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Changes in adult obesity prevalence in Denmark, 1987–2021: age–period–cohort analysis of nationally representative data

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Background: During the last decades, the prevalence of obesity [body mass index (BMI): weight/height^2), $\geq$30.00 kg/m^2] among adults has increased considerably. We examined whether this increase in a high-income, welfare state, like Denmark was driven by age, period or cohort effects, which would inform preventive strategies aiming at reducing the prevalence. **Methods:** We used data from the National Representative Health and Morbidity Studies, which are representative surveys of the Danish adult population (age 16 years and above), conducted in 1987, 1994, 2000, 2005, 2010, 2013, 2017 and 2021 ($N = 91\,684$). Participants reported height and weight, from which BMI was calculated after correction for systematic bias in self-reported data and non-response. Age, survey year and birth cohorts were mutually adjusted and adjusted for sex in generalized linear models. **Results:** The obesity prevalence increased from 6.1% in 1987 to 18.4% in 2021, similarly in men (18.8%) and women (18.0%) and in all age groups. Age had an inverted u-shaped effect on the prevalence. Compared with individuals aged 16–24 years, the highest rate of obesity was seen for the age group 55–64 years [rate ratio 3.27, 95% confidence interval (CI): 2.58; 4.14]. The increasing rate for each recent survey year over time was compatible with a period effect without any birth cohort effects. The rate for obesity in 2021 was 4.16 in 1987 vs. 1987 (95% CI: 3.10; 5.59). **Conclusions:** Obesity prevalence in Denmark increased steadily during the period 1987 through 2021, primarily driven by secular changes over time across all ages and birth cohorts.

Introduction

The increasing prevalence of obesity over the last decades, both globally and in Europe, is a growing public health concern.[1–3] Obesity is associated with a higher risk of several chronic conditions and with all-cause mortality,[1] which further reduces years lived without disease, quality of life[4,5] and life expectancy.[6–8] A range of interventions and policies to reduce obesity, particularly addressing behavioural factors, have been investigated in several high-income countries, but with limited evidence to stop the rise in the obesity prevalence.[1,2,9]

Continued monitoring of the obesity prevalence at a national level is needed for identification, implementation and evaluation of public health policies and evidence-based interventions.[2] One monitoring approach is to analyse the age–period–cohort effects in order to adequately targeting the actions possibly preventing the rise in the obesity prevalence. The analyses decomposes temporal trends, where the age effect refers to changes across the life course, which occurs among all cohorts and independent of time.[10] The period effect refers to changes over time that equally affect all age groups and birth cohorts, whereas the birth cohort effect refers to changes or exposures that affects a population born in a particular point in time.[10] Disentangling period and cohort effects are not only important for targeted preventive measure, but also for future predictions of the prevalence and burden of obesity, and consequential demands on health services. For example, if the obesity prevalence among all cohorts is assumed to develop similarly over time and if they then do not, the predictions will be misleading.[11]

A common finding from previous studies among adults, is a significant age effect independent of period and cohort effects. The age effect has been characterized by an inverted u-shape where the risk of obesity in adults increases by age and peaks around late middle-age followed by a decrease.[10,12–14] However, there is conflicting results regarding period and cohort effects. For example, studies from Estonia, the USA and New Zealand have reported strong period effects with no birth cohort effects, where the risk of obesity increases over time.[10,12,15] In contrast, studies from France and Australia have found cohort effects, of which the risk of obesity accelerates among cohorts born from approximately 1960 and onwards.[11,14,16] The main hypotheses behind cohort effects are that more recent birth cohorts are exposed to obesogenic modern environment at a younger age, and experience persisting biological changes in response to early life exposures (before conception, *in utero* and during early childhood) that may lead to increased lifetime risk of obesity, independent of changes in contemporary environmental influences.[12,17,18] Moreover, these conflicting results may be linked to regional-specific contextual factors such as economic conditions and more specific obesogenic environments resulting in different levels of obesity prevalence.

In this study, we analysed data for the obesity prevalence with regard to age–period–cohort effects among adults aged 16 years and above in Denmark from 1987 to 2021 based on data from eight nationally representative surveys.

