Eur J Nutr 40 : 282 – 288 (2001)


ORIGINAL CONTRIBUTION

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# Five year changes in waist circumference, body mass index and obesity in Augsburg, Germany

Received: 8 August 2001
Accepted: 14 November 2001

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**Summary** *Aims* To assess temporal changes in body fat distribution, body mass index and obesity in Augsburg, Germany. *Methods* Waist circumference, weight and height were measured in two independent samples of 4804 and 4792, men and women, aged 25–74 years, in the MONICA Augsburg surveys 1989/90 and 1994/95. Abdominal obesity was defined as waist circumference greater than the 80$^{th}$ gender-specific percentile (men:103, women: 92 cm) in the 1989/90 population. Obesity was defined as a body mass index (BMI) ≥ 30 kg/m$^2$. *Results* Age-standardized mean waist circumference increased by more than 1 cm (p-value < 0.00003) in both men and women while BMI increased by 0.3–0.4 kg/m$^2$ (p-value < 0.01). We observed both a shift to higher values in the waist circumference distribution plus – particularly in women older than 45 years – a substantial right shift in the top of the distribution. Moreover, survey participants in 1994/95 who were at the higher end of the BMI distributions were disproportionately more obese than their respective peers in 1989/90. The prevalence of abdominal obesity rose by 3.3 % in men and 3.6 % in women, while the prevalence of obesity rose by 2 % from 17 % in men and by 2.5 % from 19 % in women. *Conclusions* While changes in the Augsburg population may not be as alarming as in other countries, the secular increase in waist circumferences in both men and women occurring over a short time period indicates a need for prevention given the already high absolute weight, BMI and waist circumference levels in the population.

**Key words** body fat distribution – obesity – secular trends

## Introduction

Overweight and obesity are reaching epidemic proportions worldwide [1]. Between 1976 and 1991, a 8–9 % increase in the prevalence of overweight was observed among adults in the United States, approximately one third of the population being overweight in 1991 [2]. Increasing trends in the average body mass index (BMI) have also been reported for Germany albeit at a substantially lower level. Currently about 20 % of the population can be considered obese [3–6].

Being overweight and obesity are associated with increased risk of total mortality, cardiovascular disease, diabetes, hypertension and many other health conditions including gallbladder disease, osteoarthritis and certain types of cancer [1]. High waist circumference and waist-to-hip ratio (WHR) have been shown to be predictive of coronary heart disease [7, 8], stroke [9] and type 2 diabetes [10]. Intra-abdominal fat seems to be a

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particularly potent metabolic cardiovascular risk factor [11]. Research has now established that a reduction in fat mass (though not a weight loss per se) is in fact associated with decreased mortality [12].

The assessment of overweight and obesity is usually based on BMI which is a surrogate for percent body fat [13]. To date, few studies have assessed population trends in fat distribution or fat patterning using alternative anthropometric measures such as waist or hip circumferences [14, 15]. These indices are more closely related to abdominal fat [16]. The purpose of this study was to assess five year changes in waist circumference, body mass index, and both abdominal and overall obesity in two large, population-based samples of German adults covering a wide age range.

## Methods

### Study design

The MONICA Augsburg surveys have been described in detail [5]. The WHO MONICA project, by design, required three independent cross-sectional surveys to be carried out five years apart. These surveys were conducted in 1984/85, 1989/90 and 1994/95. Because measurement of waist and hip circumferences was newly introduced in 1989, only the latter two surveys could be used. A simple random sample within each 10-year age and gender group of the population aged 25–74 years was selected in Augsburg city and a two stage cluster sample drawn in the two adjacent counties. A total of 664 individuals were sampled in each age and gender group. Total participation rates were defined as the proportion of participants out of those eligible (i. e., sampled individuals minus sample losses such as migration, death, confinement to an institution, etc.). Participation reached 77 % in 1989/90 and 75 % in 1994/95 resulting in a sample size of 4940 and 4856, respectively. In total, 136 individuals in 1989/90 and 64 in 1994/95 were missing data on height, weight, waist or hip circumference leaving analyzable data on 4804 and 4792 men and women, for the respective survey.

