

ORIGINAL ARTICLE

Changes in body weight and obesity status in German adults: results of seven population-based prospective studies

M Haftenberger¹, GBM Mensink¹, B Herzog², A Kluttig², KH Greiser^{2,9}, B Merz³, U Nöthlings³, S Schlesinger⁴, S Vogt⁵, B Thorand⁵, A Peters^{5,6}, T Ittermann⁷, H Völzke^{7,8}, S Schipf⁷, J Neamat-Allah⁹, T Kühn⁹, R Kaaks⁹, H Boeing¹⁰, U Bachlechner¹⁰, C Scheidt-Nave¹ and A Schienkiewitz¹

BACKGROUND/OBJECTIVES: The objective of this study was to quantify body weight changes in German adult populations during the past decades.

SUBJECTS/METHODS: Longitudinal analysis of seven cohort studies covering different age ranges between 18 and 83 years. Baseline examinations were between 1994 and 2007 and follow-up durations between 4.0 and 11.9 years. For each study, mean change in body weight per year and 10-year change in body mass index (BMI) classification were analyzed. For the middle age group of 45–64 years, meta-analysis was conducted to obtain an overall estimate for Germany.

RESULTS: Among men weight gain was highest in the youngest participants and decreased with advancing age. Among women weight gain was on a stable high level among those younger than 45 years and decreased at older age. Within 10 years, 30–40% of middle-aged participants with normal baseline weight became pre-obese or obese and 20–25% of those with pre-obesity at baseline became obese, whereas >80% of persons who were obese at baseline remained obese over time. The estimated average weight change in adults aged 45–64 years was 0.25 (95% confidence interval (CI): 0.18–0.33) kg/year among men and 0.24 (0.17–0.30) kg/year among women.

CONCLUSIONS: We could observe a moderate weight gain over the past years in German middle-aged populations of 0.25 kg/year. Obesity prevention needs to be targeted to specific subgroups in the population, especially to younger adults, who seem to be most vulnerable for gaining weight. Obesity intervention needs to be improved, as the majority of obese adults remained obese over time.

European Journal of Clinical Nutrition (2016) **70**, 300–305; doi:10.1038/ejcn.2015.179; published online 28 October 2015

INTRODUCTION

During the past decades, the prevalence of overweight (body mass index, BMI ≥ 25.0 kg/m²) and obesity (BMI ≥ 30.0 kg/m²) has rapidly increased worldwide.^{1–3} Because of the health-related consequences of obesity⁴ and the associated medical costs,^{5,6} long-term weight management is of major importance. Prospective cohort studies may provide insight into patterns of weight change due to directly observing individuals over time and may help identify critical periods of weight change during life, which is relevant for planning public health actions.

In Germany, weight change has already been described for several single prospective studies such as the Cooperative Health Research in the Region of Augsburg (KORA) Platform,^{6–8} the German arm of the European Prospective Investigation into Cancer and Nutrition (EPIC)^{9–12} and the German sites of the European Community Respiratory Health Survey (ECRHS).¹³ Recently, first national data on adult weight change in Germany were generated by the German Health Interview and Examination Survey for Adults (DEGS), which allows the description of individual weight change from 1998 until 2008–2011 in Germany.¹⁴

The present analysis aims to quantify individual changes in body weight in the German adult population over time with special reference to sex, age and region. Furthermore, the change in obesity status of individuals will be described. The analysis is based on data from the nationwide prospective study of DEGS and six regional prospective population-based studies involved in the EPI Germany Consortium of the German Competence Network Obesity. Compiling the results from the nationwide study with results of regional prospective studies will provide a more comprehensive overview of adult weight change in Germany during the past decade and may help to better identify critical periods of weight change during adult life than a single study.

MATERIALS AND METHODS

The study includes a national cohort from DEGS¹⁴ and six regional cohort studies covering the control cohort of the PopGen bio-bank from Kiel,¹⁵ the Study of Health in Pomerania (SHIP),^{16,17} the two German study sites from the EPIC study in Potsdam (EPIC-Potsdam) and Heidelberg (EPIC-Heidelberg),¹⁸ the study of Cardiovascular Disease, Living and Ageing in

¹Department of Epidemiology and Health Monitoring, Robert Koch Institute, Berlin, Germany; ²Institute of Medical Epidemiology, Biostatistics and Informatics, Martin-Luther-University Halle-Wittenberg, Halle (Saale), Germany; ³Institute for Nutrition and Food Science, Rheinische Friedrich-Wilhelms-University Bonn, Bonn, Germany; ⁴Institute of Epidemiology, Christian-Albrechts University of Kiel, Kiel, Germany; ⁵Institute of Epidemiology II, Helmholtz Center Munich, German Research Center for Environmental Health, Neuherberg, Germany; ⁶German Centre for Diabetes Research (DZD e.V.), Neuherberg, Germany; ⁷Institute for Community Medicine, University Medicine Greifswald, Greifswald, Germany; ⁸German Centre of Cardiovascular Research, Partner Site Greifswald, University Medicine Greifswald, Greifswald, Germany; ⁹Division of Cancer Epidemiology, German Cancer Research Center (DKFZ), Heidelberg, Germany and ¹⁰Department of Epidemiology, German Institute of Human Nutrition, Potsdam-Rehbrücke, Nuthetal, Germany. Correspondence: M Haftenberger, Department of Epidemiology and Health Monitoring, Robert Koch Institute Berlin, Postbox 65 02 61, 13302 Berlin, Germany. E-mail: haftenbergerm@rki.de

Received 23 April 2015; revised 17 September 2015; accepted 28 September 2015; published online 28 October 2015

Halle (CARLA) Saxony-Anhalt^{19,20} and the fourth KORA survey and follow-up study.²¹ These studies decided to form a consortium to study the determinants and consequences of weight development in the adult population.