Methods

We used data from the Danish National Representative Health and Morbidity Studies, which are representative of the adult Danish population, conducted in 1987, 1994, 2000, 2005, 2010, 2013, 2017 and 2021. In total, 95 471 individuals aged 16 years and above participated of whom 91 684 had full information in height and weight.[19,20] General characteristics of the study populations for each survey year are presented in supplementary material (Supplementary table S1). Body mass index (BMI) was calculated as weight (kg) divided by squared height (m). Obesity was defined as BMI $\geq 30\,kg/m^2$.

Correction for errors in self-reported height and weight

We used data from the Danish Health Examination Survey to adjust for errors in self-reported height and weight.[21] In short, calibration equations were derived from information of self-reported and objectively measured height and weight in 15 692 participants. Weight was generally reported with a high accuracy in men and women in all age groups, whereas height was over-reported in both men and women and increasingly so with advancing age.

We calculated the prevalence of obesity overall, by sex and per age group, separately for each examination and birth cohort. Also, obesity prevalence standardized to the age-distribution of the Danish population in 1987 was calculated in order to assess the difference in the observed prevalence of obesity and an age-standardized prevalence using the age groups 16–24, 25–34, 35–44, 45–54, 55–64, 65–74 and 75 years and above. For descriptive presentations, age was grouped into categories of 16–24, 25–34, 35–44, 45–54, 55–64, 65–74 and 75 years and above, period effect was represented by the eight survey years and cohort effects were defined by the individual's birth decade and catgorized as 1920–29, 1930–39, 1940–49, 1950–59, 1960–69, 1970–79, 1980–80 and 1990–99.

To investigate if an increase in obesity appeared in all age groups, we estimated the linear trend representing the average yearly change in obesity prevalence over the period 1987–2021 in each of the age groups separately. This was done by fitting a model including main effects of survey year (continuous) and age group, and cross products between the two, allowing the trend to differ in age groups.

The response rates of the Danish National Representative Health and Morbidity Studies were 79.9%, 77.8%, 74.2%, 66.7%, 60.1%, 57.1%, 56.1% and 45.4% for the years 1987, 1994, 2000, 2005, 2010, 2013, 2017 and 2021, respectively (Supplementary table S1). All analyses included a weight indicating response probability for each individual with the purpose of increasing the degree of representativity of each survey. Weights were constructed using auxiliary information from Statistics Denmark's registers in order to take into account the different sampling probabilities. As all individuals with a permanent residence in Denmark have a unique personal identification number, it was possible to link on an individual level the personal identification numbers of both respondents and non-respondents to relevant central registers. Weights were computed by Statistics Denmark and based on information such as sex, age, municipality of residence, highest completed level of education, income, marital status, ethnic background, number of visits to the general practitioner 3 years prior to each survey wave, occupational status and owner/tenant status.[19,20]

The age–period–cohort effects were estimated using a generalized linear model with Poisson distribution and a loglink function with obesity as the dependent variable and age, survey years and birth cohorts as independent variables, mutually adjusted and adjusted for sex. In order to break the dependency between three key components (e.g. period – age = year of birth), we used different interval lengths modelling the period and cohort effect, following common practice[10,12,15]; full age years as a continuous variable and age squared, survey years and birth cohorts in intervals of 10 years. For illustrative reasons, the age effects were shown as age groups as in the descriptive presentations. In analysis of cohort effects, strata with few individuals were excluded (i.e. birth year before 1915 or after 1995, corresponding approximately to the first and 99th percentiles). Average marginal effects were used to calculate the adjusted prevalence of obesity. No sex-differential effects were found. Therefore, analysis was conducted with men and women combined.

Results

The prevalence of obesity increased from 6.1% in 1987 to 18.4% in 2021 for the total population (figure 1), similarly in men and women (5.7% and 6.5% in 1987, and 18.8% and 18.0% in 2021 for men and women, respectively). The prevalence in 2021 was 16.6% when standardized to the age-distribution in 1987 (figure 1). Thus, of the 12.3 percentage point increase from 1987 (6.1%) to 2021 (18.4%), 1.8 percentage points (14.6%) was attributable to an altered age-distribution since 1987.