Anthropometric measurements were taken after participants had removed shoes and heavy clothing. Body weight was measured to the nearest 0.1 kg on a scale (SECA 709) with attached height measure (SECA 207). Height was assessed to the nearest 0.5 cm. Waist and hip circumferences were measured with a non-elastic plastic tape measure while the participant was standing. Measurements were taken at the level midway between the lower rib margin and the iliac crest with the participant breathing out gently. Hip circumference was measured at the level of maximal gluteal protrusion.

To maximize standardization of data collection across surveys, particular emphasis was placed on observer training and quality control. Prior to each survey, extensive training was conducted including a certification test before the start of field work. Quality and performance were checked at regular intervals and assessed by internal review.

Abdominal obesity was defined as a waist circumference greater than the 80$^{th}$ gender-specific percentiles of the analysis population in 1989/90, which corresponded to a waist circumference of 103 cm in men and 92 cm in women. We chose to use population-specific percentiles because the cutpoints and waist action levels recently proposed have exhibited a low sensitivity in our Augsburg population [17, 18]. Body mass index (BMI) was calculated as weight/height$^2$ (kg/m$^2$). Obesity was defined as a BMI $\geq$ 30 kg/m$^2$ [19].

### Statistical methods

Mean and median values of anthropometric characteristics and prevalence of abdominal and overall obesity are presented. Temporal changes were analyzed by comparison between 1989/90 and 1994/95. Statistical significance was assessed in age-specific and age-standardized analyses using unpaired t-tests for the comparison of mean values and chi-square tests for the comparison of prevalence.

To express both the magnitude and precision of the effect 95 % confidence intervals (CI) were calculated. Overall estimates for men and women were age-standardized by the direct method using the weights derived from the age distribution of the Federal Republic of Germany as of December 31, 1980. All analyses were conducted using SAS version 6.12.

We present mean-difference plots to explore the question whether changes in mean waist circumferences were due to an overall shift of the distribution or due to an increase in the upper portion of the distribution [20]. For each survey, the waist circumference values were ranked from lowest to highest within gender, and 20 distinct percentile points calculated (at increments of five percent). For example, 10 % of the male population had a waist circumference below 81.5 cm in 1989/90. Five years later, the first decile had increased to 83.0 cm. The waist circumference values were then compared between these surveys at the 20 percentile points. At each point, the mean of the percentile values from the two distributions and the difference of the percentile points of the two distributions were calculated. In our example of the first decile, this mean was (81.5+83.0)/2=82.25 and the corresponding difference (83.0–81.5)=1.5. The differences at 19 percentile points were subsequently plotted against the means to create the mean-difference plot. The mean difference for the highest percentile point was omitted from the figure because, by nature, the maximum values are the most extreme and may give a misleading impression.

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The plots are interpreted as follows: if the entire distribution of waist circumference were shifted to the right by a constant amount, the mean-difference plot shows a horizontal line greater than zero by the amount of the difference. If, however, only the right tail of the distribution is shifted and becomes more skewed, i. e., only individuals at the highest waist levels are more voluminous than their respective peers five years earlier, then the differences would become larger at higher waist values. It must be kept in mind that these changes occur in independent population samples and reflect secular trends, not changes in cohorts of individuals.

## Results

As shown in Table 1, the mean waist circumference increased by roughly one centimeter in all age groups among both men and women between 1989/90 and 1994/95. Among men, the mean age-standardized waist circumference increased from 94.0 cm to 95.3 cm in five years (p-value < 0.00003), and from 80.9 cm to 82.5 cm (p-value < 0.00001) in women. Simultaneously, the mean age-standardized BMI increased by 0.3 kg/m$^2$ (p-value < 0.01) among men and 0.4 kg/m$^2$ (p-value < 0.00001) among women (Table 2). Table 3 provides an overview of the age group specific median anthropometric characteristics and their five year changes. The median waist circumference increased indicating that the entire distribution shifted toward higher values

