DANISH MEDICAL JOURNAL

Original Article

Dan Med J 2023;70(10):A03230139

Time trends in body mass index distribution in the general population in Denmark from 1987 to 2021

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Dan Med J 2023;70(10):A03230139

ABSTRACT

INTRODUCTION. The epidemic increase in obesity is well documented and of intensive public health interest. Attention has almost entirely focused on a dichotomous measure of obesity such as how the prevalence of BMI ≥ 30 kg/m^2 has changed over time. Less consideration has been given to how the general distribution of BMI has evolved.

METHODS. We used data from the National Health and Morbidity Surveys, which are surveys of the adult Danish population (16 years or above) conducted in 1987, 2000, 2005, 2010, 2013, 2017 and 2021. Participants reported height and weight from which BMI was calculated following correction for systematic bias in self-reported data and non-response.

RESULTS. The prevalence of obesity in Denmark increased from 6.1% in 1987 to 18.4% in 2021. A right shift in BMI distribution was observed with positive linear slopes for high and low BMI percentiles and for all socioeconomic groups, although with steeper slopes for high BMI percentiles and for short education.

CONCLUSIONS. The right shift in the distribution curve of BMI from 1987 to 2021 with gradually higher values in all BMI percentiles and in all socioeconomic strata show that the increasing obesity prevalence may, to some extent, be attributed to a generally higher BMI in the entire Danish population.

FUNDING. None.

TRIAL REGISTRATION. Not relevant.

The rise in the prevalence of obesity in past decades, is a growing public health concern [1]. At the population level, monitoring of weight status over time is mostly operationalised by grouping the BMI into categories of overweight and obesity as defined by the World Health Orgainsation's cut-offs. This approach is intuitive, simple and facilitates comparison of developments within and across populations. However, important details of how the entire BMI spectrum develops is not illustrated by this approach [2].

In principle, when the prevalence of obesity increases (i.e. the fraction of individuals with a BMI above a certain cutpoint of the right tail of the distribution), two underlying mechanisms may be occuring. In one scenario, the whole distribution shifts towards higher values, increasing both the median and all other percentiles [2-4]. In this scenario, everybody in the population is experiencing a higher BMI – everybody is simply gaining weight. In the second scenario, the shape of the BMI distribution changes, by widening, having a longer tail or getting more skewed. This affects the prevalence of those in the high end of the distribution but not so much the median. Such movements actualise a situation in which mostly a subset of people in the population is becoming heavier. Last and naturally, any combination of the two scenarios is possible and likely, and the rate and nature of change of the distribution may vary among sub-groups, including socioeconomic groups [2, 5].

Understanding these mechanisms is important as they can help identify whether specific population groups are at a higher risk of an increasing BMI, or whether the population as a whole is experiencing weight gain. Different public health and clinical responses are required depending on the scenario experienced [2, 6], e.g., population-based strategies or high-risk targeted subgroup strategies.

Here, we present a detailed description of how the BMI distribution changes in Danish adults overall and by educational level and local area wealth. For this purpose we use data from nationally representative surveys conducted repeatedly and similarly from 1987 to 2021.

METHODS

We used data from the Danish Health and Morbidity Surveys, which are representative of the adult Danish population. These surveys were conducted in 1987, 1994, 2000, 2005, 2010, 2013, 2017 and 2021. A total of 95,471 participated among whom 91,684 had full information on height and weight [7, 8]. General characteristics of the study populations for each survey year are presented in Supplementary Table A **(https://content.ugeskriftet.dk/sites/default/files/2023-08/a03230139-supplementary.pdf)**.

BMI was calculated as weight (kg) divided by squared height (m). Obesity was defined as BMI ≥ 30 kg/m^2. We used data from the Danish Health Examination Survey to adjust for errors in self-reported height and weight [9]. 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 and by sex and per age group, separately for each examination. As no significant difference was observed in the prevalence by sex, the overall prevalence of obesity was presented. BMI distributions for five selected survey years were presented in a density plot and with a cumulative distribution plot. We used quantile regression to estimate selected BMI percentiles (10th, 25th, 50th = median, 75th and 90th) by survey year, adjusted for age and sex. Analyses also included an analytical weight indicating the response probability for each individual with the purpose of increasing the degree of representativity of each survey. The Danish Health and Morbidity Surveys are nationally representative and independent cross-sectional surveys. Thus, any overlap is not accounted for and treated as random.