For all survey years, the lowest obesity prevalence was seen among the youngest age group (16–24 years, figure 1) and the highest prevalence among the age group 65–74 years, apart from 2021. The increase in obesity prevalence was seen for all age groups, where the prevalence was higher for the most recent survey years (figure 1). During 1987–2021, the obesity prevalence among adults aged 16–24, 25–44, 45–54, 55–64, 65–74 and 75 years and above, increased by 4.4, 11.3, 11.4, 15.4, 13.0, 8.7 and 11.6 percentage points, respectively. Hence, the age group 45–54 years had the largest increase in the prevalence over the total period (from 7.0% in 1987 to 22.4% in 2021), whereas the age group 55–64 years had the highest prevalence in year 2021 (23.2%).

Estimating a linear trend for each age group for the period 1987–2021, the observed increase for all age groups was confirmed. Overall, the same trend was seen when limiting the period from 2000 to 2021, and from 2010 to 2021. Although, a steeper increase in the obesity prevalence was seen among the oldest age group (75 years and above) from 2010 to 2021 (Supplementary table S2, also illustrated in figure 1).

Figure 2 illustrates the prevalence of obesity for each age group, stratified by survey year. Similar trends were seen across survey years, whereby the prevalence increases with age until 65–74 and then slightly decreases for the oldest age group (75 years and above) (figure 2). In figure 2, the prevalence of obesity is shown by age group stratified by birth cohorts and unadjusted for period effects. The slope of each birth cohort represents the change in the obesity prevalence throughout the life course, hence with increasing age. The prevalence increased with increasing age within each birth cohort, slightly steeper for the younger birth cohorts than for the older cohorts, whereas the prevalence of obesity tended to decrease in the oldest age groups for some, but not all birth cohorts (figure 2). Within each age group, the obesity prevalence was higher in the later birth cohorts than in earlier birth cohorts.

The unadjusted period-, age- and cohort effects, illustrated in figures 1 and 2, where largely confirmed by results from the adjusted generalized linear model (table 1). The rate ratio of adult obesity confirmed a strong period effect with monotonically increasing rate for each recent survey year over time. In comparison to the baseline survey year, 1987, the rate for adult obesity in most recent survey year, 2021, was 4.16 [95% confidence interval (CI): 3.10; 5.59]. The adjusted rate ratios for age groups showed an inverted u-shape with the highest rate reported for the age group 55–64 years of age (rate ratio 3.27, 95% CI: 2.58; 4.14). When adjusting for age and period, there was no clear evidence for cohort effects (table 1). Figure 3 shows the adjusted cohort effects, illustrated by the percentages change in obesity prevalence, which remained largely stable by different birth cohorts. Although, a small downward trend in the obesity prevalence for the cohort 1950–59 was seen, the differences in the adjusted obesity prevalence compared to the baseline cohort (1960–69) was small (percentage change: −1.06, 95% CI: −2.10; −0.02) (figure 3).

Lastly, projecting the linear trend through the whole period, the obesity prevalence is expected to increase from 18.4% in 2021 to 21% (95% CI: 21; 22) in 2025 (data not shown).