**Table 1** Mean values and five-year difference in waist circumference in men and women of the MONICA Augsburg surveys 1989/90 and 1994/95

| | | 1989/90 | | | 1994/95 | | | 1994/95–1989/90 | |
|---|---|---|---|---|---|---|---|---|---|
| | Age | Sample size | Mean (cm) | SE | Sample size | Mean (cm) | SE | Mean difference (cm) | 95% Confidence interval |
| Men | 25–34 | 461 | 87.3 | 0.44 | 443 | 88.6 | 0.43 | 1.3 | 0.1–2.5 |
| | 35–44 | 453 | 92.9 | 0.46 | 455 | 94.0 | 0.44 | 1.1 | –0.2–2.3 |
| | 45–54 | 509 | 95.7 | 0.44 | 481 | 97.5 | 0.47 | 1.8 | 0.5–3.0 |
| | 55–64 | 506 | 98.3 | 0.40 | 526 | 99.8 | 0.42 | 1.5 | 0.4–2.7 |
| | 65–74 | 502 | 98.9 | 0.44 | 476 | 99.4 | 0.43 | 0.5 | –0.7–1.7 |
| | 25–74* | 2431 | 94.0 | 0.20 | 2381 | 95.3 | 0.20 | 1.3 | 0.7–1.8 |
| Women | 25–34 | 438 | 74.0 | 0.46 | 446 | 75.0 | 0.45 | 1.0 | –0.2–2.3 |
| | 35–44 | 475 | 77.8 | 0.50 | 509 | 78.9 | 0.48 | 1.1 | –0.3–2.4 |
| | 45–54 | 530 | 82.2 | 0.48 | 504 | 84.4 | 0.53 | 2.1 | 0.8–3.6 |
| | 55–64 | 493 | 87.5 | 0.46 | 510 | 87.8 | 0.48 | 0.3 | –1.0–1.6 |
| | 65–74 | 437 | 87.4 | 0.48 | 442 | 90.7 | 0.52 | 3.4 | 2.0–40.7 |
| | 25–74* | 2373 | 80.9 | 0.22 | 2411 | 82.5 | 0.22 | 1.5 | 0.9–2.1 |

* age standardized in 10 year age groups to the population of the Federal Republic of Germany as of December 31, 1980

**Table 2** Mean values and five-year differences in body mass index in men and women of the MONICA Augsburg surveys 1989/90 and 1994/95

| | | 1989/90 | | | 1994/95 | | | 1994/95–1989/90 | |
|---|---|---|---|---|---|---|---|---|---|
| | Age | Sample size | Mean (kg/m$^2$) | SE | Sample size | Mean (kg/m$^2$) | SE | Mean difference | 95% Confidence interval |
| Men | 25–34 | 461 | 25.2 | 0.16 | 443 | 25.5 | 0.16 | 0.2 | –0.2–0.7 |
| | 35–44 | 453 | 26.7 | 0.17 | 455 | 26.9 | 0.17 | 0.2 | –0.3–0.7 |
| | 45–54 | 509 | 27.4 | 0.16 | 481 | 27.8 | 0.17 | 0.4 | –0.1–0.9 |
| | 55–64 | 506 | 28.0 | 0.15 | 526 | 28.5 | 0.15 | 0.5 | 0.1–0.9 |
| | 65–74 | 502 | 27.9 | 0.16 | 476 | 27.9 | 0.17 | 0.1 | –0.4–0.5 |
| | 25–74* | 2431 | 26.9 | 0.07 | 2381 | 27.2 | 0.08 | 0.3 | 0.1–0.5 |
| Women | 25–34 | 438 | 23.6 | 0.21 | 446 | 23.7 | 0.20 | 0.2 | –0.4–0.7 |
| | 35–44 | 475 | 24.9 | 0.21 | 509 | 25.3 | 0.21 | 0.5 | –0.1–1.0 |
| | 45–54 | 530 | 26.6 | 0.21 | 504 | 27.2 | 0.23 | 0.6 | 0.0–1.2 |
| | 55–64 | 493 | 28.1 | 0.20 | 510 | 28.4 | 0.21 | 0.3 | –0.3–0.8 |
| | 65–74 | 437 | 28.0 | 0.20 | 442 | 28.8 | 0.22 | 0.8 | 0.2–1.4 |
| | 25–74* | 2373 | 26.0 | 0.09 | 2411 | 26.4 | 0.10 | 0.4 | 0.2–0.7 |

* age standardized in 10 years age groups to the population of the Federal Republic of Germany as or December 31, 1980.