The quantile regression was presented for the study population overall, by educational level and by municipality wealth. Lastly, we repeated the quantile regression using weight measurements instead of BMI values, stratified by sex and adjusted for height. STATA version 17 was used for all analyses.

Trial registration: not relevant.

RESULTS

The prevalence of obesity as defined by a BMI ≥ 30 kg/m^2 increased from 6.1% in 1987 to 18.4% in 2021 (**Figure** 1). The distribution of BMI in selected years (1987, 1994, 2000, 2010, and 2021) is shown in **Figure** 2A. Overall, a shift to the right from one survey wave to the next was observed, indicating a general, higher BMI for the whole population. This was confirmed by the cumulative quantile regression (Figure 2B).

FIGURE 1 Obesity prevalence (BMI ≥ 30 kg/m²) in Denmark, 1987-2021.

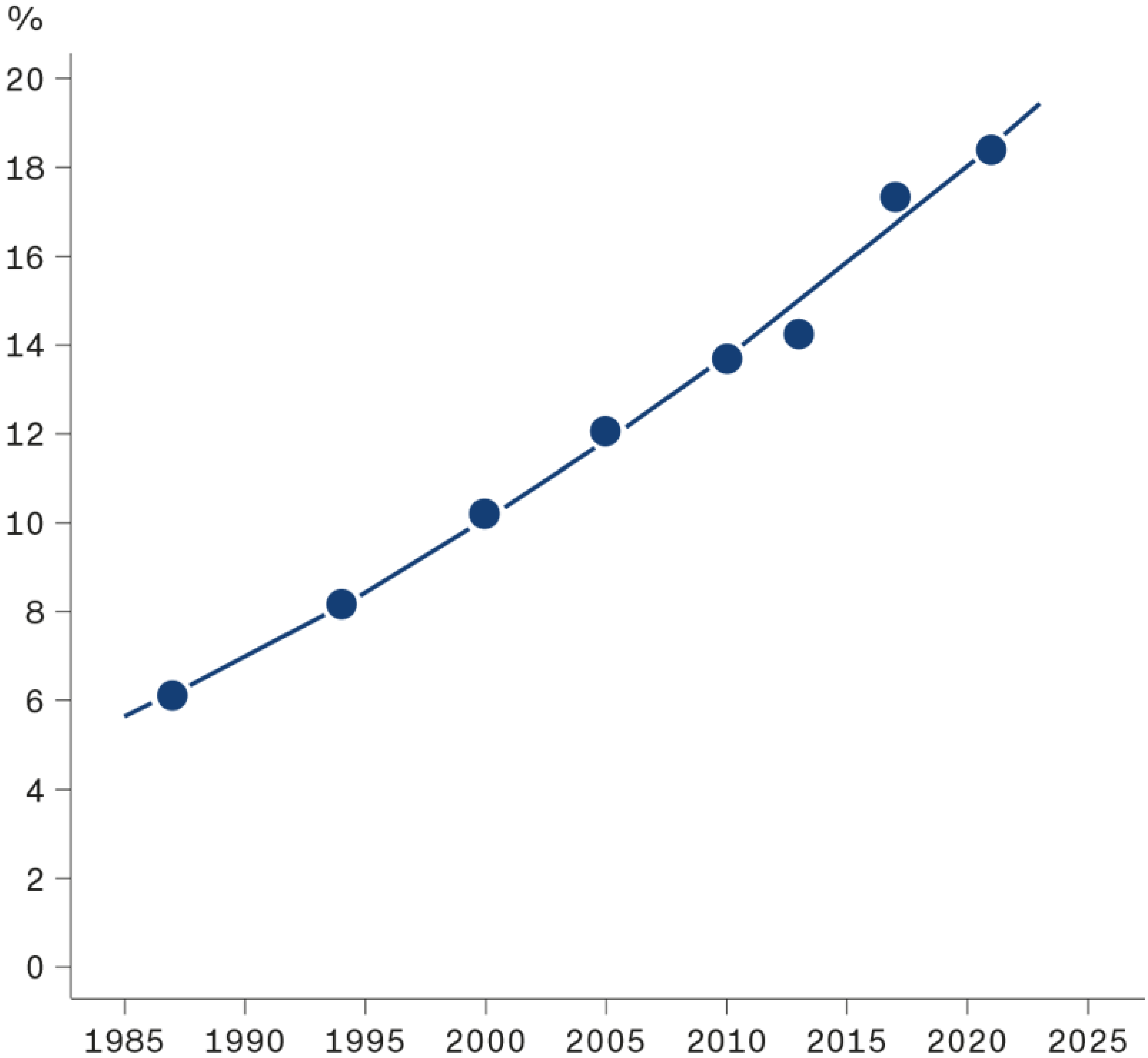
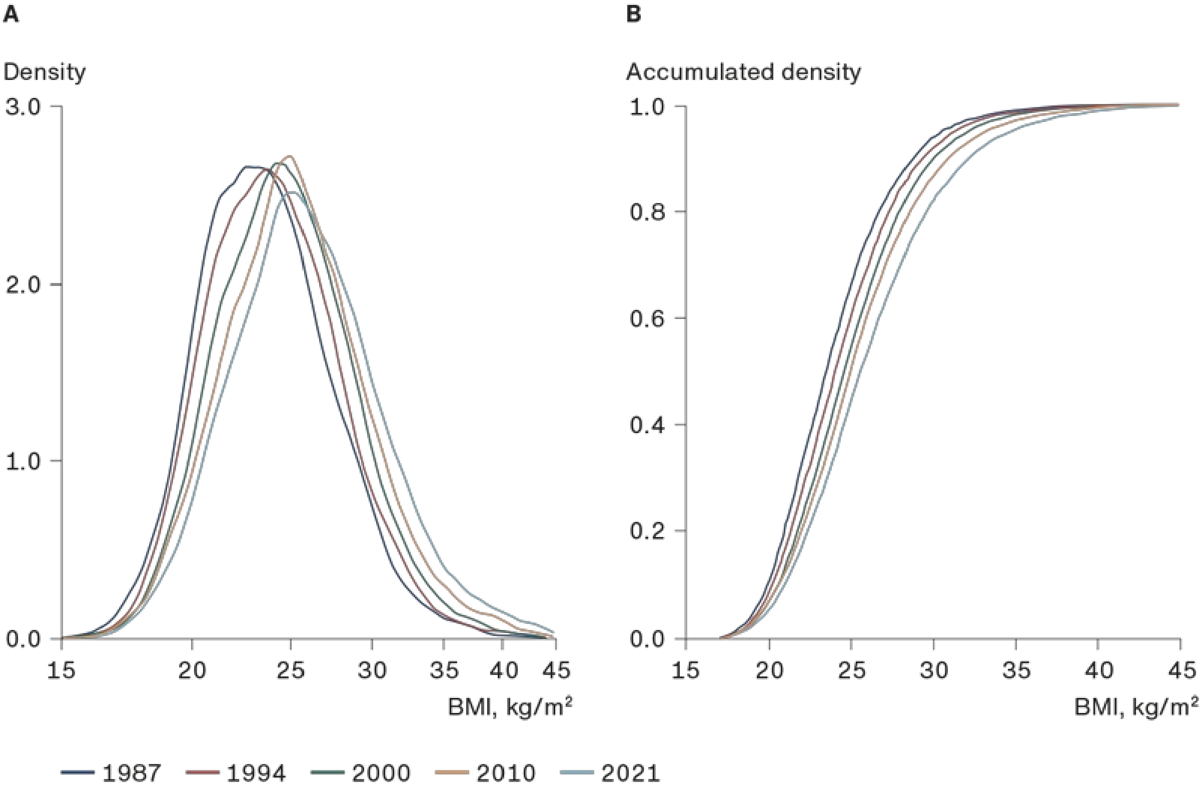
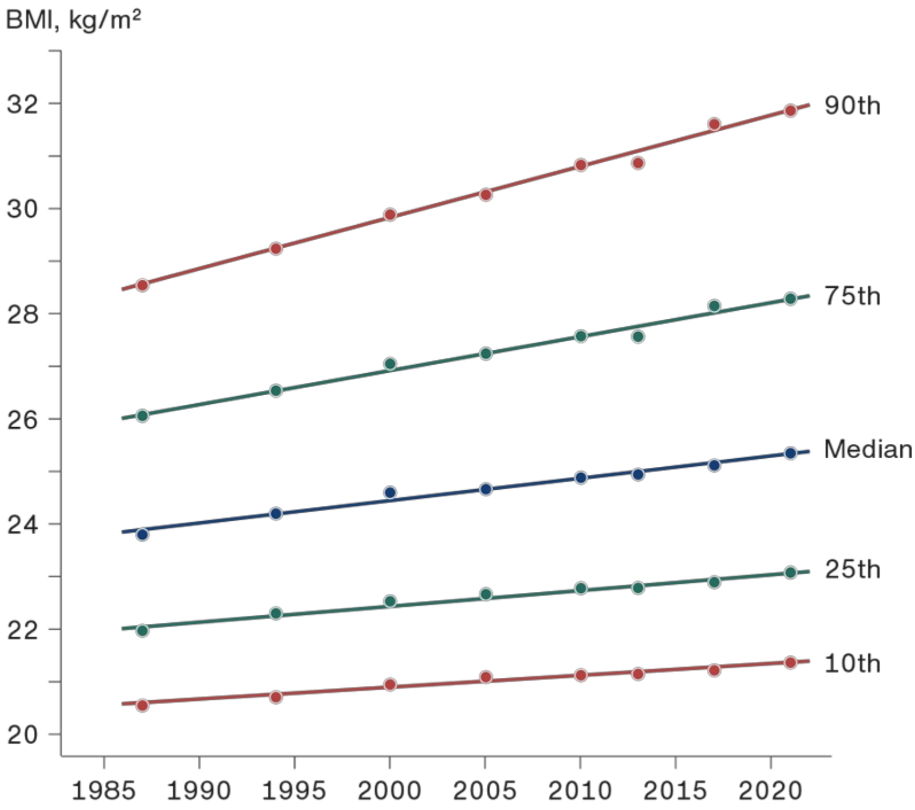


