27.5	34.2
Asturias		1958	70.9	0.2	58.6	69.6	85.0	1954	155.4	0.1	148.4	155.4	162.5	1950	29.4	0.1	24.4	28.8	35.0
Italy																			
Ragusa		943	67.6	0.4	54.5	66.0	82.3	943	155.6	0.2	148.0	155.5	163.3	943	27.9	0.1	22.6	27.3	34.0
Naples		2304	67.5	0.2	54.7	66.1	82.1	2306	155.7	0.1	148.5	155.7	162.8	2304	27.9	0.1	22.9	27.3	33.6
Florence		6505	66.0	0.1	53.6	64.5	80.2	6507	159.2	0.1	151.5	159.1	167.0	6505	26.0	0.1	21.5	25.4	31.5
Turin		2418	63.6	0.2	51.3	62.2	77.7	2414	158.3	0.1	150.6	158.3	166.1	2413	25.4	0.1	20.7	24.8	30.5
Varese		4470	65.0	0.2	52.4	63.6	79.1	4469	157.4	0.1	150.1	157.4	164.7	4469	26.3	0.1	21.5	25.6	31.9
France																			
South coast	Measured	1668	60.4	0.2	49.6	59.3	72.3	1669	160.2	0.1	152.7	160.2	167.9	1668	23.5	0.1	19.8	23.0	27.9
	Self-reported	5407	59.0	0.1	49.1	57.9	69.9	5575	161.0	0.1	154.1	160.5	168.3	5279	22.5	0.0	19.1	22.0	26.5
South	Measured	2903	60.2	0.2	49.4	59.1	72.2	2903	160.2	0.1	153.0	160.2	167.6	2901	23.5	0.1	19.6	23.0	27.9
	Self-reported	9606	59.0	0.1	48.9	57.7	70.8	9895	161.0	0.1	154.0	160.7	168.7	9386	22.5	0.0	19.1	21.9	26.5
North-west	Measured	1764	60.8	0.2	50.0	59.1	73.6	1764	159.5	0.1	152.5	159.3	166.6	1764	23.9	0.1	19.9	23.3	28.6
	Self-reported	5753	58.0	0.1	47.8	56.3	69.9	5895	160.0	0.1	153.0	159.7	167.2	5588	22.7	0.0	19.1	22.1	26.8
North-east	Measured	5481	61.4	0.1	49.7	59.9	75.1	5477	160.4	0.1	152.9	160.3	167.7	5476	23.9	0.1	19.7	23.2	29.1
	Self-reported	15822	60.0	0.1	49.1	58.7	72.6	16395	162.0	0.0	154.8	161.8	169.5	15493	22.8	0.0	19.2	22.3	27.1
Germany																			
Heidelberg		6392	69.9	0.2	55.9	68.1	86.0	6421	162.8	0.1	155.2	162.7	170.6	6387	26.4	0.1	21.3	25.7	32.5
Potsdam		7400	70.4	0.1	56.2	68.5	86.8	7375	161.9	0.1	154.6	161.8	169.4	7361	26.9	0.1	21.9	26.1	32.9
The Netherlands																			
Bilthoven		3560	70.6	0.2	56.7	69.1	86.0	3559	163.1	0.1	155.1	163.0	171.1	3559	26.5	0.1	21.6	25.8	32.2
Utrecht		13464	68.8	0.1	55.9	67.3	83.5	13461	164.5	0.1	156.8	164.6	172.1	13461	25.4	0.0	21.0	24.8	30.6
United Kingdom																			
General population		9325	67.5	0.1	54.2	65.5	83.0	9323	161.7	0.1	154.2	161.8	169.4	9314	25.8	0.0	21.0	24.9	31.7
'Health-conscious'*		8391	65.7	0.1	53.6	63.9	79.9	8456	162.6	0.1	155.9	162.2	169.9	8366	24.8	0.0	20.7	24.1	29.8
Denmark																			
Copenhagen		20866	69.0	0.1	55.4	67.2	84.8	20866	164.3	0.0	156.7	164.2	171.9	20864	25.6	0.0	20.9	24.8	31.2
Aarhus		8597	68.6	0.1	55.2	66.9	84.2	8599	163.9	0.1	156.7	163.8	171.4	8597	25.5	0.0	20.9	24.8	31.1
Sweden																			
Malmö		9318	67.2	0.1	54.0	65.6	82.6	9319	163.9	0.1	156.4	163.9	171.4	9318	25.0	0.0	20.4	24.3	30.7
Umeå		5555	67.9	0.2	55.1	66.2	83.2	5557	163.0	0.1	155.7	162.8	170.6	5549	25.6	0.1	21.0	24.9	31.1

*Weight and height predicted from self-reports.