**Table 3** Median values and five-year changes in anthropometric characteristics of the MONICA Augsburg population 1989/90 to 1994/95

| | Age | Waist (cm) | | Hip (cm) | | WHR | | Weight (kg) | | Height (cm) | | BMI (kg/m$^2$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1989/90 median | 5-year change | 1989/90 median | 5-year change | 1989/90 median | 5-year change | 1989/90 median | 5-year change | 1989/90 median | 5-year change | 1989/90 median | 5-year change |
| Men | 25–34 | 86.0 | 2.0 | 101.0 | 0.0 | 0.86 | 0.004 | 78.9 | 1.1 | 178.0 | 0.5 | 24.9 | 0.2 |
| | 35–44 | 92.0 | 1.0 | 102.5 | 0.0 | 0.91 | –0.001 | 82.0 | 0.0 | 176.0 | 0.5 | 26.5 | –0.1 |
| | 45–54 | 95.0 | 2.0 | 103.0 | 0.5 | 0.93 | 0.005 | 81.0 | 2.3 | 174.0 | 0.0 | 27.1 | 0.3 |
| | 55–64 | 98.0 | 1.0 | 103.5 | 0.5 | 0.94 | 0.011 | 81.3 | 2.7 | 172.0 | 0.0 | 27.7 | 0.5 |
| | 65–74 | 99.0 | –0.3 | 104.0 | –1.0 | 0.95 | 0.004 | 79.5 | 0.3 | 170.0 | 0.5 | 27.7 | 0.0 |
| Women | 25–34 | 72.0 | 1.0 | 94.0 | 3.0 | 0.76 | –0.011 | 61.0 | 1.3 | 164.5 | 0.5 | 22.5 | 0.3 |
| | 35–44 | 76.0 | –0.5 | 96.5 | 3.0 | 0.79 | –0.015 | 64.0 | 0.5 | 162.5 | 0.5 | 24.0 | 0.1 |
| | 45–54 | 80.0 | 2.5 | 101.0 | 2.0 | 0.80 | 0.001 | 67.9 | 1.5 | 161.5 | 0.5 | 25.9 | 0.4 |
| | 55–64 | 87.0 | 0.0 | 104.0 | 1.0 | 0.83 | –0.001 | 70.0 | 0.0 | 159.0 | 0.0 | 27.5 | 0.1 |
| | 65–74 | 86.0 | 40.0 | 104.0 | 2.0 | 0.83 | 0.010 | 68.3 | 2.8 | 156.5 | 1.0 | 27.7 | 0.5 |

(Table 3). In women, median hip circumference was substantially larger in 1994/95 than five years earlier, a trend not observed among men. A very small rise in median height was observed in most age groups among both men and women.

Changes in the distribution were furthermore explored by the use of mean-difference plots, first in the total 25–74 year age group and by gender. As shown in Fig. 1a in men, the distribution of waist circumferences seemed to be shifted by a fairly constant amount toward higher values. There was a slight indication of a greater increase in waist circumferences at both the lower and upper end of the distribution. No marked age effects were observed (data not shown). Among women we present the results stratified into two age groups in Fig. 1b. Analyses revealed that the striking upward trend at increasing waist levels was largely limited to women age 45–74 years. Women aged 25–44 years experienced a constant upward shift in the distribution similar to men.