Each study was conducted according to the guidelines laid down in the Declaration of Helsinki. The study protocol of the nationwide DEGS was consented with the Federal and State Commissioners for Data Protection and approved by the Charité-Universitätsmedizin Berlin ethics committee in September 2008 (No. EA2/047/08). The regional studies were approved by the local ethic committees and the local public data protection offices. All participants provided a written informed consent before study participation.

Study populations

Table 1 summarizes relevant characteristics of each study. Years of baseline examination were between 1994 and 2007, and follow-up duration varied between 4 and 12 years. At the time of analysis, only the EPIC studies completed more than one follow-up. To assure similar duration of follow-up across studies, the data of the third follow-up assessment from EPIC-Heidelberg and the fourth follow-up assessment from EPIC-Potsdam were included in the analysis. All studies were population based, except the PopGen cohort, which additionally included a sample of voluntary blood donors.¹⁵ Analysis was limited to the population-based sample. The study populations from DEGS, SHIP and KORA virtually covered the whole adult life span, whereas the EPIC studies involved adults aged 35–64 years and the CARLA as well as the PopGen study involved adults aged 45 and older. Participation rate at follow-up, calculated as the ratio of the number of participants at follow-up and the number of participants at baseline minus the number of subjects who died or withdrew, varied from 47 to 92%.

Anthropometry

Baseline body weight (kg) and body height (cm) were measured using standardized procedures. Measurements were conducted in light clothing without shoes (SHIP, KORA and DEGS), in underwear without shoes (EPIC and CARLA) or in normal clothing without shoes (PopGen). Baseline height was measured in standing position without shoes in each study.

At follow-up, body weight and height were measured using the same measurement procedures in most studies. At follow-up of DEGS, participants were wearing only underwear for body weight measurements. In EPIC, follow-up assessment of body weight, but not body height, relies on self-reports from a postal questionnaire.

For PopGen participants, a correction factor to adjust for clothing amounting to –2 kg was applied to the measured weight at each examination. In EPIC, self-reported body weight was corrected using prediction equations to reduce possible bias resulting from self-reports conforming to previous analyses.^{22,23}

BMI was calculated as body weight (kg) divided by the square of body height (m) and classified as underweight (BMI < 18.5 kg/m²), normal weight (18.5 ≤ BMI < 25 kg/m²), overweight (BMI ≥ 25 kg/m²), pre-obesity (25 ≤ BMI < 30 kg/m²) and obesity (BMI ≥ 30 kg/m²) according to the criteria of the World Health Organization.⁴ As the proportion of adults, who were underweight, was small (for example, 0.8% at baseline in DEGS), the categories underweight and normal weight were combined and

further referred to as normal weight. In the EPIC studies, where height was not assessed at follow-up, BMI at follow-up was calculated using baseline height.

Statistical analysis

Statistical analyses were performed at each study site separately according to a common plan of analysis. Data analyses were performed using SAS (SAS Institute, Cary, NC, USA) 9.4 (DEGS, PopGen, CARLA and EPIC), SAS 9.2 (KORA) or STATA (Stata Corporation, College Station, TX, USA) 12.0 (SHIP).

Women who were pregnant and participants with missing values for weight or height at either baseline or follow-up examinations were excluded from the analysis. This generally concerned < 3% of participants, and only in PopGen the proportion of participants with missing information on anthropometry was higher (19%).

For each study, mean change in body weight per year of follow-up was calculated, and linear regression models were applied to describe the relationship between annual weight change and baseline age. Further, the change in BMI classification over a 10-year period was described by cross-tabulating baseline BMI category and projected BMI category after 10 years. BMI category after 10 years is based on BMI after 10 years, calculated as the sum baseline BMI and 10 × BMI-change per year of follow-up. The 10-year time frame was chosen to account for the differences in follow-up duration and complies with the time frame of the nationwide DEGS.

Analyses were stratified by sex and baseline age group. Baseline age was categorized as < 45 years, 45–64 years old and ≥ 65 years following

Table 2. Change in body weight per year of follow-up (kg/year) by region among men and women aged 18–79 years from the nationwide DEGS cohort (weighted for drop-out and deviations of the German population as of 31 December 1997)

Region ^a	Change in body weight per year (kg/year)					
	Men			Women		
	n	Mean	95% CI	n	Mean	95% CI
DEGS	1452	0.30	0.25–0.35	1555	0.23	0.19–0.26
North West	181	0.24	0.13–0.34	213	0.22	0.13–0.32
Central West	414	0.24	0.17–0.31	427	0.23	0.16–0.29
South West	337	0.37	0.27–0.48	337	0.22	0.15–0.30
North East	175	0.35	0.13–0.56	197	0.27	0.18–0.35
South East	345	0.32	0.19–0.46	381	0.20	0.10–0.30

Abbreviations: CI, confidence interval; DEGS, German Health Interview and Examination Survey for adults. ^aNorth West: Schleswig-Holstein, Hamburg, Bremen and Lower Saxony; North East: Mecklenburg-West Pomerania, Brandenburg and Berlin; South East: Thuringia, Saxony and Saxony-Anhalt; Central West: North-Rhine-Westphalia, Hessen, Rhineland-Palatinate and Saarland; South West: Bavaria and Baden-Württemberg.