Table 4 Prevalence of underweight, normal weight, overweight and obesity in men and women aged 50–64 years in the European Prospective Investigation into Cancer and Nutrition (EPIC) centres (adjusted for age)

Country and centre		Men					Women				
		n	BMI < 18.5 kg m^{-2} (%)	BMI = 18.5–24.9 kg m^{-2} (%)	BMI = 25.0–29.9 kg m^{-2} (%)	BMI ≥ 30.0 kg m^{-2} (%)	n	BMI < 18.5 kg m^{-2} (%)	BMI = 18.5–24.9 kg m^{-2} (%)	BMI = 25.0–29.9 kg m^{-2} (%)	BMI ≥ 30.0 kg m^{-2} (%)
Greece											
Greece		3662	0.3	19.3	50.6	29.9	5980	0.2	17.7	39.5	42.6
Spain											
Granada		879	0.1	10.5	49.3	40.1	2566	0.0	8.5	38.3	53.2
Murcia		1264	0.1	11.6	55.9	32.4	2303	0.0	10.1	41.9	48.0
Navarra		1907	0.0	7.4	55.2	37.4	1730	0.1	15.6	46.9	37.4
San Sebastian		2143	0.0	12.8	61.2	25.8	1637	0.1	24.1	47.2	28.6
Asturias		1352	0.0	12.1	56.7	31.2	1950	0.0	13.7	48.2	38.1
Italy											
Ragusa		1057	0.0	20.2	54.8	25.0	943	0.3	26.7	44.8	28.2
Naples*		–	–	–	–	–	2304	0.4	27.2	45.6	26.8
Florence		1708	0.2	31.9	53.5	14.2	6505	0.7	44.6	39.5	15.2
Turin		2841	0.2	36.8	50.9	12.1	2413	1.6	50.4	35.8	12.2
Varese		1587	0.4	32.1	53.4	14.1	4469	1.3	41.9	40.4	16.4
France											
South coast*	Measured	–	–	–	–	–	1668	3.4	70.5	20.9	5.2
	Self-reported	–	–	–	–	–	5279	5.4	77.5	14.6	2.5
South*	Measured	–	–	–	–	–	2901	3.6	69.9	21.5	5.0
	Self-reported	–	–	–	–	–	9386	5.8	76.6	14.7	2.9
North-west*	Measured	–	–	–	–	–	1764	2.8	67.7	22.7	6.7
	Self-reported	–	–	–	–	–	5588	5.6	75.9	15.0	3.5
North-east*	Measured	–	–	–	–	–	5476	4.0	64.9	23.6	7.6
	Self-reported	–	–	–	–	–	15493	5.1	74.6	16.4	3.9
Germany											
Heidelberg		7100	0.2	26.5	53.6	19.7	6387	0.9	42.4	37.4	19.3
Potsdam		6086	0.3	26.3	54.4	19.0	7361	0.5	38.1	39.8	21.6
The Netherlands											
Bilthoven		3232	0.4	31.6	53.5	14.5	3559	0.8	40.3	41.0	17.9
Utrecht*		–	–	–	–	–	13461	1.2	51.0	35.6	12.2
United Kingdom											
General population		6473	0.4	39.2	49.1	11.3	9314	1.4	49.2	34.2	15.2
'Health-conscious'†		2415	0.6	51.1	40.9	8.0	8366	1.4	58.9	30.5	9.2
Denmark											
Copenhagen		18511	0.3	35.1	49.3	15.3	20864	1.5	50.1	34.3	14.1
Aarhus		8320	0.2	33.4	51.3	15.1	8597	1.3	50.6	34.7	13.5
Sweden											
Malmö		7299	0.7	41.0	47.1	11.2	9318	2.3	54.8	30.8	12.1
Umeå		5154	0.3	43.3	47.1	9.3	5549	1.3	49.9	35.5	13.3

BMI – body mass index.
* Only women.
† Weight and height predicted from self-reports.

women at baseline was lower than measured weight of the sub-group. For height the opposite pattern was observed.

Descriptive statistics of waist and hip circumferences and WHR are shown in Tables 5 and 6 for men and women, respectively. The difference between mean and median was consistently less than ± 2.3% for each centre, indicating that the distribution of the data was symmetrical. Examination of the skewness of the sex-stratified distributions using pooled data from all centres indicated the following values for skewness: WC, 0.51; HC, 0.73; and WHR, 0.39 in men; and WC, 0.81; HC, 0.85; and WHR, 1.07 in women. WC and WHR were generally lower in women than in men, while HC in women was similar to or higher than in men in all centres. The widest range of means of WC in the different centres was observed in those centres where WC was measured at the narrowest circumference. Irrespective of the method used for measuring WC, mean WC varied from 92.1 cm ('health-conscious' group, UK) to 103.0 cm (Navarra, Spain) in men and from 77.2 cm (South of France) to 95.0 cm (Murcia, Spain) in women. Relatively high values for WC were observed in centres in Spain and Greece and in the Italian centres of Ragusa and Naples, compared with the other centres. HC ranged from 99.0 cm (Florence, Italy) to 106.3 cm (Murcia, Spain) in men and from 97.9 cm (South of France) to 110.7 cm (Murcia, Spain) in women. In men, mean WHR ranged from 0.91 ('health-conscious' group, UK) to 0.98 (Ragusa, Italy) in the centres with measurements at the narrowest circumference; from 0.94 (Asturias, Spain) to 0.97 (Granada, Murcia and Navarra, Spain) in the centres using both methods of waist measurement; and from 0.94 (Malmö, Sweden) to 0.95 (Potsdam, Germany) in the centres with measurements midway between the lower ribs and the iliac crest. In women, these ranges were 0.77 ('health-conscious' group, UK) to 0.84 (Ragusa and Naples, Italy) for the centres with measurements at the narrowest circumference; 0.82 (Heidelberg, Germany) to 0.86 (Murcia and Navarra, Spain) in the centres using both methods of waist measurement; and 0.79 (Malmö, Sweden) to 0.83 (Bilthoven, The Netherlands) in the centres with measurements of WC midway between the lower ribs and the iliac crest.