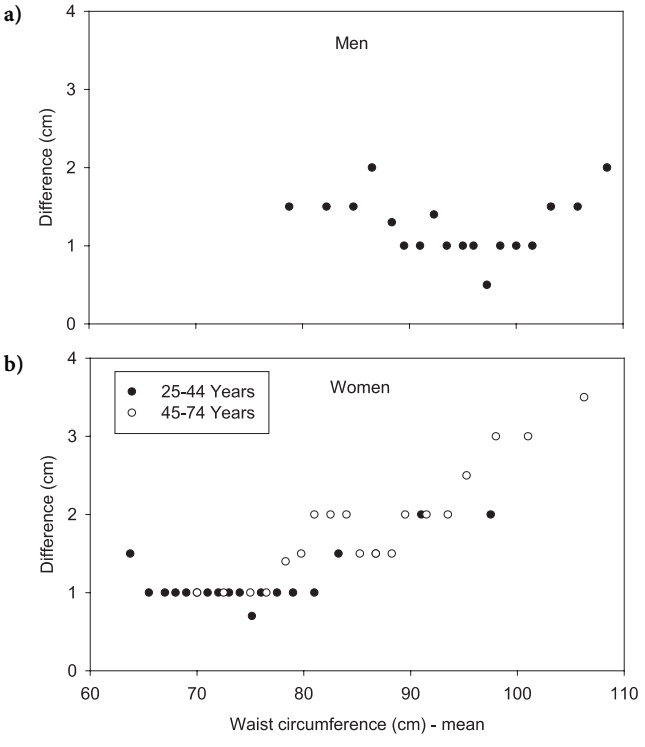


**Fig. 1** Five-year changes in the distribution of waist circumference in the MONICA Augsburg surveys 1989/90–1994/95: mean-difference plot for men and women.

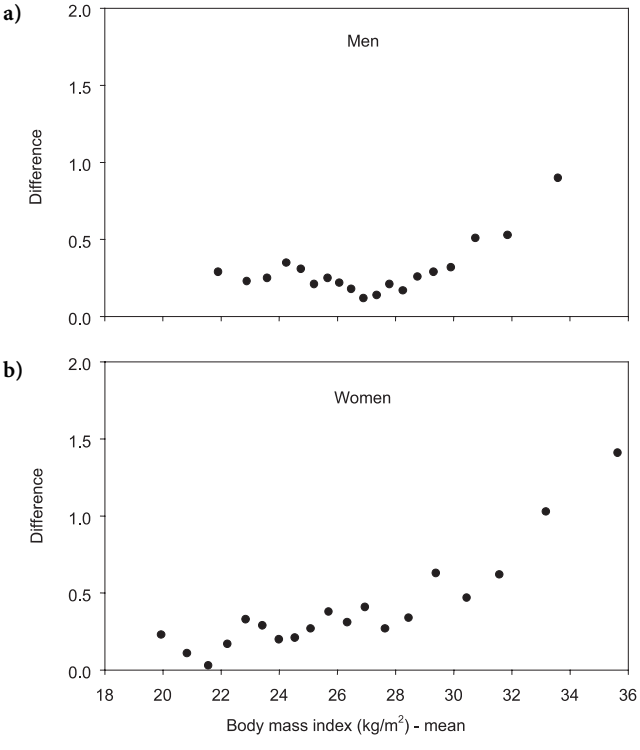


**Fig. 2** Five-year changes in the distribution of body mass index (BMI) in the MONICA Augsburg surveys 1989/90–1994/95: mean-difference plot for men and women.

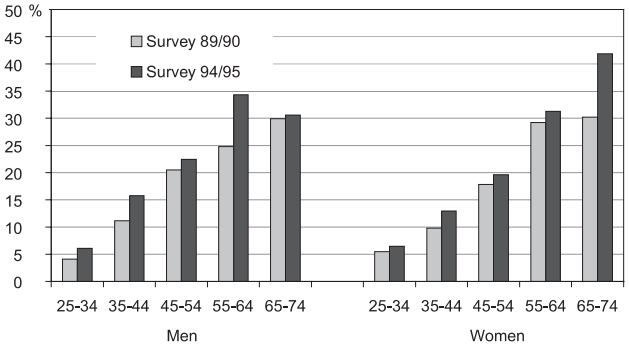


**Fig. 3** Age-specific prevalence of abdominal obesity (defined > gender-specific 80$^{th}$ percentile of waist circumference in 1989/90) in men and women of the MONICA Augsburg surveys 1989/90–1994/95.

