# Socioeconomic Status and Anthropometric Changes—A Meta-Analytic Approach from Seven German Cohorts

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**Objective:** To study the association between socioeconomic status (SES) and annual relative change in anthropometric markers in the general German adult population.

**Methods:** Longitudinal data of 56,556 participants aged 18–83 years from seven population-based German cohort studies (CARLA, SHIP, KORA, DEGS, EPIC-Heidelberg, EPIC-Potsdam, PopGen) were analyzed by meta-analysis using a random-effects model. The indicators of SES were education and household income.

**Results:** On average, all participants gained weight and increased their waist circumference over the study's follow-up period. Men and women in the low education group had a 0.1 percentage points greater annual increase in weight (95% CI men: 0.06-0.20; and women: 0.06-0.12) and waist circumference (95% CI men: 0.01-0.45; and women: 0.05-0.22) than participants in the high education group. Women with low income had a 0.1 percentage points higher annual increase in weight (95% CI 0.00-0.15) and waist circumference (95% CI 0.00-0.14) than women with high income. No association was found for men between income and obesity markers.

**Conclusions:** Participants with lower SES (education and for women also income) gained more weight and waist circumference than those with higher SES. These results underline the necessity to evaluate the risk of weight gain based on SES to develop more effective preventive measures.

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## Introduction

Overweight and obesity are widespread, modifiable risk factors for metabolic-related diseases and mortality across all age and income levels worldwide. The prevalence of these conditions has recently substantially increased in several countries (1,2). Whereas in 1980, approximately 857 million people were affected, in 2013, it was estimated that almost 2.1 billion people, i.e., 30% of the population worldwide (2), had overweight or obesity. Germany is among the 10 countries globally with the highest prevalence, with 64% of men and 49% of women classified as suffering from overweight or obesity (2).

The Global Burden of Disease Study has estimated that in 2010, overweight caused 3.4 million deaths and 3.8% of global disability-adjusted life-years (DALYs) worldwide (3). These consequences together with the high prevalence of the condition underline the urgent need for useful interventions and mark its public health relevance. Actually, there are now numerous ongoing interventions, but the rise in prevalence of being overweight and obesity in recent years indicates that none has been successful enough (2). To develop more effective interventions, Keating et al. (4) proposed to report obesity trends for populations according to their socioeconomic status (SES). A clear association has been shown between SES and obesity in developed countries. People with a low SES have a greater risk to develop overweight than those with high SES and, interestingly, this association is more pronounced in women than men (5,6). In addition, Rokholm et al. (7) recently reported a SES

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gradient affecting the response to obesity interventions, where therapies are deemed less effective in the lower SES groups.

Few studies have been conducted that investigate the change of anthropometric markers in adults depending on SES (1). Several sociodemographic factors have been shown to be associated to weight gain: employment (8), low educational level, economic difficulties (9,10). Other indicators such as income have not yet been explored in detail. Together with weight, waist circumference appears to be the best simple anthropometric measure of abdominal fat (11). Some studies indicate that abdominal fat, but not total body fat, is related to metabolic disturbances and health risks (12,13). To examine the link between SES and waist and weight changes in adults may help identify the determinants of developing overweight and obesity and support the development of new, more adequate, and proficient interventions for specific SES groups. Therefore, the aim of the present work was to investigate the relationship between SES and change of anthropometric markers (weight and waist circumference) over a period of on average 7.2 years in the general German adult population taking several representative cohort studies into account (aged 18-83 years).

# Methods

## Study population

The meta-analysis included data from seven population-based longitudinal German cohort studies: CARLA (Cardiovascular Disease, Living and Ageing in Halle, Saxony-Anhalt), SHIP (Study of Health in Pomerania), KORA (Cooperative Health Research in the Region of Augsburg, Bavaria), the longitudinal section of the DEGS (German Health Interview and Examinations Survey for Adults), PopGen (Population Genetic Biobank, Kiel), EPIC-Heidelberg and EPIC-Potsdam (two study centers of the European Prospective Investigation into Cancer and Nutrition). These studies belong to the "German Competence Network Obesity," a project reviewed and funded by the Federal German Ministry of Education and Science (BMBF). They are characterized by a longitudinal data collection in an epidemiological setting with harmonized and comparable instruments to measure socioeconomic and anthropometric characteristics of the study participants. Only participants without missing values for weight and waist circumference at baseline and follow-up were included in this study. Exclusion criteria were pregnancy, limb amputation, or prosthesis implantation between baseline and follow-up, because they involve changes in body weight and/or waist circumference that are not associated with obesity. Thus, in total, data from 56,556 Caucasian participants was analyzed. The main characteristics of these studies are outlined in Table 1. Detailed information on study design and methods from each study has been published previously (14-21). The response rates at baseline ranged from 18% (PopGen) to 69% (SHIP), and at follow-up varied from 43% (DEGS) to 89% (EPIC-Potsdam), and were calculated as the ratio of the number of participants at follow-up and the number of participants at baseline excluding subjects who died or changed residence.