A total of 25% of men and 27% of women had a large WC, and 49% of men and 48% of women had a high WHR. There was considerable variation in the prevalence of large WC or high WHR among regional EPIC cohorts. Generally, more subjects had a high WHR than a large WC. The proportion of subjects with a large WC or a high WHR was lowest in the 'health-conscious' group (UK) and women from the French centres. A large WC and a high WHR was most often observed in men and women from the Spanish and Greek centres, as well as in women from Bilthoven (The Netherlands), Potsdam and Heidelberg (Germany), Ragusa and Naples (Italy) (Table 7).

In both men and women, BMI was highly correlated with WC and WHR, respectively, on an individual level in all centres. The correlation coefficients were on average higher between BMI and WC than between BMI and WHR, or between WC and WHR. The correlation coefficients between BMI and WC ranged from 0.71 ('health-conscious' group, UK) to 0.89 (Potsdam, Germany) in men and from 0.73 ('health-conscious' group, UK) to 0.88 (Varese and Ragusa, Italy; Potsdam, Germany) in women. The correlation coefficients between BMI and WHR ranged from 0.34 (San Sebastian, Spain) to 0.62 (Malmö, Sweden) in men and from 0.20 (Granada, Spain) to 0.50 (Aarhus, Denmark) in women. The correlation coefficients between WC and WHR ranged from 0.61 (Murcia, Spain) to 0.81 (general population and 'health-conscious' group, UK; Bilthoven, The Netherlands) in men and from 0.58 (Murcia, Spain) to 0.78 (Aarhus, Denmark) in women.

Figures 1 and 2 show the relationships between the prevalence of general obesity and the prevalence of a large WC or high WHR. Both the prevalence of a large WC and the prevalence of a high WHR were positively associated with the prevalence of general obesity. The association between the prevalence of a large WC and general obesity was stronger than that seen between the prevalence of a high WHR and general obesity. The prevalence of a large WC or a high WHR varied considerably between centres with equal prevalence of general obesity.

Discussion

This study describes the variation of anthropometric characteristics among the EPIC study populations. The sex- and centre-specific data of weight, height and BMI showed considerable variation in these measures among regional study populations and even within countries. This was particularly evident for the centres from Italy and Spain, where differences in mean BMI and prevalence of obesity were observed. Relatively high values were observed in men from the Spanish centres of Granada (southern Spain) and Navarra (north-east of Spain) and in women from the southern Spanish centres of Murcia and Granada, and in men and women from the centres of Naples and Ragusa (southern Italy), in comparison with other centres in these countries.

A direct comparison of results from EPIC with those from other studies should be interpreted with caution, as EPIC was not intended to represent the general population of the study regions. Some of the study populations from Spain and southern Italy represented special groups. Blood donors dominated the study populations from Spain and Ragusa (Italy). Interestingly, similar geographical variations in the distribution of obesity, as were shown in EPIC, have been documented in Spain and Italy in previous studies[31–33]. Also, in women from the Dutch centres, there was a difference in the prevalence of obesity of almost 6% between participants from the Bilthoven centre, a population-based cohort, and participants from the Utrecht centre, a cohort recruited from women

Table 5 Age-adjusted mean, standard error (SE), and 10th, 50th and 90th percentiles (P_{10}, P_{50} and P_{90}) of waist circumference (cm), hip circumference (cm) and waist-to-hip ratio in men aged 50–64 years in the European Prospective Investigation into Cancer and Nutrition (EPIC) centres