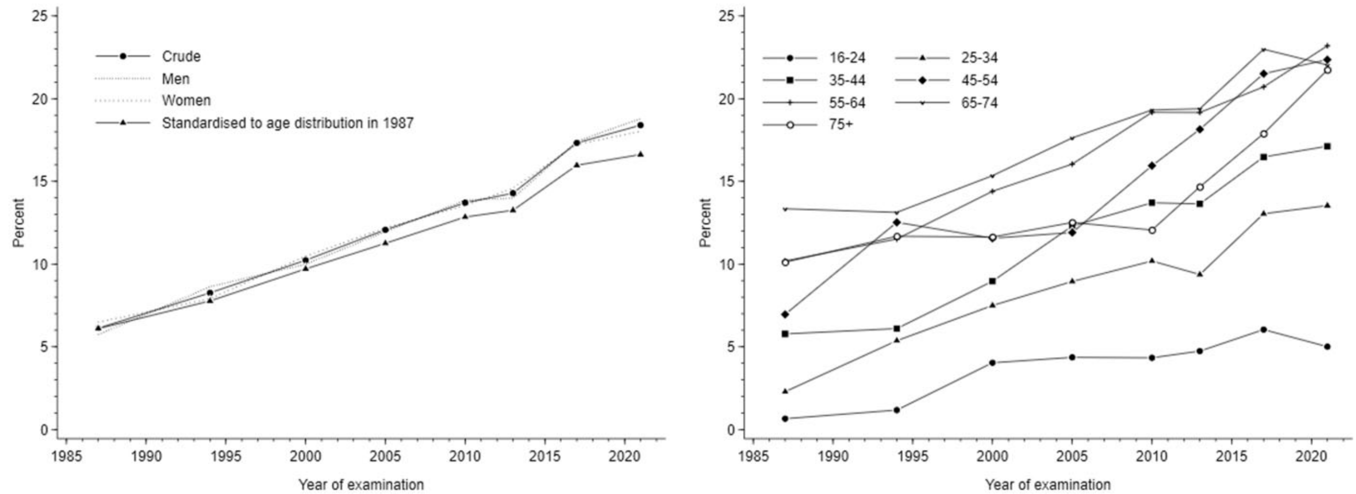

Figure 1 Prevalence of obesity by suvey year (year of examination), overall, stratified by sex, overall standardized to the age-distribution in 1987 and age group

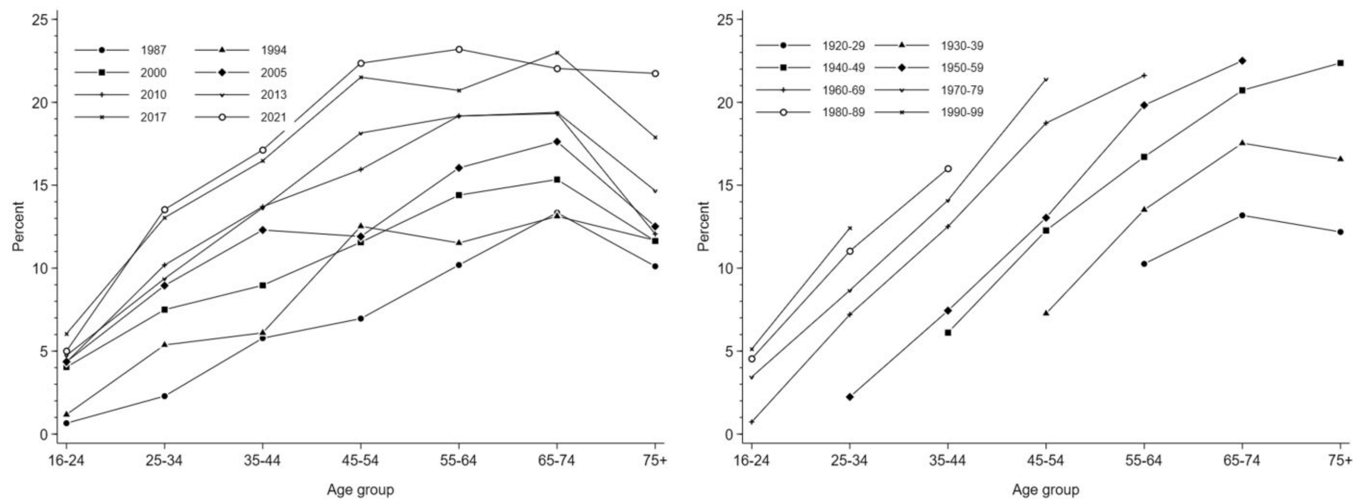

Figure 2 Prevalence of obesity by age group, stratified by survey year and birth cohort

Discussion

Our study presents data on obesity prevalence from 1987 to 2021 with eight nationally representative samples of the adult Danish population. The prevalence of adult obesity increased 12.3 percentage points since 1987 and was 18.4% in 2021. We found an inverted u-shaped age effect with higher rate of obesity with increasing age until late middle-age and then a decrease for older age groups; a strong period effect characterized by higher rate of obesity over time; and no evidence of cohort effects. The obesity prevalence adjusted for the age-distribution at the baseline survey year (1987) showed that a minor part of the increase in obesity prevalence could be explained by changes in the age-distribution of the Danish population. The strong evident period effect combined with the lack of cohort effect indicates that the increasing obesity prevalence in the adult Danish population is primarily driven by secular changes over time affecting all groups rather than differences in groups born at a specific time.