The implementation of each study conformed to the principles of the Helsinki Declaration. The studies were approved by the responsible ethics committees and public data protection offices. All participants provided written informed consent prior to study participation.

## Anthropometric markers

Weight and waist circumference were selected for the analyses of change in anthropometric markers. Weight, height, and waist circumference were measured similarly in CARLA, DEGS, KORA, and SHIP with standardized procedures (Haftenberger M, Mensink GBM, et al., unpublished data). Briefly, weight was measured to the nearest 0.1 kg, without shoes and wearing light clothing. Height was recorded to the nearest 0.1 cm. Waist circumference was measured using a rubber measuring tape, horizontally halfway between the lower border of the rib cage and the iliac crest. EPIC used comparable measurements at baseline but self-reported information from study participants at follow-up. PopGen used similar procedures for measurement of height and waist circumference, but weight was measured in fully-dressed barefoot participants, data on body weight was subsequently corrected for clothing by subtracting 2 kg.

Participants were classified as underweight (BMI $< 18.5$ kg/m$^2$), normal weight (BMI 18.5 kg/m$^2$ to $<25$ kg/m$^2$), overweight (BMI 25 kg/m$^2$ to $< 30$ kg/m$^2$), or people with obesity (BMI $\geq 30$ kg/m$^2$) according to the official criteria of the World Health Organization (22). As a result of the small numbers of underweight participants, the categories underweight and normal weight were merged and labeled as normal weight (BMI $< 25$ kg/m$^2$) for further analyses.

The relative annual changes in weight and waist circumference were calculated as follows:

$$\text{Annual relative weight change} = \frac{\text{weight}_{\text{Follow-up}} - \text{weight}_{\text{Baseline}}}{\text{weight}_{\text{Baseline}} \times \text{Follow-up}_{\text{Time}}} \times 100$$

$$\text{Annual relative waist change} = \frac{\text{waist}_{\text{Follow-up}} - \text{waist}_{\text{Baseline}}}{\text{waist}_{\text{Baseline}} \times \text{Follow-up}_{\text{Time}}} \times 100$$

A value of 0 means that there was no change; positive values indicate an increase, while negative values suggest a decrease in weight or waist circumference. In order to reflect the different follow-up times from each participant, we included follow-up time in the formula.

## Socioeconomic status

SES was determined as the highest education level for each participant and their current household income. No index for SES was used as we aimed to identify the individual determinants of anthropometric change over time (23).

*Education*. The education level was defined in accordance with the International Standard Classification of Education (ISCED, version 1997) (24). It includes compulsory, professional, and academic education. Study participants were classified as follows: low (9 or 10 years: lower secondary), medium (11-13 years: upper secondary), high (14-16 years: higher education), and highest level of education (17 years or more: university degree). Information on education level was available for all participants.

*Net household income*. Information on income of the participants was collected in CARLA, DEGS, SHIP, and KORA, but not in the PopGen and EPIC studies. For each study, participants were classified into three categories of income within approximately defined tertiles of the population: low/medium/high. These categories of income take regional differences into account. An additional difference was marked by political and economic changes in Europe: baseline recruitment took place before (DEGS, SHIP, KORA) or after (CARLA) currency changeover from the German