Country and centre	Waist circumference (cm)						Hip circumference (cm)						Waist-to-hip ratio					
	n	Mean	SE	P_{10}	P_{50}	P_{90}	n	Mean	SE	P_{10}	P_{50}	P_{90}	n	Mean	SE	P_{10}	P_{50}	P_{90}
Greece																		
Greece*	3668	99.6	0.2	86.9	99.1	112.5	3667	102.4	0.1	93.9	101.9	111.2	3666	0.97	0.001	0.89	0.97	1.05
Spain																		
Granada*	891	102.2	0.3	90.2	102.0	114.4	891	105.5	0.3	96.2	104.8	115.7	891	0.97	0.002	0.90	0.97	1.04
Murcia*	1287	102.8	0.2	92.4	102.5	114.0	1287	106.3	0.2	97.9	106.0	114.8	1287	0.97	0.001	0.91	0.97	1.03
Navarra*	1915	103.0	0.2	92.8	102.4	114.9	1915	106.2	0.1	99.1	105.8	114.3	1914	0.97	0.001	0.91	0.97	1.04
San Sebastian*	2145	99.8	0.2	90.5	99.1	110.0	2145	105.4	0.1	97.9	104.7	113.6	2145	0.95	0.001	0.89	0.95	1.00
Asturias*	1357	99.1	0.2	88.9	98.6	110.1	1358	105.1	0.2	96.9	104.7	113.7	1357	0.94	0.001	0.88	0.94	1.01
Italy																		
Ragusa†	1057	97.3	0.3	85.9	96.8	108.8	1057	99.6	0.2	91.1	99.1	108.3	1057	0.98	0.002	0.91	0.98	1.04
Florence†	1449	92.4	0.2	81.4	91.9	103.9	1452	99.0	0.2	91.6	98.5	107.0	1449	0.94	0.002	0.86	0.93	1.01
Turin†	2747	94.5	0.2	83.5	93.9	106.0	2747	100.6	0.1	93.1	100.1	108.8	2747	0.94	0.001	0.87	0.94	1.01
Varese†	1588	93.0	0.2	82.3	92.6	104.5	1588	99.4	0.2	91.6	99.0	107.6	1588	0.94	0.001	0.87	0.94	1.00
Germany																		
Heidelberg*	7218	97.4	0.1	85.6	96.8	110.0	7215	102.1	0.1	94.2	101.7	110.7	7213	0.95	0.001	0.88	0.95	1.03
Potsdam‡	6123	96.0	0.1	83.9	95.4	108.6	6121	100.5	0.1	93.0	99.9	108.2	6120	0.95	0.001	0.88	0.96	1.03
The Netherlands																		
Bilthoven‡	3226	95.5	0.2	83.4	95.0	108.4	3227	100.4	0.1	92.9	99.9	108.2	3226	0.95	0.001	0.87	0.95	1.04
United Kingdom																		
General population†	6470	93.3	0.1	81.9	92.7	105.4	6469	100.7	0.1	93.5	100.2	108.4	6466	0.93	0.001	0.85	0.93	1.00
'Health-conscious'§	2434	92.1	0.1	83.9	90.8	100.7	2121	101.6	0.1	96.0	101.3	107.3	2114	0.91	0.001	0.85	0.90	0.97
Denmark																		
Copenhagen†	18505	95.9	0.1	84.0	94.9	108.7	18502	100.0	0.1	92.1	99.7	108.2	18502	0.96	0.000	0.88	0.96	1.04
Aarhus†	8319	96.4	0.1	84.8	95.8	108.9	8319	101.1	0.1	93.2	100.8	109.2	8319	0.95	0.001	0.88	0.95	1.03
Sweden																		
Malmö‡	7295	93.7	0.1	81.6	93.0	106.7	7294	99.1	0.1	91.0	98.7	107.8	7294	0.94	0.001	0.87	0.94	1.02

* Waist measured either at the narrowest torso circumference or midway between the lower ribs and the iliac crest.
† Waist measured at the narrowest torso circumference.
‡ Waist measured midway between the lower ribs and the iliac crest.
§ Waist and hip predicted from self-reports.

Table 6 Age-adjusted mean, standard error (SE), and 10th, 50th and 90th percentiles (P_{10}, P_{50} and P_{90}) of waist circumference (cm), hip circumference (cm) and waist-to-hip ratio in women aged 50–64 years in the European Prospective Investigation into Cancer and Nutrition (EPIC) centres