Table 1. Summary of main characteristics of the involved population-based cohort studies

Study	Region	Recruitment period	Age at recruitment (years)	N _{baseline}	Baseline response (%)	Follow-up assessment	n _{follow-up}	Participation follow-up (%)	Mean duration of follow-up (years)
DEGS	National	1997–1999	18–79	7124	61	2008–2011	3045	47	11.9
PopGen	Kiel, Schleswig-Holstein	2005–2006	48–77	747	20	2010–2012	561	75	5.1
SHIP	Mecklenburg- West Pomerania	1997–2001	20–79	4308	69	2001–2006	3300	81	5.0
EPIC-P	Potsdam, Brandenburg	1994–1998	35–64	27 468	23	2004–2008	24 569	92	6.9
CARLA	Halle (Saale), Saxony-Anhalt	2002–2006	45–83	1779	64	2007–2010	1436	84	4.0
EPIC-Hd	Heidelberg, Baden-Württemberg	1994–1998	35–64	25 546	38	2004–2007	21 695	88	6.8
KORA	Augsburg, Bavaria	1999–2001	25–74	4261	67	2006–2008	3080	75	7.1

Abbreviations: CARLA: Study of Cardiovascular Disease Risk, Living and Ageing; DEGS, German Health Interview and Examination Survey for adults; EPIC-P, European Prospective Investigation into Cancer and Nutrition, Potsdam; EPIC-Hd: European Prospective Investigation into Cancer and Nutrition, Heidelberg; KORA, Cooperative Health Research in the Region Augsburg; PopGen, population-based genetic biobank; SHIP, Study of Health in Pomerania.

practical considerations referring to the age ranges included in the different studies. Regional differences were studied in the nationwide study. Regions were defined based on residential state with 'North West' including Schleswig-Holstein, Hamburg, Bremen and Lower Saxony, 'North East' including Mecklenburg-West Pomerania, Brandenburg and Berlin, 'South East' including Thuringia, Saxony and Saxony-Anhalt, 'South West' including Bavaria and Baden-Württemberg and 'Central West' including North-Rhine-Westphalia, Hessen, Rhineland-Palatinate and Saarland.

To obtain an overall estimate weight change in Germany, the results of the cohort-by-cohort analysis were combined for the common age group 45–64 years in a meta-analysis based on the random-effect model using the Review Manager release 5.2 (Cochrane Collaboration, Oxford, England).

Analyses for the common age group of 45–64 years were standardized to the age structure of the German population as of 31 December 2010. To reduce bias due to drop-out, study-specific weighting factors were calculated by inverse probability weighting.²⁴ Therefore, the probability of re-participation was assessed in multivariable logistic regression models, with response at follow-up (yes/no) as the dependent variable and potential predictors of drop-out as the independent variables. The potential predictors selected by pragmatic considerations included socio-demographic variables (age, sex, education and income), BMI and lifestyle factors (smoking, alcohol consumption and physical activity) as long as assessed at the baseline examination in each study. Subjects, who died during the follow-up period, were not considered in the construction of