Our results regarding age effects are in line with previous studies and expected.[10–12,14–16] This study and most previous studies were based on repeated cross-sectional data rather than longitudinal data. Due to the nature of cross-sectional data, it has previously been questioned whether the decrease in the obesity prevalence among elderly reflects that elderly lose weight or if it in fact reflects birth cohort effects reflecting that older birth cohorts have not gained similar weight with age as birth cohorts born later.[22] The decrease among elderly may also be caused by attrition related to morbidity and mortality.[22] We have not been able to explore this in present study. However, in the study by Dobson *et al.*,[11] the same age effect was found using longitudinal data.

Regarding period and cohort effects, three other studies from Estonia,[15] the USA[10] and New Zealand[12] have reported similar findings with strong period effects and no cohort effects. A linear trend in the period effect was also reported for the increased BMI in the Estonian population.[15] In contrast, three studies from Australia[11,13,16] and one study from France[14] have reported cohort effects, where an acceleration of the obesity prevalence was seen in cohorts born after 1960. Two of the Australian studies found no period effect, whereas in the study by Allman-Farinelli *et al.*,[13] period effects were still identified as the principle mechanism of the obesity increase. The inconsistency in findings regarding period and cohort effects may reflect a true difference in the effects of the changing underlying causes of the increasing obesity prevalence across countries. However, differences in study populations, design and methods may also explain the conflicting findings. For example, previous studies that have reported significant period effects with no or limited cohort effects, have included surveys that expand over relatively long time periods (from 18 to 30 years),[10,12,15] whereas the study from France by Diouf *et al.*[14] and two of the studies from

Table 1 Adjusted rate ratios and 95% confidence intervals

	Rate ratio (95% CI)
Sex[a]	
Male	1
Female	1.00 (0.95; 1.04)
Age group (years)[b]	
16–24	1
25–34	2.01 (1.74; 2.32)
35–44	2.54 (2.14; 3.01)
45–54	3.06 (2.50; 3.75)
55–64	3.27 (2.58; 4.14)
65–74	3.04 (2.31; 4.01)
75 and above	2.06 (1.50; 2.84)
Survey year[a]	
1987	1
1994	1.55 (1.28; 1.88)
2000	2.02 (1.68; 2.43)
2005	2.43 (1.98; 2.98)
2010	2.89 (2.30; 3.64)
2013	3.05 (2.38; 3.90)
2017	3.83 (2.93; 5.02)
2021	4.16 (3.10; 5.59)
Birth cohort[a]	
1920–29	1.17 (0.86; 1.59)
1930–39	1.16 (0.92; 1.46)
1940–49	1.08 (0.92; 1.26)
1950–59	0.90 (0.81; 0.99)
1960–69	1
1970–79	1.00 (0.90; 1.11)
1980–89	1.05 (0.87; 1.27)
1990–99	0.99 (0.75; 1.30)

CI: confidence interval.

a: Adjusted for sex, age in years, age squared, survey year and birth cohort.

b: Adjusted for sex, survey year and birth cohort.

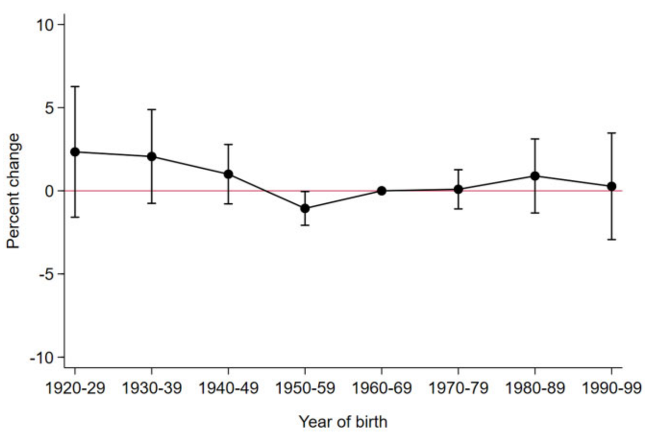

Figure 3 Adjusted cohort effects, illustrated by the percentages change in obesity prevalence and 95% confidence intervals. Adjusted for sex, age in years, age squared and survey year