Country and centre	Waist circumference (cm)						Hip circumference (cm)						Waist-to-hip ratio					
	n	Mean	SE	P_{10}	P_{50}	P_{90}	n	Mean	SE	P_{10}	P_{50}	P_{90}	n	Mean	SE	P_{10}	P_{50}	P_{90}
Greece																		
Greece*	5987	90.3	0.2	75.6	89.3	106.3	5986	108.3	0.1	96.9	107.2	120.9	5983	0.83	0.001	0.74	0.83	0.93
Spain																		
Granada*	2587	93.2	0.2	80.0	93.0	106.9	2586	110.5	0.2	98.7	109.6	123.7	2586	0.84	0.001	0.78	0.84	0.91
Murcia*	2329	95.0	0.2	83.0	94.3	107.9	2330	110.7	0.2	99.8	109.7	122.5	2329	0.86	0.001	0.80	0.86	0.92
Navarra*	1743	91.9	0.3	78.8	90.6	106.7	1743	107.2	0.2	98.0	106.0	118.8	1743	0.86	0.002	0.77	0.85	0.96
San Sebastian*	1637	87.8	0.2	75.8	86.6	101.1	1637	105.6	0.2	94.9	104.2	117.6	1637	0.83	0.001	0.77	0.83	0.89
Asturias*	1956	89.2	0.2	77.5	88.5	101.6	1954	107.3	0.2	97.1	106.1	119.1	1954	0.83	0.001	0.76	0.83	0.90
Italy																		
Ragusa†	943	87.6	0.3	75.3	86.7	101.3	943	104.3	0.3	93.2	103.4	116.8	943	0.84	0.002	0.78	0.84	0.91
Naples†	2306	87.5	0.2	75.2	86.4	101.0	2306	104.6	0.2	94.3	103.7	116.6	2306	0.84	0.001	0.77	0.83	0.91
Florence†	6462	79.9	0.1	68.3	78.5	93.4	6462	100.2	0.1	90.9	99.5	110.6	6462	0.80	0.001	0.72	0.79	0.88
Turin†	2326	81.0	0.2	68.8	79.9	95.1	2326	100.7	0.2	91.0	99.7	111.5	2323	0.80	0.001	0.73	0.80	0.89
Varese†	4470	81.3	0.2	69.4	79.9	94.8	4470	101.1	0.1	91.3	100.1	112.3	4470	0.80	0.001	0.73	0.80	0.88
France																		
South coast†	1669	77.3	0.2	67.6	75.8	89.0	1669	98.3	0.2	90.1	97.4	107.7	1669	0.79	0.001	0.72	0.78	0.86
South†	2900	77.2	0.2	66.8	75.9	89.2	2898	97.9	0.1	89.3	97.4	107.4	2897	0.79	0.001	0.71	0.78	0.86
North-west†	1764	77.8	0.2	67.2	76.3	89.8	1764	98.8	0.2	89.9	98.1	108.8	1764	0.79	0.002	0.72	0.78	0.86
North-east†	5479	78.1	0.1	67.4	76.4	91.1	5479	99.2	0.1	90.1	98.3	109.8	5479	0.79	0.001	0.71	0.78	0.86
Germany																		
Heidelberg*	6430	84.4	0.1	70.8	83.1	99.5	6429	102.6	0.1	92.2	101.5	114.4	6428	0.82	0.001	0.74	0.82	0.91
Potsdam‡	7411	83.7	0.1	70.8	82.2	98.7	7411	103.1	0.1	93.0	101.8	114.8	7410	0.81	0.001	0.73	0.81	0.90
The Netherlands																		
Bilthoven‡	3554	85.3	0.2	71.6	84.1	100.9	3555	102.4	0.1	92.5	101.4	113.5	3554	0.83	0.001	0.75	0.83	0.93
Utrecht‡	13366	81.4	0.1	70.1	80.1	94.7	13367	103.6	0.1	94.3	102.6	113.9	13364	0.79	0.001	0.71	0.78	0.86
United Kingdom																		
General population†	9326	79.9	0.1	67.9	78.1	94.3	9320	101.9	0.1	91.8	100.4	113.8	9316	0.78	0.001	0.71	0.78	0.86
'Health-conscious'§	8233	77.6	0.1	69.0	76.1	87.7	8236	101.0	0.1	93.8	99.8	108.9	8208	0.77	0.001	0.71	0.76	0.83
Denmark																		
Copenhagen†	20861	82.0	0.1	69.3	80.3	97.4	20860	101.5	0.1	91.3	100.4	112.7	20860	0.81	0.001	0.72	0.80	0.90
Aarhus†	8597	82.3	0.1	70.0	80.4	97.1	8597	102.3	0.1	92.5	101.5	112.7	8597	0.80	0.001	0.72	0.79	0.90
Sweden																		
Malmö‡	9315	77.7	0.1	66.0	76.0	91.6	9313	98.0	0.1	87.0	96.9	110.5	9313	0.79	0.001	0.73	0.79	0.86

*Waist measured either at the narrowest torso circumference or midway between the lower ribs and the iliac crest.
†Waist measured at the narrowest torso circumference.
‡Waist measured midway between the lower ribs and the iliac crest.
§Waist and hip predicted from self-reports.

Table 7 Prevalence of large waist circumference (WC) and high waist-to-hip ratio (WHR) in men and women aged 50–64 years from different European Prospective Investigation into Cancer and Nutrition (EPIC) centres (adjusted for age)

Country and centre	Men			Women		
	n	Large WC ($\geq$ 102 cm) (%)	High WHR ($\geq$ 0.95) (%)	n	Large WC ($\geq$ 88 cm) (%)	High WHR ($\geq$ 0.80) (%)
Greece						
Greece*	3668	38.8	63.8	5987	54.5	65.8
Spain						
Granada*	891	49.7	62.7	2587	68.3	80.9
Murcia*	1287	52.3	63.3	2329	76.3	88.2
Navarra*	1915	51.6	64.1	1743	60.6	78.5
San Sebastian*	2145	34.8	46.7	1637	44.0	73.2
Asturias*	1357	34.1	43.6	1956	52.7	72.6
Italy						
Ragusa†	1057	29.2	69.8	943	43.9	78.3
Naples†‡	–	–	–	2306	44.7	72.6
Florence†	1449	14.1	37.4	6462	19.2	43.3
Turin†	2747	18.9	39.8	2326	21.7	49.9
Varese†	1588	14.6	38.7	4470	22.9	51.0
France						
South coast†‡	–	–	–	1669	11.3	34.2
South†‡	–	–	–	2900	11.9	36.2
North-west†‡	–	–	–	1764	12.9	35.4
North-east†‡	–	–	–	5479	14.7	34.7
Germany						
Heidelberg*	7218	29.3	50.4	6430	33.5	60.1
Potsdam§	6123	25.0	53.8	7411	30.9	53.9
The Netherlands						
Bilthoven§	3226	23.9	50.1	3554	36.8	66.1
Utrecht†‡	–	–	–	13366	22.5	37.2
United Kingdom						
General population†	6470	16.2	32.6	9326	19.8	35.4
'Health-conscious'¶	2434	8.9	17.3	8233	9.4	21.8
Denmark						
Copenhagen†	18526	23.5	53.4	20861	25.7	50.0
Aarhus†	8323	25.2	49.1	8597	25.8	46.9
Sweden						
Malmö§	7295	18.4	44.5	9315	15.0	40.3

* Waist measured either at the narrowest torso circumference or midway between the lower ribs and the iliac crest.
† Waist measured at the narrowest torso circumference.
‡ Only women.
§ Waist measured midway between the lower ribs and the iliac crest.
¶ Waist and hip predicted from self-reports.

attending breast cancer screening, indicating that the latter are selected in the direction of a healthier lifestyle. In the UK, mean weight and BMI, as well as the prevalence of overweight and obesity, were considerably lower in subjects from the 'health-conscious' group than in the general population cohort.