**TABLE 1** Study and participant characteristics of the involved cohort studies

| | CARLA | DEGS | EPIC-H (FU3) | EPIC-P (FU4) | KORA (S4/F4) | PopGen | SHIP |
|---|---|---|---|---|---|---|---|
| **Study region** | East: Halle (Saale) | National | Southwest: Heidelberg | East: Potsdam | South: Augsburg | North: Kiel | Northwest: Greifswald/Stralsund |
| **Federal state** | Saxony-Anhalt | National | Baden Württem-berg | Brandenburg | Bavaria | Schleswig-Holstein | Mecklenburg-West Pomerania |
| **Baseline** | | | | | | | |
| **Period** | 2002-2006 | 1997-1999 | 1994-1998 | 1994-1998 | 1999-2001 | 2005-2007 | 1997-2001 |
| **Participants** | 1,779 | 7,124 | 25,540 | 27,468 | 4,261 | 1,316 | 4,308 |
| **Response** | 64% | 61% | 38% | 23% | 67% | 18% | 69% |
| **Age range (years)** | 45-83 | 18-77 | 35-65 | 20-70 | 25-74 | 21-77 | 20-81 |
| ***Follow-up*** | | | | | | | |
| **Period** | 2007-2010 | 2008-2011 | 2004-2007 | 2004-2008 | 2006-2008 | 2010-2012 | 2001-2006 |
| **Participants** | 1,436 | 3,045 | 21,695 | 24,569 | 3,080 | 942 | 3,300 |
| **Response** | 81% | 43% | 85% | 89% | 72% | 72% | 77% |
| **Follow-up time (years)** | 4.0 ± 0.25 | 11.9 ± 1.0 | 8.6 ± 0.7 | 8.6 ± 0.9 | 7.1 ± 0.3 | 4.9 ±0.5 | 5.3 ± 0.6 |
| ***Baseline characteristics of men included in the analysis*** | | | | | | | |
| ***N*** | 783 | 1,443 | 9,522 | 9,273 | 1,476 | 509 | 1,578 |
| **Age (years)** | 63.7 ± 10.0 | 45.5 ± 13.4 | 52.4 ± 7.1 | 52.3 ± 8.0 | 49.6 ± 13.4 | 56.5 ± 11.6 | 50.2 ± 15.5 |
| **Weight (kg)** | 84.5 ± 13.9 | 84.2 ± 12.5 | 83.3 ± 11.9 | 82.6 ± 11.8 | 84.1 ± 12.3 | 85.7 ± 13.0 | 85.4 ± 13.4 |
| **Waist (cm)** | 102.9 ± 10.7 | 96.7 ± 10.8 | 95.6 ± 9.9 | 94.7 ± 9.9 | 97.1 ± 10.2 | 97.4 ± 11.1 | 95.7 ± 11.4 |
| **BMI categories, *N* (%)** | | | | | | | |
| **Normal weight** | 178 (22.7) | 429 (29.7) | 2,997 (31.5) | 2,762 (29.8) | 368 (24.9) | 179 (35.2) | 395 (25.0) |
| **Overweight** | 391 (49.9) | 755 (52.3) | 4,921 (51.7) | 4,935 (53.2) | 792 (53.7) | 249 (48.9) | 786 (49.8) |
| **Obesity** | 214 (27.3) | 259 (17.9) | 1,591 (16.7) | 1,576 (17.0) | 316 (21.4) | 81 (15.9) | 397 (25.2) |
| ***Education, N (%)*** | | | | | | | |
| **9-10 years** | 24 (3.1) | 112 (7.9) | 196 (2.1) | 125 (1.4) | 63 (4.0) | 15 (3.0) | 76 (5.0) |
| **11-13 years** | 307 (39.2) | 706 (50.0) | 4,714 (49.7) | 2,742 (29.6) | 689 (47.0) | 222 (43.6) | 953 (61.0) |
| **14-16 years** | 170 (21.7) | 286 (20.2) | 1,727 (18.2) | 1,690 (18.2) | 409 (28.0) | 101 (19.8) | 188 (12.0) |
| **>17 years** | 282 (36.0) | 309 (21.9) | 2,856 (30.1) | 4,711 (50.8) | 312 (21.0) | 171 (33.6) | 358 (23.0) |
| ***Income, N (%)*** | | | | | | | |
| **1. tertile (low)** | 218 (28.2) | 347 (28.1) | Not available | Not available | 276 (19.5) | Not available | 452 (30.3) |
| **2. tertile (medium)** | 225 (29.1) | 317 (25.6) | | | 576 (40.7) | | 477 (32.0) |
| **3. tertile (high)** | 331 (42.8) | 573 (46.3) | | | 563 (39.8) | | 561 (37.7) |
| ***Baseline characteristics of women included in the analysis*** | | | | | | | |
| ***N*** | 637 | 1,546 | 11,352 | 14,793 | 1,566 | 390 | 1,688 |
| **Age (years)** | 62.6 ± 9.3 | 45.7 ± 12.7 | 49.4 ± 8.5 | 49.0 ± 9.3 | 48.8 ± 13.0 | 55.6 ± 13.0 | 48.4 ± 15.0 |
| **Weight (kg)** | 73.0 ± 14.1 | 69.9 ± 13.4 | 67.8 ± 12.2 | 68.0 ± 12.6 | 70.4 ± 13.5 | 71.2 ± 14.2 | 71.1 ± 13.6 |
| **Waist (cm)** | 94.7 ± 13.2 | 84.0 ± 12.5 | 80.7 ± 11.3 | 80.4 ± 11.4 | 84.8 ± 12.3 | 84.6 ± 13.0 | 82.8 ± 12.8 |
| ***BMI categories, N (%)*** | | | | | | | |
| **Normal weight** | 188 (29.5) | 753 (48.7) | 6359 (56.0) | 7623 (51.5) | 641 (40.9) | 190 (48.7) | 720 (42.7) |
| **Overweight** | 248 (38.9) | 487 (31.5) | 3360 (29.6) | 4778 (32.3) | 562 (35.9) | 140 (35.9) | 547 (32.4) |
| **Obesity** | 201 (31.6) | 306 (19.8) | 1623 (14.3) | 2392 (16.2) | 363 (23.2) | 60 (15.4) | 421 (24.9) |