Australia[13,16] included surveys covering relatively short time periods (from 9 to 11 years). A longer time period is preferred for age–period–cohort analysis, as a potential period effect may not be identified and the estimates for cohort effects may not be adequately adjusted for period effects with a shorter time span. In this study, we have used survey data covering over a period of 34 years (1987–2021). Additionally, the study population used by Diouf *et al.*[14] was based on a permanent panel of a poll institute and not a random sample, where 23% participated in two survey years. Nationally representative surveys would be preferred if the aim is to inform public health policy at a population level.

Two previous studies from Denmark, one among boys and young men in Denmark by Olsen *et al.*[23] and one among adults in the surrounding area of the capital, Copenhagen, by Heitmann *et al.*[24] showed indication of cohort effects. Olsen *et al.*[23] reported a non-linear increase over time with increasing obesity prevalence in cohorts born 1940–1955 and 1970 onward for both boys and young men and stable prevalence for those born 1930–1939 and 1955–1969. Heitmann *et al.*[24] reported a general large heterogeneity in the prevalence of obesity among adults across cohorts and an irregular increase in obesity prevalence over time and across gender. However, these studies did not use formal age–period–cohort analysis,[23,24] but the former study inferred the cohort effects from the year of birth concordance of the non-linear changes in prevalence. Differences in methodology and study population characteristics, including age range, which for the former study was only children and young adults, may explain the difference in results compared to this study.

It was beyond the scope of present study to examine factors that causes the age and period effects. These factors can be a complex combination of the economic and social environment that affect obesity-related risk factors such as behavioural and psychosocial factors.[1,2]

The repeated cross-sectional studies that are nationally representative and cover a 34-year period is a major strength of the study. However, the response rate has varied across survey year and overall decreased from 79.9% in 1987 to 45.4% in 2021.[19,20] Although the response rates are similar in other studies,[15,16] the response rates may be influenced by degree of health, including BMI and sociodemographic factors.[25] To account for this, sampling weights based on sociodemographic information of non-respondents were applied to all results presented in this study. Yet, it is possible that the sampling weights have not adequately accounted for bias related to non-response.[25,26] The self-reported weight and height measures from the described surveys in this study has previously been validated, where a sub-sample of 15 692 participants had both filled out questionnaires and participated in a health examination with weight and height measures.[21]

Continued monitoring is important, including inspection of measurement validity and representativeness across studies over time. Future studies could include indicators for socioeconomic inequalities in disentangling the causes and mechanisms of the rising obesity prevalence in Denmark, Europe and globally.[27] Studies among children and adolescents would contribute to the understanding of the rising obesity prevalence,[23] and lastly, longitudinal studies that track BMI from childhood to adulthood.[28]

In conclusion, the prevalence of adult obesity in Denmark has increased from 6.1% in 1987 to 18.4% in 2021, with no indication of stagnation within recent years. Age and period effects, but no clear cohort effects, were identified. The increase in the obesity prevalence was mainly explained by the period effect with changes over time that affect the population as a whole. No difference was seen between men and women.

Supplementary data

Supplementary data are available at *EURPUB* online.

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Conflicts of interest: The authors declare no conflict of interest.

Ethics statement

This is an observational study. No ethical approval is required for this study.

Consent to participate

Informed consent was obtained from all individual participants included in the study. In the letter of introduction for each survey wave it was emphasized that participation was voluntary. Thus, upon participation the respondent provided consent to participate in the survey.

Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Key points

- This study estimated the age–period–cohort effects in the Danish adult population, based on data from eight nationally representative surveys, covering a period of 34 years.
- We identified an inverted u-shaped age effect on obesity and a positive period effect with increasing obesity risk over time, but no clear cohort effect.
- The strong evident period effect combined with the lack of cohort effect indicate that the increasing obesity prevalence in the adult Danish population is primarily driven by secular changes over time rather than differences in groups born at a specific time.

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