Overall, the mean BMI of most EPIC centres exceeded 25 kg m^{-2}. More than 50% of all EPIC participants were overweight or obese. The prevalence of obesity was lowest in the French centres and the 'health-conscious' group (UK) and highest in the most southern EPIC centres (Granada, Murcia and Navarra, Spain; Naples and Ragusa, Italy; Greece).

Despite co-ordinated planning, complete standardisation of anthropometric measurement procedures was not achieved in EPIC, partly due to pre-existing protocols in cohorts joining EPIC after study inception and partly due to logistic constraints. Measurements of height were considered comparable, as were those of weight, after adjustment for clothing. Furthermore, waist and hip circumferences were corrected for clothing. Other methodological differences for measurement of WC, with consequences for WHR, are still prevailing due to lack of adequate standardisation of measurement techniques. In a previous report on 437 European women aged 38 years[34], measurements of WC at the narrowest circumference were on average 2.7 cm lower than measurements of WC midway between the lower ribs and the iliac crest. No evidence for systemic differences between these methods in middle-aged subjects has been found in the literature, but this methodological inconsistency may affect comparison of WC and WHR data from the different EPIC populations described here. Such systematic error may affect the ranking of a centre; however, for the present analysis, it is likely that inter-individual variation is by far a more important source of variation than the potentially existing systematic error.

Another methodological issue may be the use of self-reported values as estimators of anthropometric measures in the 'health-conscious' group (UK). The use of
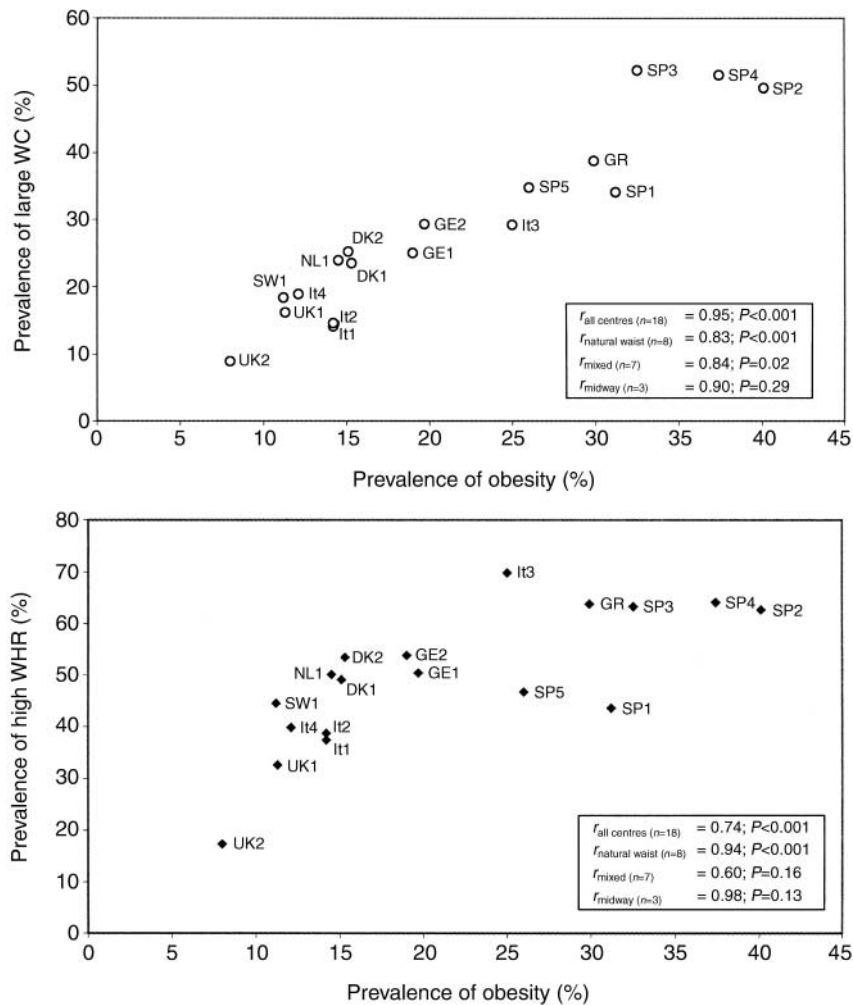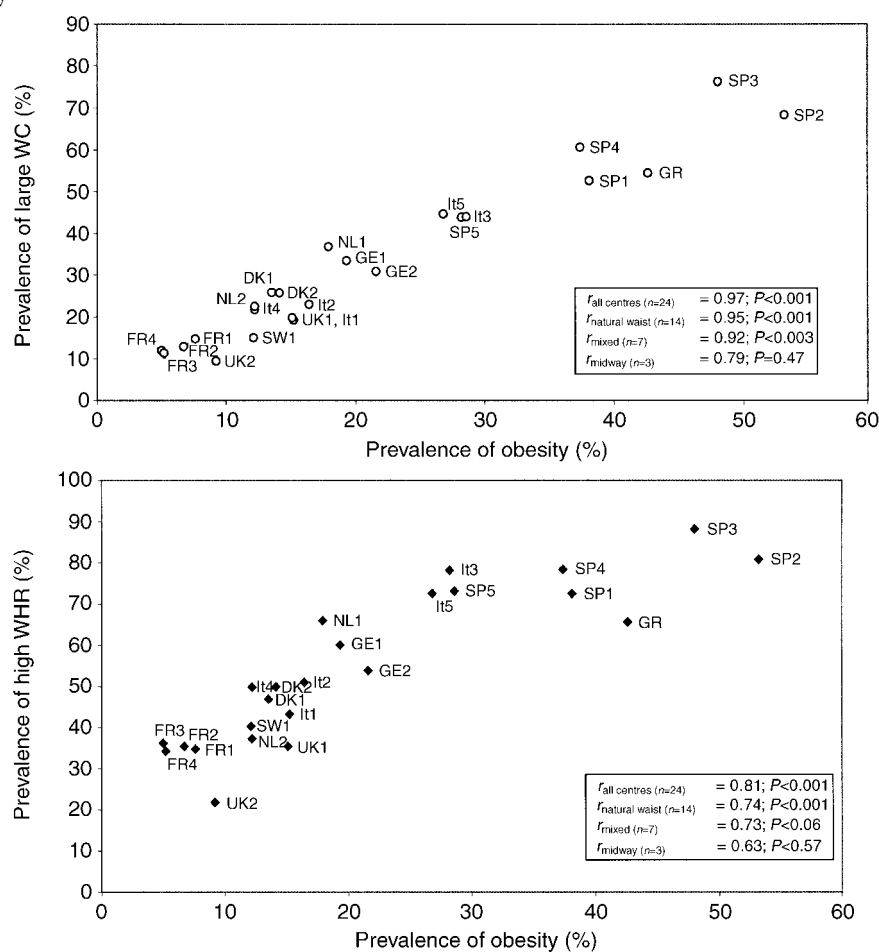
Fig. 1 The prevalence of large waist circumference (WC; top panel) and high waist-to-hip ratio (WHR; lower panel) in relation to the prevalence of general obesity in men. Abbreviations: It1 – Florence, Italy; It2 – Varese, Italy; It3 – Ragusa, Italy; It4 – Turin, Italy; SP1 – Asturias, Spain; SP2 – Granada, Spain; SP3, Murcia, Spain; SP4 – Navarra, Spain; SP5 – San Sebastian, Spain; UK1 – general population, UK; UK2 – 'health-conscious' group, UK; NL1 – Bilthoven, The Netherlands; GR – Greece; GE1 – Heidelberg, Germany; GE2 – Potsdam, Germany; SW1 – Malmö, Sweden, DK1 – Aarhus, Denmark; DK2 – Copenhagen, Denmark