**TABLE 1.** (continued).

| | CARLA | DEGS | EPIC-H (FU3) | EPIC-P (FU4) | KORA (S4/F4) | PopGen | SHIP |
|---|---|---|---|---|---|---|---|
| *Education, N (%)* | | | | | | | |
| **9-10 years** | 73 (11.5) | 228 (14.9) | 1122 (9.9) | 441 (3.0) | 255 (16.0) | 37 (9.5) | 227 (13.0) |
| **11-13 years** | 306 (48.0) | 890 (55.8) | 4027 (35.6) | 5308 (35.9) | 815 (52.0) | 213 (54.6) | 1048 (62.0) |
| **14-16 years** | 146 (22.9) | 218 (14.3) | 3684 (32.6) | 4704 (31.8) | 315 (20.0) | 75 (19.2) | 168 (10.0) |
| **> 17 years** | 112 (17.6) | 190 (12.5) | 2473 (21.9) | 4334 (29.3) | 179 (11.0) | 65 (16.7) | 242 (14.0) |
| *Income, N (%)* | | | | | | | |
| **1. tertile (low)** | 284 (45.2) | 447 (35.6) | Not available | Not available | 426 (29.2) | Not available | 615 (38.2) |
| **2. tertile (medium)** | 143 (22.7) | 296 (23.6) | | | 543 (37.3) | | 526 (32.7) |
| **3. tertile (high)** | 202 (32.1) | 512 (40.8) | | | 488 (33.5) | | 470 (29.2) |

BMI = body mass index; CARLA = CARdiovascular disease, Living and Aging in Halle; DEGS = German Health Interview and Examination Survey for Adults; EPIC = European Prospective Investigation into Cancer and Nutrition; KORA = Cooperative Health Research in the Region of Augsburg; POPGEN = Population Genetic Biobank; SHIP = Study of Health in Pomerania.

Mark (DM) to the Euro (€). Monthly net household income was categorized as:

- CARLA: low ≤1,500 €; medium = 1,500 €-2,000 €; high ≥2,000 €
- DEGS: low ≤3,000 DM; medium = 3,000 DM-4,000 DM; high ≥4,000 DM
- SHIP: low ≤2,250 DM; medium = 2,250 DM-3,500 DM; high ≥3,500 DM
- KORA: low ≤3,000 DM; medium = 3,000 DM-5,000 DM; high ≥5,000 DM.

### Statistical approach

Each study performed individual statistical analyses according to a common plan of analysis. Analyses were done with SAS®, version 9.3 (SAS Inc., Cary, NC). The association between education level or income categories and annual relative changes in weight or waist circumference were analyzed by linear regression models. Assumptions of linearity were confirmed by visual inspection of the residuals. Associations between changes in anthropometry and education were adjusted for age and age$^2$ (the latter to model non-linear relations) and those with income were additionally adjusted for education years. All analyses were sex-stratified. The results of all studies were summarized with a meta-analysis approach using Review Manager Version 5.3. (Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014). Effect measures were presented as differences between SES groups in annual relative changes of anthropometric markers with their 95% confidence intervals (95% CI). Based on the 1) high heterogeneity in subject characteristics and measurement of key parameters such as income between included cohort studies, and 2) to draw inferences about the general population from which the participants were recruited, the random-effects model for meta-analyses and calculated Forest plots were applied.

A sensitivity analysis was carried out to test the robustness of the findings in those participants free from diseases that potentially influence body constitution. Therefore, participants with myocardial infarction, stroke, cancer, diabetes, heart failure, or thyroid disease at baseline or follow-up were excluded ($N = 19{,}932$) for sensitivity analysis.

## Results

### Study population

Seven German cohort studies with a total of 56,556 participants (24,584 men and 31,972 women) were included in the present meta-analysis (Table 1). The mean interval between the baseline and follow-up examination was 7.2 years with a range from 3.2 years (PopGen) to 14.1 years (DEGS). The mean age at baseline for men was 52.9 years (range 18-83 years) and the mean age for women was 51.3 years (range 18-83 years). Age ranges varied between studies from the broad spectrum in DEGS (18-77 years) to mostly older adults in CARLA (45-83 years). The overall proportion of study participants with obesity was 20.2% for men—with a range of 15.9% (PopGen) to 27.3% (CARLA)—and 20.8% for women—with a range of 14.3% (EPIC-H) to 31.6% (CARLA). About 26.2% of men with obesity and 33.5% of women with obesity were in the lowest