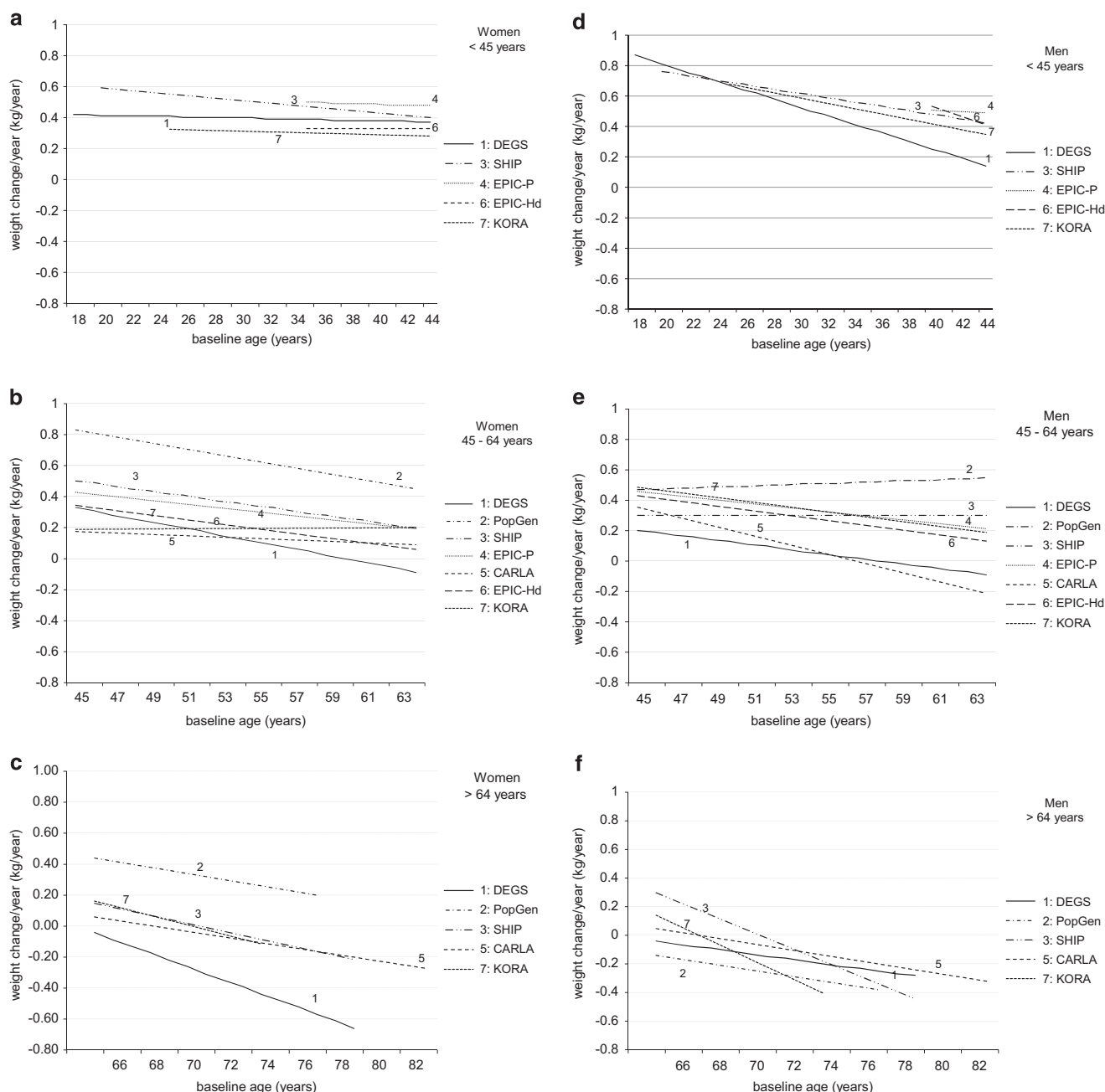


Figure 1. Weight change per year by baseline age in population-based cohort studies in Germany by sex and age group (a) women < 45 years, (b) women 45 to 64 years, (c) women > 64 years, (d) men < 45 years, (e) men 45–64 years and (f) men > 64 years. CARLA, Study of Cardiovascular Disease Risk, Living and Ageing; DEGS, German Health Interview and Examination Survey for adults; EPIC-P, European Prospective Investigation into Cancer and Nutrition, Potsdam; EPIC-Hd, European Prospective Investigation into Cancer and Nutrition, Heidelberg; KORA: Cooperative Health Research in the Region Augsburg; PopGen, population-based genetic biobank; SHIP, Study of Health in Pomerania.

the weighting factor. The weighting factor applied in DEGS additionally corrects deviations of the sample with regard to age, sex, region, nationality, type of municipality and education from the population structure as of 31 December 1997.

RESULTS

Among women aged 18–79 years from the nationwide study DEGS, mean weight change was 0.23 (95% confidence interval: 0.19–0.26) kg/year for women and 0.30 (0.25–0.35) kg/year for men (Table 2). During follow-up, over 50% of men and women gained >2 kg body weight, and >35% gained over 5 kg, whereas 22% lost >2 kg body weight (data not shown). In all regions within the nationwide cohort, men exhibited a higher average weight gain, but the sex difference was only statistically significant among participants from South West Germany. Among both men and women from DEGS, there were no statistically significant differences in weight gain between regions (Table 2).

Figure 1 describes the association between annual weight change and baseline age by age group for all population-based cohorts with data available. In all studies with eligible data, we observed the highest weight gain among the youngest men and a significant decrease in weight gain with advancing baseline age among men from the age group <45 years. Among women of this age group, annual weight change was almost stable at a high level. Until the age of about 35–40 years, men gained more weight than women (Figures 1a and d). Among adults aged 45–64 years, annual weight change was inversely associated with baseline age among men and women of most studies (Figures 1b and e). The inverse relationships were not so strong among middle-aged women from the CARLA and the KORA study, and we did not observe an inverse relationship among middle-aged men from SHIP and PopGen. Among adults aged 65 years and older, annual weight change decreased with advancing baseline age, and older participants lost weight (Figures 1c and f).

Age standardized analysis of weight change among the common age group of 45–64 years shows some variation in average weight change between studies (Table 3). The smallest average weight gain of 0.10 and 0.20 kg/year was observed among men and women from DEGS and CARLA, whereas the highest average weight change >0.30 kg/year was observed among participants from the cohorts of EPIC-Potsdam, SHIP and PopGen and men from EPIC-Heidelberg. The estimated average weight change among adults of the age group 45–64 years by a random-effects meta-analysis combining the results from the single studies was 0.25 (95% CI: 0.18–0.33) kg/year among men and 0.24 (95% CI: 0.17–0.30) kg/year among women.