Fig. 2 shows the mean-difference plots for changes in BMI in men and women, respectively. In both gender groups a trend toward higher BMI values at the upper end of the distributions was observed, indicating that over five years, the upper end of the BMI distribution in the population was becoming even more overweight.

Fig. 3 shows the prevalence of abdominal obesity by 10-year age and gender group for both surveys. A rise in prevalence was observed in all age groups and both men and women. Over five years, the age-standardized prevalence of abdominal obesity rose by 3.3 % (95 %CI 1.2–5.4) from 16.7 % in 1989/90 in men and by 3.6 % (95 %CI 1.5–5.6) from initially 16.9 % in 1989/90 in women. Over the same time period, the age-standardized prevalence of overall obesity (BMI ≥ 30 kg/m$^2$) rose by 2 % (95 %CI –0.2–4.1 %) from 17.3 % in men and by 2.5 % (95 %CI 0.3–4.7 %) from 19 % in 1989/90 in women (age-specific data not shown).

Fig. 4 displays five-year changes in both abdominal obesity and overall obesity by age group in men and women. Among men, the largest rise was observed among those 55–64 years old, another smaller peak being observed among 35–44 year old men. Among women, the highest age group [65–74] experienced the largest secular increase in prevalence of abdominal and overall obesity, while all younger women showed fairly similar increasing patterns of smaller magnitude. Increasing secular changes in both anthropometric characteristics were observed in women in the age groups 25–74, with the exception of the 55–64 year age group.

## Discussion

We observed a consistent increase in mean waist circumference and BMI as well as an increase in the prevalence of abdominal and overall obesity over five years in

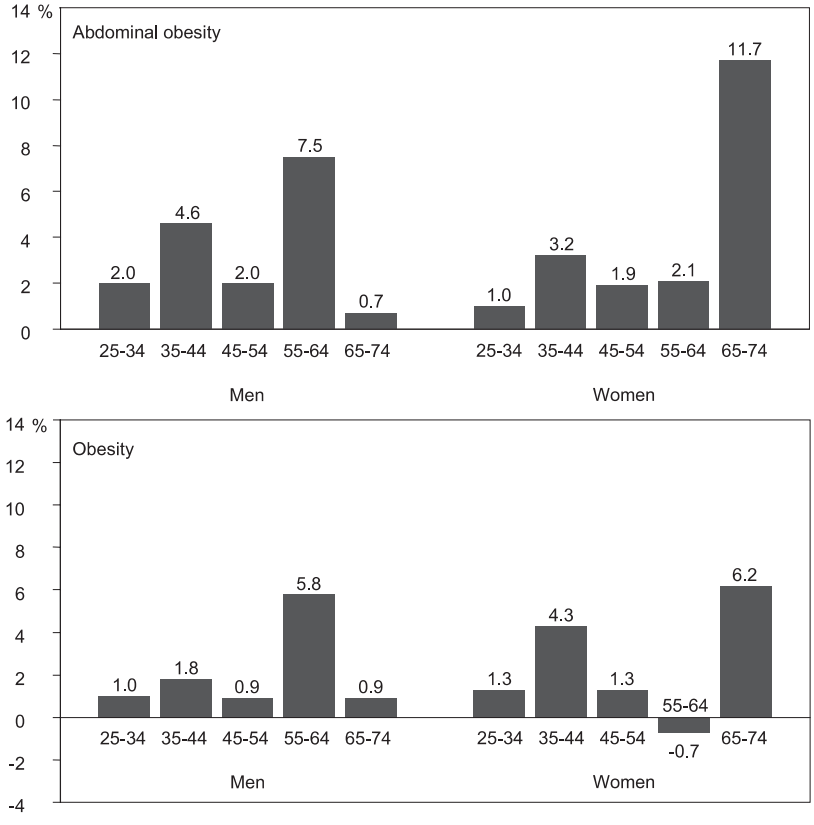


**Fig. 4** Five-year, age-group specific changes in the prevalence of abdominal obesity (> 80$^{th}$ waist percentile) and overall obesity (body mass index ≥ 30 kg/m$^2$) in men and women of the MONICA Augsburg surveys 1989/90–1994/95.

the Augsburg population. The pattern (i. e., direction and order of magnitude) of these five-year differences was similar for both waist circumference and BMI. This is noteworthy because waist circumference and weight and height are independently conducted measurements. Thus, our results show good internal consistency of the five-year changes.