prediction equations significantly reduced the proportion of misclassification in BMI groups from 22% to 15% in men and from 18% to 14% in women, for self-reported vs. predicted values, and thereby enhanced the accuracy of self-reported values (data not shown).

Prediction equations, such as those used to assess anthropometric measures from self-reports in the 'health-conscious' group (UK), could not be determined for the French participants. In the latter case, the time interval between measurements and self-reports was too long for the determination of reliable predictions in the majority of participants with both examination and self-reports. Tables 3 and 4 present data from both the anthropometric examination and the self-reports for all French women. Underestimation of weight and overestimation of height seem to be present in the self-reported values. However, owing to the time interval between measurements and self-reports, no definite conclusions can be drawn regarding misclassification by self-reports.

In most EPIC centres, WC was measured at the narrowest torso circumference. Comparing results from these centres, a considerable variation of WC, HC and WHR was observed. WC and WHR of the Italian centres of Ragusa and Naples and of the Spanish and Greek centres (most participants were measured at the narrowest area) were notably high. Assuming that measurements at the narrowest circumference are systematically lower than measurements at midway between the lower ribs and the iliac crest, this indicates even higher WC in these centres relative to other centres. The high values for WC in the southern centres were associated with high BMI in these centres.

Although both WC and WHR are used as measures of abdominal fatness, the variation in the proportion of subjects with a high WHR was not identical across centres to that in the proportion of subjects with a large WC. The greatest discrepancy between both measures was observed in men and women from the Ragusa (Italy)

Fig. 2 The prevalence of large waist circumference (WC; top panel) and high waist-to-hip ratio (WHR; lower panel) in relation to the prevalence of general obesity in women. Abbreviations: FR1 – North-east of France; FR2 – North-west of France; FR3 – South of France; FR4 – South coast of France; It1 – Florence, Italy; It2 – Varese, Italy; It3 – Ragusa, Italy; It4 – Turin, Italy; It5 – Naples, Italy; SP1 – Asturias, Spain; SP2 – Granada, Spain; SP3, Murcia, Spain; SP4 – Navarra, Spain; SP5 – San Sebastian, Spain; UK1 – general population, UK; UK2 – 'health-conscious' group, UK; NL1 – Bilthoven, The Netherlands; NL2 – Utrecht, The Netherlands; GR – Greece; GE1 – Heidelberg, Germany; GE2 – Potsdam, Germany; SW1 – Malmö, Sweden, DK1 – Aarhus, Denmark; DK2 – Copenhagen, Denmark