**TABLE 2** Relative annual anthropometric changes in each study

| | Men | | | Women | | |
|---|---|---|---|---|---|---|
| Project | *N* | Mean | 95% CI | *N* | Mean | 95% CI |
| *Relative annual weight change* | | | | | | |
| CARLA | 783 | −0.02 | −0.11; 0.07 | 637 | 0.08 | −0.04; 0.20 |
| DEGS | 1443 | 0.26 | 0.22; 0.29 | 1546 | 0.35 | 0.31; 0.39 |
| EPIC-H | 9522 | 0.12 | 0.10; 0.14 | 11352 | 0.21 | 0.19; 0.23 |
| EPIC-P | 9273 | 0.19 | 0.18; 0.21 | 14793 | 0.33 | 0.31; 0.34 |
| PopGen | 509 | 0.37 | 0.27; 0.47 | 390 | 0.43 | 0.28; 0.58 |
| SHIP | 1578 | 0.39 | 0.33; 0.46 | 1688 | 0.56 | 0.49; 0.63 |
| KORA | 1476 | 0.33 | 0.28; 0.37 | 1566 | 0.33 | 0.28; 0.39 |
| *Relative annual waist circumference change* | | | | | | |
| CARLA | 783 | 0.30 | 0.22; 0.37 | 637 | −0.22 | −0.34; −0.10 |
| DEGS | 1443 | 0.28 | 0.24; 0.31 | 1546 | 0.50 | 0.46; 0.54 |
| EPIC-H | 8228 | 0.59 | 0.56; 0.61 | 9860 | 1.01 | 0.98; 1.04 |
| EPIC-P | 9273 | 0.72 | 0.70; 0.73 | 14793 | 1.10 | 1.09; 1.12 |
| PopGen | 509 | 0.77 | 0.65; 0.88 | 390 | 1.61 | 1.44; 1.78 |
| SHIP | 1578 | 0.65 | 0.59; 0.71 | 1688 | 1.02 | 0.96; 1.09 |
| KORA | 1476 | 0.39 | 0.35; 0.44 | 1566 | 0.59 | 0.53; 0.64 |

CARLA = CARdiovascular disease, Living and Aging in Halle; CI = confidence interval; DEGS = German Health Interview and Examination Survey for Adults; EPIC = European Prospective Investigation into Cancer and Nutrition; KORA = Cooperative Health Research in the Region of Augsburg; POPGEN = Population Genetic Biobank; SHIP = Study of Health in Pomerania.

education level (9 to 10 years of education) and 12.8% of men with obesity and 9.1% of women with obesity were in the highest education level (≥ 17 years of education).

## Change of anthropometric measures

In every individual study, the mean weight increased over the follow-up time, except for men from the CARLA study, where no mean weight change was seen (Table 2). The mean annual relative weight change for all cohort studies was 0.23% (95% CI 0.16; 0.30) for men and 0.33% (95% CI 0.25; 0.40) for women. Furthermore, for each study, the mean waist circumference increased over the study follow-up time, except for women from the CARLA study, where a slight decrease in mean waist circumference was observed. The mean annual relative change in waist circumference for all cohort studies was 0.53% (95% CI 0.38; 0.67) for men and 0.80% (95% CI 0.57; 1.03) for women.

## General association between SES and change in anthropometric markers

Weight and waist circumference rose in all education and income categories in women and in all education categories in men (Figures 1 and 2). However, the magnitude of this increase was dependent on SES, with a greater gain of weight and waist circumference in groups with lower education or income, respectively.

*Association between education and change in anthropometric markers*. The weight increase was strongest in participants with the lowest education level (level 1: 9-10 years) (Figure 3). Compared to those with the highest education level (level 4: ≥ 17 years), men in the low education group had a 0.13 percentage points (95% CI 0.06; 0.20) higher annual increase in weight. The total effect estimate for women with low education was similarly high. Women in the low education group had a 0.14 percentage points (95% CI 0.09; 0.20) higher annual increase in weight than women with ≥ 17 years of education. The differences in weight change were less between the higher education levels. Women with 11-13 years of education had 0.09 percentage points (95% CI 0.06; 0.12) higher and women with 14-16 years of education had 0.03 percentage points (95% CI 0.00; 0.06) higher annual increase in weight than those with ≥ 17 years of education. For men, the differences in weight change between the participants with education levels 2 and 3 compared with 4 were not significant. The described associations between education and change in weight could be confirmed in sensitivity analyses on participants without prevalent diseases (data not shown).

Regarding the association between education and changes in waist circumference, a similar pattern to weight changes was established. The relationship was stronger for women than for men. Thus, women with lowest education level (9-10 years) had 0.14 percentage points (95% CI 0.05; 0.22) greater annual increase in waist circumference than women with the highest education level (≥ 17 years), whereas the annual increase in waist circumference in men with lower education level was 0.09 percentage points (95% CI 0.01; 0.45) higher than in men with the highest education. Similar results were seen in the sensitivity analyses on participants without diseases which increase the risk of obesity ($n = 36{,}624$). Additionally, women with 11-13 years of education had a 0.12 percentage points (95% CI 0.09; 0.15) higher annual increase and those with 14-16 years of education had a 0.06 percentage points (95% CI 0.02; 0.09) higher annual increase than women with ≥ 17 years of education. In men without prevalent diseases, there was a difference in change of weight between the participants in the highest versus lowest level of