The 10-year change in BMI classification accompanying weight change for the common age group of 45–64 years is shown in Table 4. In most studies, almost 70% of women and almost 60% of men with normal weight at baseline remained at normal weight, whereas almost 30% of the women and almost 40% of the men became pre-obese. A shift from normal weight to pre-obesity or obesity was observed most frequently among men and women from PopGen, SHIP and EPIC-Potsdam. These groups were previously identified as having the strongest weight gain. A shift from pre-obesity to obesity was most frequent among participants from PopGen and SHIP: 45% of the participants from PopGen and 30% of men and 35% of women from SHIP classified as pre-obese at baseline became obese after 10 years. These cohorts counted to the cohorts with the highest average weight gain. It should be noted that a shift from pre-obesity to obesity was also frequent among men from the CARLA cohort, exhibiting only a small average weight change. Among men and to some extent also among women of the CARLA cohort, we observed a higher proportion of participants who shift to a lower BMI category compared with the other cohort studies. In most studies, >80% of

Table 3. Change in body weight per year of follow-up (kg/year) by region among men and women aged 45–64 years from German cohort studies (weighted for drop-out and standardized to the population of 31 December 2010)

Region	Change in body weight per year (kg/year)					
	Men			Women		
	n	Mean	95% CI	n	Mean	95% CI
DEGS	668	0.08	0.02–0.14	708	0.13	0.08–0.18
PopGen ^a	85	0.52	0.35–0.70	98	0.34	0.13–0.55
SHIP	643	0.33	0.24–0.42	711	0.39	0.31–0.48
EPIC-P ^b	6334	0.35	0.33–0.36	8328	0.32	0.31–0.34
CARLA	433	0.05	–0.07–0.16	387	0.11	–0.02–0.24
EPIC-Hd ^b	7604	0.29	0.27–0.30	7253	0.24	0.22–0.26
KORA	665	0.23	0.17–0.30	699	0.16	0.10–0.22

Abbreviations: CARLA, Study of Cardiovascular Disease Risk, Living and Ageing; CI, confidence interval; DEGS, German Health Interview and Examination Survey for adults; EPIC-P, European Prospective Investigation into Cancer and Nutrition, Potsdam; EPIC-Hd, European Prospective Investigation into Cancer and Nutrition, Heidelberg; KORA, Cooperative Health Research in the Region Augsburg; PopGen, population-based genetic biobank; SHIP, Study of Health in Pomerania. ^aIncluding only the population-based sample. ^bBased on corrected self-reports of body weight at follow-up.

participants, who were obese at baseline, remained obese over a period of 10 years.

DISCUSSION

Analyzing seven population-based cohort studies, we found a moderate average weight gain of about 0.25 kg/year among middle-aged adults in Germany during the past decade. The amount of change depended on age at baseline, with larger increases among the young adults aged <45 years. The results further suggest sex differences in age-related patterns of weight change. We did not observe regional differences in weight change within the nationwide cohort, but we observed some differences between regional studies. The development of weight change over time was reflected by changes in BMI classes.

Overall, previous cohort studies showed a broad variation in weight change over time in different populations.^{25–30} The observed weight change in German middle-aged adults seems to be moderate but was within the range of change observed in previous prospective studies. Adults participating in at least two waves of the FINRISK study, an ongoing series of population-based nationally representative health surveys at 5-year intervals since 1972 in Finland, exhibited a higher weight change of 0.31 kg/year in men and 0.35 kg/year in women²⁵ compared with German adults. Similarly, weight change was higher among participants of the Norwegian Nord-Trøndelag health studies showing a mean body weight change between 1984–86 and 1995–97 of 0.39 kg/year for men and 0.43 kg/year for women²⁶ and a mean body weight change between 1995–97 and 2008 of 0.39 kg/year for men and 0.37 kg/year for women.²⁷ Women in the Framingham Heart Study Offspring/Spouse Nutrition Study exhibited a stronger weight gain (0.33 kg/year) and men a smaller weight gain (0.22 kg/year)²⁸ compared with their German counterparts. Both German men and women exhibited a stronger weight gain in comparison with men and women from the BLSA (Baltimore Longitudinal Study of Aging): 0.24 (our study) vs 0.20 kg/year (BLSA) for men and 0.25 (our study) vs 0.18 kg/year (BLSA) for women.²⁹ Overall, it seems that in western countries weight gain in aging adult populations amounts to 200–400 g/year.