centre: about 30% of the subjects had a large WC, while over 70% had a high WHR. The difference between these two measures of central adiposity is in part due to the chosen cut-off points used for WHR and WC. A relative consensus for classification based on WC was found in the literature. However, this classification remains somewhat arbitrary. There is less of a consensus on cut-off points for WHR[35]. We examined the different cut-off points for WHR reviewed by Molarius and Seidell[35]. As expected, the proportion of subjects with a high WHR was considerably smaller when a higher cut-off point was used. In addition, different cut-off points for WHR resulted in different rankings of the centres regarding the prevalence of high WHR (data not shown). Besides the issue of appropriate cut-off points, our data also indicate that WHR and WC seem to measure different aspects of obesity. The correlation coefficients for the association between WC and WHR were lower (0.58–0.81) than the correlation coefficients for the association between WC and BMI (0.71–0.89). In addition, BMI is more clearly associated

with WC (correlation coefficients >0.70) than with WHR (correlation coefficients <0.62). Currently, there is no consensus on the most appropriate measure for abdominal fatness[35] and both WC and WHR should be used as indicators of fat distribution.

Our analyses were restricted to participants aged 50–64 years, because this age group was represented in all EPIC centres. The examination of anthropometric characteristics in younger age groups is also of interest, particularly in women, since there is a difference in the effect of weight on breast cancer in premenopausal and postmenopausal women[11,12]. A detailed description of anthropometric characteristics was not intended here, but additional analyses using data from the centres including younger age groups (France, 40–50 years; Italy, Spain, general population of the UK, Germany, 35–50 years; Umeå (Sweden), 29–50 years; Malmö (Sweden), 45–50 years; 'health-conscious' group (UK), Greece, Bilthoven (The Netherlands), 20–50 years) showed a lower prevalence of general and central obesity in participants younger than 50

years, compared with the age group 50–64 years. The geographical distribution in the prevalence of both general and central obesity across centres was similar in both age groups, with relatively high values in centres from Spain, Greece and the Italian centres of Naples and Ragusa, lower values in the northern centres and the lowest values in centres from France and the 'health-conscious' group (UK) (data not shown).

One of the most striking results of this study was the finding of high values for BMI, WC and WHR in the populations from southern Europe, especially in view of the results of another large study involving various European populations: the World Health Organization's MONICA study (MONItoring trends and determinants in CArdiovascular disease), covering the age range 35–64 years. This study did not observe an excess of adiposity in the centres of the Mediterranean area[36]. The Spanish and Italian regions included in the MONICA study were located in the north, while the EPIC study centres with extremely high values were in the south of Italy and Spain. The north–south gradient in the prevalence of obesity in Spain[31,33] and Italy[32] may explain part of the discrepancy between results of the MONICA study and EPIC. There is also, however, strong evidence for a secular increase of general and central obesity[1,31,37,38], since EPIC's baseline data were collected about 5 years later than the latest MONICA survey.

The finding of high values for anthropometric characteristics in the southern European populations is not (yet) reflected in disease risk expected from these high values. In Mediterranean countries, the absolute risk of obesity-related diseases such as coronary heart disease is among the lowest in Europe[39]. Further follow-up of the cohorts will reveal how obesity-related diseases develop in these countries. It will also be of interest to examine how obesity interacts with other factors such as the Mediterranean diet or low prevalence of smoking, especially in the older Greek and Spanish women. Obesity results from a number of different behaviours, including dietary patterns and physical inactivity. The effect of different lifestyles on body size may differ in magnitude in different populations. The predictive value of different measures of obesity for chronic diseases such as coronary heart disease is not consistent and this may reflect the different aetiological factors involved in obesity. Thus, a comparative study of obesity and its correlates and their predictive value for various chronic diseases in the EPIC study populations is of interest in the future.

In summary, a wide variation in anthropometric characteristics has been observed at baseline across different centres within the EPIC study, providing a strong starting point for an in-depth examination of the effects of body size and shape on the risk of chronic diseases, especially cancer, in different European study populations.

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Appendix – Prediction equations of weight, height, and waist and hip circumferences from self-reported values and age in men and women from the UK representing the 'health-conscious' group

Men:

$$\text{Weight} = 0.561 + (1.012 \times \text{sr\_weight}) + (0.006 \times \text{age})$$

$$\text{Height} = 15.032 + (0.923 \times \text{sr\_height}) - (0.052 \times \text{age})$$

$$\text{Waist} = 7.791 + (0.972 \times \text{sr\_waist}) - (0.035 \times \text{age})$$

$$\text{Hip} = 42.812 + (0.637 \times \text{sr\_hip}) - (0.075 \times \text{age})$$

Women:

$$\text{Weight} = 0.444 + (1.010 \times \text{sr\_weight}) + (0.006 \times \text{age})$$

$$\text{Height} = 27.096 + (0.853 \times \text{sr\_height}) - (0.069 \times \text{age})$$

$$\text{Waist} = 9.022 + (0.847 \times \text{sr\_waist}) + (0.091 \times \text{age})$$

$$\text{Hip} = 20.040 + (0.818 \times \text{sr\_hip}) - (0.011 \times \text{age})$$

In the above equations, sr_weight is self-reported weight, sr_height is self-reported height, sr_waist is self-reported waist circumference and sr_hip is self-reported hip circumference. Weight is in kg; height, waist circumference and hip circumference are in cm; age is in years.