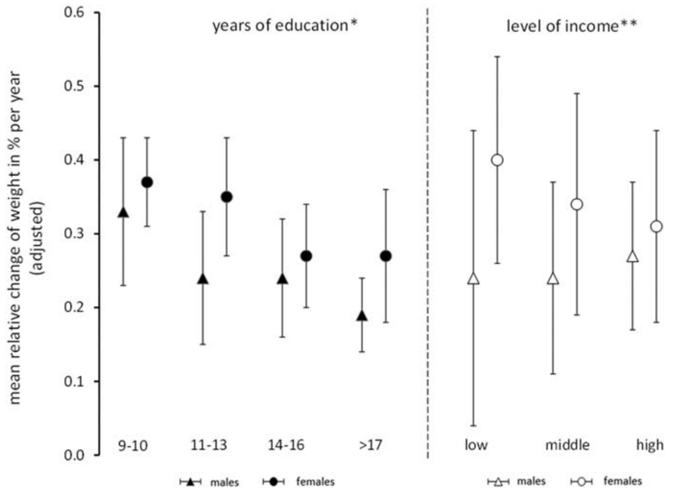


**Figure 1** Sex-stratified mean annual relative change of weight (%) according to education and income level. *Adjusted for age and age$^2$. **Adjusted for age, age$^2$, and education. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

education, but there was no education gradient and no stable association between education and change of waist circumference.

*Association between income and change of anthropometric markers*. Women with low income had a 0.08 percentage points (95% CI 0.00; 0.15) higher annual increase in weight versus women with high income (Figure 4). All other comparisons revealed no differences in weight change between the participants with different levels of income. The association between income and change in waist circumference showed comparable results. Women in the low income group had a 0.07 percentage points (95% CI 0.00; 0.14) greater increase in waist circumference than women in the high income group. All other comparisons revealed no differences in waist circumference between the participants with different levels of income. The sensitivity analyses showed no significant association between income and change in anthropometric markers (data not shown).

## Discussion

Consistent with the literature it can be confirmed that obesity in Germany is inversely associated with SES among women and less consistently in men (1,6). This association is also clearer for education than for income. Regardless of the level of education, average weight and waist circumference increased over the follow-up period. Additionally, in agreement with the results of the methodologically strongest studies in the review by Ball and Crawford (2005), the work presented here supports the hypothesis that a lower level of education is associated with larger weight gain (1). Men and women with low levels of education (9-10 years) had a 0.1 percentage points greater annual weight gain than those with the highest level of education ($\geq$17 years). Similarly participants with the lowest level of education had a 0.1 percentage points larger increase in waist circumference than participants with the highest levels of education. Arguably, the overall effect size is probably too small to be of clinical relevance. There are few data, however, that specify the exact weight and waist circumference changes deemed clinically significant. It has been documented that loss or gain of weight equivalent to 25% of body weight can lead to enhanced morbidity and mortality (25). Comparable to education level, women with a low income had a 0.1 percentage points greater increase in weight and a 0.1 percentage points higher increase in waist circumferences than those with what was considered high income. Nonetheless, sensitivity analyses for the association between income and anthropometric changes in women revealed less stable links for the women without prevalent disease. This is in accordance with data by Ball and Crawford (1) where income showed inconsistent results for both men and women. No connections between income and change in anthropometric markers for men were found in the current work. A possible explanation for this lack of association is that the income differences in Germany, at least for men, are not big enough to show an effect on anthropometric markers. A study has showed that having an income above or below the poverty levels, but not income alone was associated with health-outcomes (26). Also status inconsistency, defined as divergences in the indicators of SES (education and income) in one person, could explain this lack of association. It has been reported that in Germany there is a status inconsistency in terms of higher employment compared to education was more prevalent for men than for women and the opposite, lower employment compared to education was more prevalent for women (27). Thus, income may not be a thorough enough indicator of SES for men in our study.

In order to explain the sex-specificity of the association between SES and obesity, Pudrovska et al. proposed the combination of two mechanisms: first, the obesogenic effect of socioeconomic disadvantage and second, the SES-impeding effect of obesity (28). Body mass and SES are simultaneously antecedents and consequences of each other over the life course via mutually reinforcing patterns of effects (28). The stronger SES gradient in anthropometric markers or change in anthropometric markers seen in women could be partially explained by weight-based stigma,

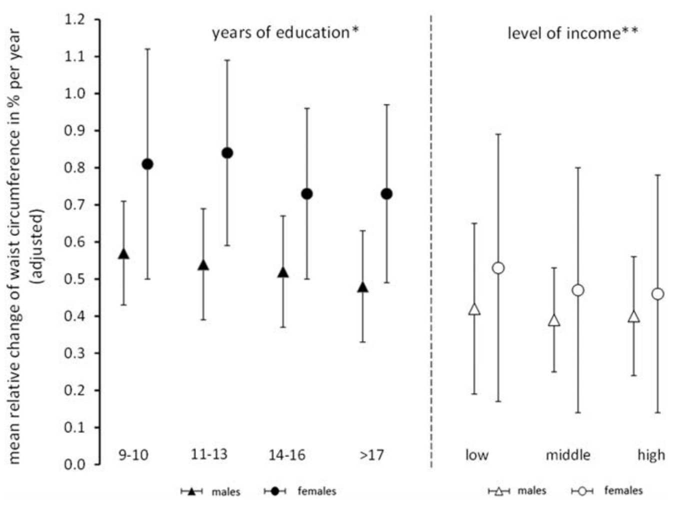


**Figure 2** Sex-stratified mean annual relative change of waist circumference (%) according to education and income level sex-stratified. *Adjusted for age and age$^2$. **Adjusted for age, age$^2$, and education. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