Table 4. Frequency of change in BMI categories over 10 years among adults aged 45–64 years and age standardized to the German population of 31 December 2010

Study	n	BMI _{baseline} < 25.0 kg/m ²			BMI _{baseline} 25.0 < 30.0 kg/m ²			BMI _{baseline} ≥ 30.0 kg/m ²		
		BMI _{10 years} < 25.0 kg/m ² (%)	BMI _{10 years} 25.0 < 30.0 kg/m ² (%)	BMI _{10 years} ≥ 30.0 kg/m ² (%)	BMI _{10 years} < 25.0 kg/m ² (%)	BMI _{10 years} 25.0 < 30.0 kg/m ² (%)	BMI _{10 years} ≥ 30.0 kg/m ² (%)	BMI _{10 years} < 25.0 kg/m ² (%)	BMI _{10 years} 25.0 < 30.0 kg/m ² (%)	BMI _{10 years} ≥ 30.0 kg/m ² (%)
Women										
DEGS	246	73.1	26.8	0.1	3.8	75.4	20.8	0.0	10.6	89.4
PopGen ^a	43	63.9	32.4	3.7	41	49.0	46.0	0.0	0.0	100.0
SHIP	218	58.0	37.7	4.4	14.3	50.8	34.9	1.8	10.5	87.7
EPIC-p ^b	3612	65.2	32.9	1.8	9.4	64.5	26.2	1.0	13.3	85.7
CARLA	133	73.0	24.7	2.3	20.7	45.2	34.1	8.7	9.6	81.8
EPIC-Hd ^b	3481	73.6	25.1	1.3	10.4	67.5	22.1	1.4	16.3	82.3
KORA	227	73.8	24.9	1.4	17.2	61.7	21.1	0.8	9.9	89.3
Men										
DEGS	142	72.5	25.9	1.6	7.1	75.9	17.0	0.0	14.2	85.8
PopGen ^a	25	30.4	66.1	3.6	13.6	37.9	48.4	0.0	0.0	100.0
SHIP	122	58.5	37.5	4.0	10.8	59.1	30.2	1.6	12.1	86.3
EPIC-p ^b	1800	53.7	45.3	1.0	4.6	74.3	21.1	0.3	12.0	87.7
CARLA	97	62.9	34.9	2.3	20.8	65.2	22.7	8.8	15.4	75.9
EPIC-Hd ^b	2215	61.0	37.6	1.4	40.55	75.2	18.2	1.0	13.34	83.8
KORA	112	70.4	28.4	1.2	38.5	64.3	22.0	1.1	13.9	85.0
Abbreviations: BMI, body mass index; CARLA, Study of Cardiovascular Disease Risk, Living and Ageing; DEGS, German Health Interview and Examination Survey for adults; EPIC-P, European Prospective Investigation into Cancer and Nutrition, Potsdam; EPIC-Hd, European Prospective Investigation into Cancer and Nutrition, Heidelberg; KORA, Cooperative Health Research in the Region Augsburg; PopGen, population-based genetic biobank; SHIP, Study of Health in Pomerania. ^a Including only the population-based sample. ^b Based on corrected self-reports of body weight at follow-up.										

Abbreviations: BMI, body mass index; CARLA, Study of Cardiovascular Disease Risk, Living and Ageing; DEGS, German Health Interview and Examination Survey for adults; EPIC-P, European Prospective Investigation into Cancer and Nutrition, Potsdam; EPIC-Hd, European Prospective Investigation into Cancer and Nutrition, Heidelberg; KORA, Cooperative Health Research in the Region Augsburg; PopGen, population-based genetic biobank; SHIP, Study of Health in Pomerania. ^aIncluding only the population-based sample. ^bBased on corrected self-reports of body weight at follow-up.

The analysis of the nationwide study did not give rise to regional differences in weight gain over time. However, we observed some variation in weight gain between regional studies, with a higher weight gain among men and women from the studies in Northern Germany (PopGen, SHIP and EPIC-Potsdam) compared with the other studies.

The variation in weight change between studies highly depends on the characteristics of the population under study—for example, the observed age range. Previous studies consistently found a higher weight gain among younger adults, which decreases with age, whereas older participants lose weight.^{26,29,30} This was also shown in our analysis. Losing weight in adults aged 65 years and older is difficult to interpret. By losing weight, overweight or obese subjects generally improve several clinical health conditions and quality of life. Meanwhile, weight loss in old age may be unintentionally and may be associated with illness involving loss of lean body mass.³¹ A sensitivity analysis among participants of the nationwide DEGS showed that average weight loss was considerably smaller after excluding participants with a lifetime diagnosis of diabetes mellitus, myocardial infarction, stroke or cancer among women aged 65 years and older, but no change among men of this age group. This indicates that prevalent diseases may in part account for weight loss with increasing age, at least among older women. However, body weight change among elderly women was still smaller compared with young adults.

In addition, we observed different patterns of weight change with age between men and women. Among men, weight gain was highest in young adults and decreased almost gradually with advancing age, whereas weight change was quite stable on a high level among women younger than 45 years and decreased among older women. This indicates that in Germany young adult men and women were most vulnerable for gaining weight and supports findings of a large increase in the prevalence of obesity among young adults in trend analysis from the cross-sectional surveys in the framework of DEGS.³²

Another important finding concerns the analysis of the change in BMI category, which indicates that the majority of obese subjects are very likely to remain obese. In addition, a considerable proportion of participants shift to a higher BMI category. The observation that especially subjects of the younger age group gain weight and become pre-obese or obese is alarming. As weight gain is a result of an imbalance between total energy intake and total energy expenditure,³³ changes in energy intake and physical activity patterns throughout the life course are important determinants for changes in weight gain with aging in individuals. Lifestyle changes related to working and family life may be the reason for the high weight gain among young adults.³⁴ From a public health perspective, high weight gain and increasing proportions of pre-obesity and obesity in young adults underline the need for preventive actions aimed at this age group.