Anthropometric and body fat distribution measurements can be ascertained with a high degree of reliability. Inter-rater reliabilities greater than 0.91 have been reported from other large, highly standardized epidemiologic studies [21, 22]. In the MONICA Augsburg surveys, particular emphasis was placed on observer training and quality control to maximize standardization of data collection across surveys. The methods and instructions for anthropometric and circumference measurements were kept identical throughout the surveys. Thus, we are highly confident that consistent increases in waist circumference and BMI observed in both men and women reflect unbiased measurements.

Comparison of the anthropometric characteristics of the MONICA Augsburg population to German national data [3, 6] demonstrates that the mean BMI of approximately 27 kg/m$^2$ in men and 26 kg/m$^2$ in women (in 1994/95) was well comparable with the mean of the average German population in 1997/98. However, the stature of the Augsburg population differs as both men and women are on average about 1.7 cm shorter and 1.1 kg lighter than their German peers [5]. This translates into both lower waist (1 cm in men, 2 cm in women) and hip (2 cm in men and women) circumferences, a higher WHR in Augsburg men but a lower WHR in Augsburg women compared to the German averages. Of the 48 populations involved in the international WHO MONICA project, men in Augsburg, Germany, ranked among those with the highest prevalence of obesity and waist circumference while Augsburg women ranged intermediate on both characteristics [1, 23].

The five year temporal changes between the early and mid 1990s described in this paper parallel national trends in BMI and obesity [24, 25]. The five year rise in BMI of 0.3 kg/m$^2$ among men and 0.4 kg/m$^2$ among women compares well with the average 0.3–0.5. kg/m$^2$ increase in Germany. We did, however, note a slight increase in average height which may be due to in-migration to the Augsburg population.

Very few data on temporal trends of body composition in populations have been published. Lissner et al. [14] observed very little changes in BMI across two 12 year intervals in Swedish women [(1968–1992). In contrast, the mean WHR, subscapular and triceps skinfold thickness increased substantially. In Finland, both waist circumference and WHR increased significantly between 1987 and 1997 in both men and women [15]. BMI increased in men but not in women. In the German MONICA Augsburg data, significant increases in waist circumferences were observed in both men and women. We furthermore observed a stronger upward trend among women aged 45 years and older, similar to that reported in the Finnish population [15].

Generally positive population-level changes in potential determinants of being overweight have been observed in the Augsburg population. The proportion of drinkers and the average amount of alcohol consumed among drinkers decreased [26] while the proportion of smokers basically did not change between 1989/90 and 1994/95 [5]. The intake of meat, meat products and potatoes as measured by a short qualitative food frequency questionnaire decreased markedly, while cheeses, rice, pasta, musli/cereal and cooked vegetables were being consumed more frequently in 1994/95 [27]. A noteworthy increase in leisure time physical activity occurred in both men and women (A. Döring, personal communication). It may therefore be argued that detrimental trends in adiposity may have been offset by these positive lifestyle influences.

The simple measure of waist circumference as applied in epidemiologic studies seems to capture the relation between obesity and disease well and has the advantage of a clearer interpretation than the WHR. Recently, so-called 'waist watchers' – color coded tape measures – have been applied as screening tools for overweight management in the UK based on previous empirical development of waist action levels [17, 28]. The cutpoints of 102 cm in men and 88 cm in women developed for the UK population do not transfer well to our Augsburg or even the German population [18]. It would be of great value, however, to develop similar population specific cutpoints for German preventive programs.

In summary, while changes in waist and BMI in the Augsburg population may not be as alarming as in other countries [2], the consistent increases observed in both men and women occurring over a short time period indicate a need for prevention given the already high absolute weight, BMI and waist circumference levels in our population.

**Acknowledgements** We would like to thank Andrea Schneider for data management, Monique Richter for preparation of the tables, Frank Meies and Ansgar Schneider for preparation of the figures.

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