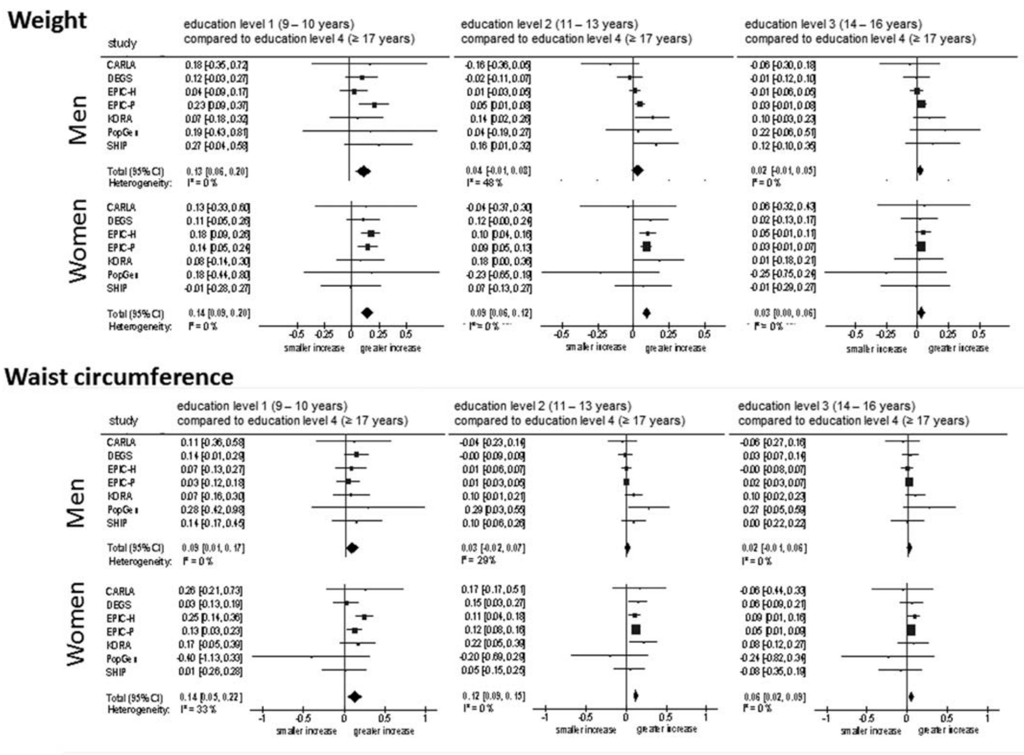


**Figure 3** Sex-stratified forest plot for differences among education levels in annual relative weight and waist circumference changes. Reference group was education level 4 (≥ 17 years of education). A value of 0 means no difference in anthropometric changes between education groups; positive values mean that participants with education level 1 or 2 have more gain than those in the reference group; and negative values that participants in the reference group have more gain than those at level 1 or 2. CI = confidence interval; $I^2$ = measure of heterogeneity (percentage of variance in a meta-analysis that is attributable to study heterogeneity).

discrimination, and social pressure, whereas a large body size in men could be valuated as an indication of power and dominance (6,28). It is suggested that understanding the social distribution of obesity would be enriched by considering obesity as potentially both a consequence and a cause of social status (29).

The principal strength of the present study is the large number of participants, an outcome of the cooperation of seven cohort studies with highly standardized data collection and methods. The use of two measures of obesity (weight and waist circumference) and two measures of SES (education and income) allows us to strengthen the results. Additionally, statistical analyses were performed according to a common plan of analysis. This meta-analysis offers the opportunity to compile data from relevant population-based prospective studies conducted during the past decade and representing most regions in Germany. On the other hand, several potential sources of heterogeneity should be noted. First, the age of the participants varied greatly between the cohorts. It is well known that younger adults have a larger weight gain that diminishes with age while older participants lose weight (30). In order to correct for the confounding effect of age, age, and age$^2$ were adjusted, yet there may be residual confounding. Thus, further studies should be done to examine the possible variability in the association of SES and obesity among various age groups. A second limitation is the use of slightly different sampling procedures between the studies, i.e., PopGen had a convenience sample and not a random sample as all other studies. The use of cohorts with variable sampling and response rates might have an impact on the generalizability of the findings as non-responders are more likely to be from the low SES group. However, influence of low response on generalizability of effects in cohort studies is controversially discussed (31,32). Another limitation might be the different follow-up intervals between the studies. The mean interval between the baseline and follow-up examination was 7.2 years with a range from 3.2 years (PopGen) to 14.1 years (DEGS). To minimize these differences, the relative change of anthropometric markers per year was calculated, however presupposing a linear change. These limitations corresponding with time factors or differences between the measurement methods could influence the results of change in anthropometric markers but should not affect their associations with SES. With this, the relatively low participation rate in a number of cohort studies might potentially cause selection bias.