The strength of the study is the comparison of different single study results based on a standardized data analytical protocol. For a certain age range, we also decided to apply a meta-analytical approach that generated a summary figure of weight development with aging for Germany. As limitations, one should consider that this study is a *post hoc* analysis, which made reference to different studies established in different settings and with different original research questions. This considers the difference of > 10 years between the baseline examination of the earliest studies (EPIC) and the last study (PopGen), which may give rise for period effects that could not be controlled for. In addition, the included studies had different follow-up durations, which we attempted to adjust for by analyzing weight change per year of follow-up and the change of BMI classification over a standardized time of 10 years. In the DEGS cohort weight change might be underestimated, due to the change in measurement instruction referring to clothing between baseline and follow-up examination. A correction was not applied. The data were similarly handled as

in previous analysis describing anthropometric measures in the German population.^{32,35} Further, non-response at baseline and drop-out at follow-up occurred in all studies, although to different magnitudes. This might have resulted in selection bias. A weighting factor was applied to correct for bias due to selective drop-out.

In conclusion, this analysis showed a moderate weight gain amounting to 0.25 kg/year among middle-aged adults in Germany. Young adults seem to be the most vulnerable group for gaining weight and reaching a weight status with increased risk for chronic diseases. Preventive actions should target to this age group. Obesity intervention needs to be improved, as the majority of obese subjects seem to remain obese over time.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ACKNOWLEDGEMENTS

We are grateful to Ronny Kuhnert and Stefan Dahm from the Department of Epidemiology and Health Monitoring of the Robert Koch Institute in Berlin for statistical advice. This work was supported by the 'Kompetenznetz Adipositas (Competence Network Obesity)' funded by the Federal Ministry of Education and Research (FKZ: 01GI1121B).

REFERENCES

- 1 OECD. Health at a Glance: Europe 2014, OECD Publishing: http://dx.doi.org/10.1787/health_glance_eur-2014-en, 2014.
- 2 WHO Global InfoBase Team. *The SuRF Report 2. Surveillance of Chronic Disease Risk Factors: Country-Level Data and Comparable Estimates*. World Health Organization: Geneva. <https://apps.who.int/infobase/Index.aspx> (update: 20/01/2011).
- 3 Finucane MM, Stevens GA, Cowan MJ, Danaei G, Lin JK, Paciorek CJ *et al*. National, regional, and global trends in body-mass index since 1980: systematic analysis of health examination surveys and epidemiological studies with 960 country-years and 9.1 million participants. *Lancet* 2011; **377**: 557–567.
- 4 WHO (World Health Organisation) *Obesity: Preventing and Managing the Global Epidemic. Report of WHO Consultation. WHO Technical Report Series no. 894*. World Health Organization: Geneva, 2000.
- 5 von Lengerke T, John J, Mielck A, KORA Study Group. Excess direct medical costs of severe obesity by socioeconomic status in German adults. *Psychosoc Med* 2010; **7**: Doc01.
- 6 Wolfenstetter SB, Menn P, Holle R, Mielck A, Meisinger C, von Lengerke T. Body weight changes and outpatient medical care utilisation: Results of the MONICA/KORA cohorts S3/F3 and S4/F4. *Psychosoc Med* 2012; **9**: Doc09.
- 7 Laxy M, Holle R, Doring A, Peters A, Hunger M. The longitudinal association between weight change and health-related quality of life: the KORA S4/F4 cohort study. *Int J Public Health* 2014; **59**: 279–88.
- 8 Holz T, Thorand B, Doring A, Schneider A, Meisinger C, Koenig W. Markers of inflammation and weight change in middle-aged adults: results from the prospective MONICA/KORA S3/F3 study. *Obesity* 2010; **18**: 2347–2353.
- 9 Lahmann PH, Schulz M, Hoffmann K, Boeing H, Tjonneland A, Olsen A *et al*. Long-term weight change and breast cancer risk: the European prospective investigation into cancer and nutrition (EPIC). *Br J Cancer* 2005; **93**: 582–589.
- 10 Schulz M, Nothlings U, Hoffmann K, Bergmann MM, Boeing H. Identification of a food pattern characterized by high-fiber and low-fat food choices associated with low prospective weight change in the EPIC-Potsdam cohort. *J Nutr* 2005; **135**: 1183–1189.
- 11 Schulz M, Liese AD, Boeing H, Cunningham JE, Moore CG, Kroke A. Associations of short-term weight changes and weight cycling with incidence of essential hypertension in the EPIC-Potsdam Study. *J Hum Hypertens* 2005; **19**: 61–67.
- 12 Steffen A, Sorensen TI, Knuppel S, Travier N, Sanchez MJ, Huerta JM *et al*. Development and validation of a risk score predicting substantial weight gain over 5 years in middle-aged European men and women. *PLoS One* 2013; **8**: e67429.
- 13 Wimmer K, Laubereau B, Wolke G, Doring A, Heinrich J. Weight gain in two adult cohorts in East and West Germany reunification. *Cent Eur J Public Health* 2003; **11**: 202–208.

- 14 Scheidt-Nave C, Kamtsiuris P, Gosswald A, Holling H, Lange M, Busch MA *et al*. German health interview and examination survey for adults (DEGS) - design, objectives and implementation of the first data collection wave. *BMC Public Health* 2012; **12**: 730.
- 15 Nothlings U, Krawczak M. [PopGen. A population-based biobank with prospective follow-up of a control group]. *Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz* 2012; **55**: 831–835.
- 16 Volzke H. [Study of Health in Pomerania (SHIP). Concept, design and selected results]. *Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz* 2012; **55**: 790–794.
- 17 John U, Greiner B, Hensel E, Ludemann J, Piek M, Sauer S *et al*. [Study of Health In Pomerania (SHIP): a health examination survey in an east German region: objectives and design]. *Soz Präventivmed* 2001; **46**: 186–194.
- 18 Boeing H, Korfmann A, Bergmann MM. Recruitment procedures of EPIC-Germany. European Investigation into Cancer and Nutrition. *Ann Nutr Metab* 1999; **43**: 205–215.
- 19 Greiser KH, Kluttig A, Schumann B, Kors JA, Swenne CA, Kuss O *et al*. Cardiovascular disease, risk factors and heart rate variability in the elderly general population: design and objectives of the Cardiovascular disease, Living and Ageing in Halle (CARLA) Study. *BMC Cardiovasc Disord* 2005; **5**: 33.
- 20 Haerting J, Kluttig A, Greiser KH, Nuding S, Werdan K. [A cohort study investigating risk factors for cardiovascular disease in an urban elderly East-German population (CARLA study)]. *Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz* 2012; **55**: 795–800.
- 21 Holle R, Happich M, Lowel H, Wichmann HE. MONICA/KORA Study Group [KORA—a research platform for population based health research]. *Gesundheitswesen* 2005; **67**: S19–S25.
- 22 von Ruesten A, Steffen A, Floegel A, van der AD, Masala G, Tjonneland A *et al*. Trend in obesity prevalence in European adult cohort populations during follow-up since 1996 and their predictions to 2015. *PLoS One* 2011; **6**: e27455.
- 23 Haftenberger M, Lahmann PH, Panico S, Gonzalez CA, Seidell JC, Boeing H *et al*. Overweight, obesity and fat distribution in 50- to 64-year-old participants in the European Prospective Investigation into Cancer and Nutrition (EPIC). *Public Health Nutr* 2002; **5**: 1147–1162.
- 24 Li L, Shen C, Li X, Robins JM. On weighting approaches for missing data. *Stat Methods Med Res* 2013; **22**: 14–30.
- 25 Pajunen P, Vartiainen E, Mannisto S, Jousilahti P, Laatikainen T, Peltonen M. Intra-individual changes in body weight in population-based cohorts during four decades: the Finnish FINRISK study. *Eur J Public Health* 2012; **22**: 107–112.
- 26 Droyvold WB, Nilsen TI, Kruger O, Holmen TL, Krokstad S, Midthjell K *et al*. Change in height, weight and body mass index: longitudinal data from the HUNT Study in Norway. *Int J Obes* 2006; **30**: 935–939.
- 27 Brumpton B, Langhammer A, Romundstad P, Chen Y, Mai XM. The associations of anxiety and depression symptoms with weight change and incident obesity: the HUNT Study. *Int J Obes* 2013; **37**: 1268–1274.
- 28 Kimokoti RW, Newby PK, Gona P, Zhu L, McKeon-O'Malley C, Pablo Guzman J *et al*. Patterns of weight change and progression to overweight and obesity differ in men and women: implications for research and interventions. *Public Health Nutr* 2013; **16**: 1463–1475.
- 29 Shimokata H, Andres R, Coon PJ, Elahi D, Muller DC, Tobin JD. Studies in the distribution of body fat. II. Longitudinal effects of change in weight. *Int J Obes* 1989; **13**: 455–464.
- 30 Sheehan TJ, DuBrava S, DeChello LM, Fang Z. Rates of weight change for black and white Americans over a twenty year period. *Int J Obes Relat Metab Disord* 2003; **27**: 498–504.
- 31 Han TS, Tajar A, Lean ME. Obesity and weight management in the elderly. *Br Med Bull* 2011; **97**: 169–196.
- 32 Mensink GB, Schienkiewitz A, Haftenberger M, Lampert T, Ziese T, Scheidt-Nave C [Overweight and obesity in Germany: results of the German Health Interview and Examination Survey for Adults (DEGS1)]. *Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz* 2013; **56**: 786–794.
- 33 Swinburn BA, Sacks G, Lo SK, Westerterp KR, Rush EC, Rosenbaum M *et al*. Estimating the changes in energy flux that characterize the rise in obesity prevalence. *Am J Clin Nutr* 2009; **89**: 1723–1728.
- 34 Nafziger AN, Lindvall K, Norberg M, Stenlund H, Wall S, Jenkins PL *et al*. Who is maintaining weight in a middle-aged population in Sweden? A longitudinal analysis over 10 years. *BMC Public Health* 2007; **7**: 108.
- 35 Bergmann KE, Mensink GBM. Körpermaße und Übergewicht. *Gesundheitswesen* 1999; **61**: 115–120.