Despite the identified limitations, an inverse association in women between SES and the change in anthropometric markers and in men between education and changes in anthropometric markers has been identified. It seems obvious that SES has a lifelong impact on anthropometric markers and their change. The socioeconomic gradient is consistently greater for women than for men and education level is a more stable influential factor than income. A gain in weight is accelerated in individuals of low SES and this is likely to further affect the already existing health inequalities for obesity-related chronic conditions. Consequently, this work aligns with

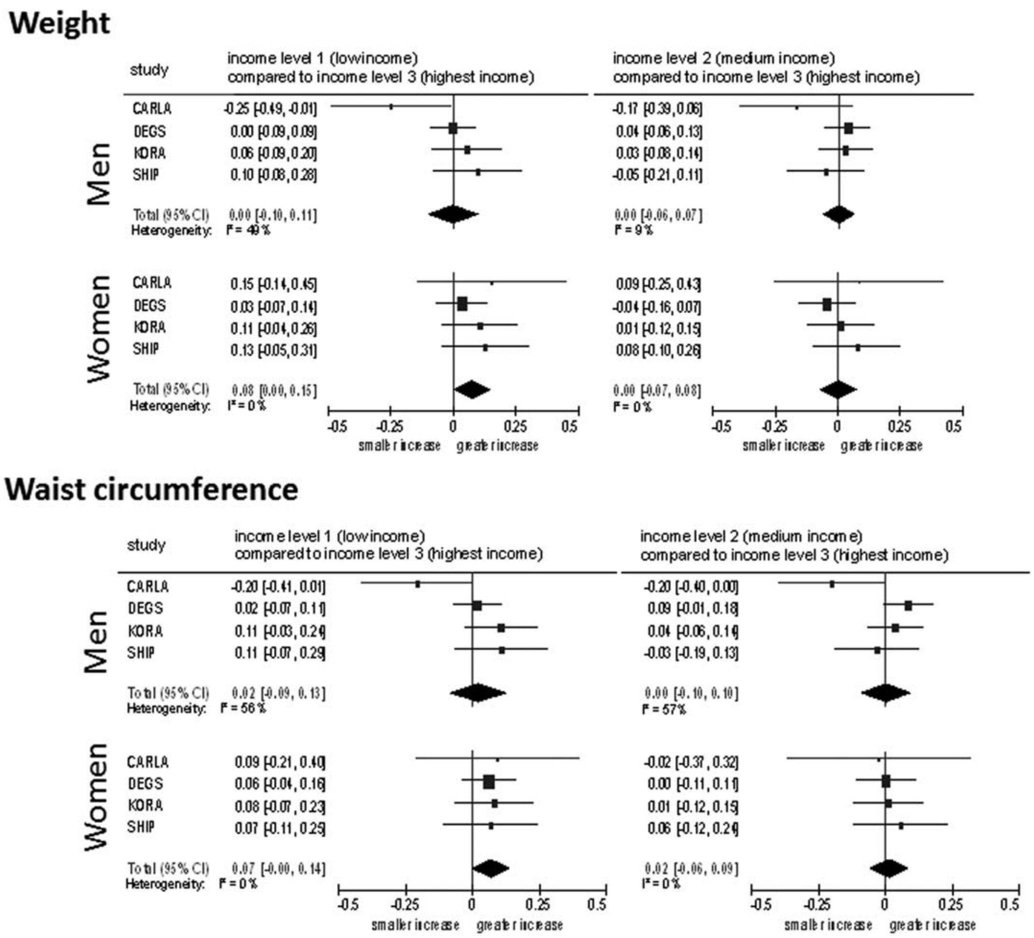


**Figure 4** Sex-stratified forest plot for differences among income groups in annual relative weight and waist circumference changes. Reference group was income level 3 (high income). A value of 0 means no difference in anthropometric changes between income groups; positive values mean that participants with income level 1 or 2 have more gain than those in the reference group; and negative values that participants in the reference group have more gain than those at level 1 or 2. CI = confidence interval; $I^2$ = measure of heterogeneity (percentage of variance in a meta-analysis that is attributable to study heterogeneity.)

previous studies in that stronger preventive efforts are required, especially for the socioeconomically disadvantaged. Nonetheless, here, on average, all people regardless of their educational level gained weight and increased their waist circumference.

## Conclusion

Ultimately, these results highlight the need for stratifying weight trends by SES in order to develop more effective preventive measures. The focus should be on the development of interventions for socially disadvantaged people, but not to the exclusion of other SES groups. The knowledge of education being a stable influencing factor may allow for the development of differentiated individual health programs to stop the rising trend of obesity. O



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