FIGURE 2 BMI distribution (**A**) and cumulative BMI distribution (**B**) by year (five survey years are selected for the graphs to remain scannable).



This visual impression was confirmed by quantile regression of the 10th, 25th, 50th, 75th and 90th percentiles of the BMI distribution (**Figure 3**). All the percentile lines exhibited increasing trends from 1987 to 2021. However, the increase was steeper in the higher percentile levels, demonstrated by a gradually larger linear slope from the lowest percentile to the highest. Hence, the lower percentiles had a small increase in BMI (0.8 BMI points in the 10th percentile), whereas the higher percentiles had a larger increase (3.4 BMI points in the 90th percentile). An increased dispersion of the BMI distribution over time was also demonstrated by a larger range between the 10th and the 90th percentile in 2021 (10.5 BMI points) compared with 1987 (7.9 BMI points). When modelling weight measurements adjusted for height, the same pattern as for BMI values was seen for the percentiles (Supplementary Figure A).

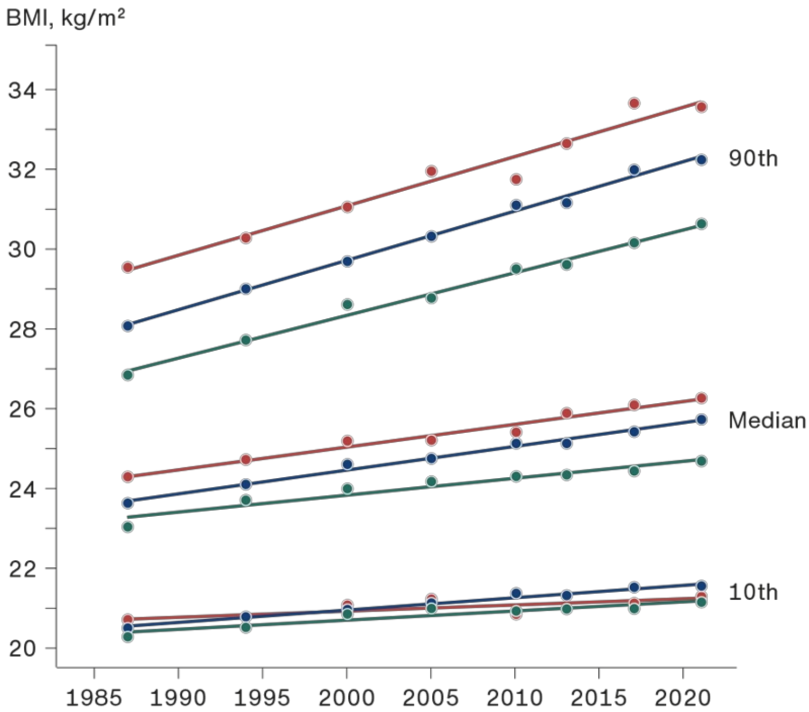
FIGURE 3 BMI percentiles (10th, 25th, 50th (median), 75th and 90th) by year of examination. Values were derived from quantile regression, adjusted for age and sex.



Percentile	Linear slope per 10 yrs, 1987-2021, kg/m²	BMI, kg/m² 1987	2021
10th	0.20 (0.17-0.24)	20.6	21.4
25th	0.28 (0.25-0.31)	22.0	23.1
Median	0.40 (0.37-0.43)	23.8	25.3
75th	0.63 (0.59-0.68)	26.1	28.3
90th	0.97 (0.90-1.04)	28.5	31.9

Analyses of BMI were repeated, stratified by educational level (short, medium and long) (**Figure 4**). For all educational levels and for all percentiles (10th, 50th and 90th), a steady increase in BMI was observed from 1987 to 2021. For the 50th and 90th percentiles, a clear separation was observed of BMI values by educational level, whereas for the 10th percentiles, the three lines were entangled. Additionally, the linear slope was less steep for long educational level than for short or medium educational level for both the 50th and 90th percentile. For example, BMI in the long educational level increased by 1.05 (0.93-1.16) kg/m^2 per ten years, whereas the increase was 1.24 (1.14-1.34) and 1.23 (1.07-1.40) for medium and short educational level. Lastly, the increase in the dispersion of the BMI distribution over time was larger for shorter educational level, illustrated by greater changes in 10th-90th percentile range from 1987 to 2021 with shorter educational level (3.4, 3.1, and 2.9 BMI points for short, medium and long educational level, respectively).

FIGURE 4 The 10th, 50th (median) and 90th percentiles, by year and category of education (short education (—), medium education (—) and long education (—)).



Level of education	Percentile	Linear slope per 10 yrs, 1987-2021, kg/m^2	BMI, kg/m^2 1987	2021
Short	10th	0.15 (0.06-0.23)	20.7	23.1
	Median	0.56 (0.49-0.64)	24.3	26.3
	90th	1.23 (1.07-1.40)	29.6	33.6
Medium	10th	0.31 (0.26-0.36)	20.5	21.5
	Median	0.57 (0.53-0.62)	23.6	25.7
	90th	1.24 (1.14-1.34)	28.1	32.2
Long	10th	0.15 (0.09-0.21)	20.3	21.2
	Median	0.35 (0.29-0.41)	23.0	24.7
	90th	1.05 (0.93-1.16)	26.8	30.6

In strata of municipality wealth as defined by the median municipal income, similar tendencies were observed. However, these were less pronounced (Supplementary Figure B). A tendency was seen towards a steeper increase in BMI in the lowest tertile compared with the middle and highest tertiles in all BMI percentiles (10th, 50th, and 90th).

DISCUSSION

This study presents trends in BMI variation in Denmark from 1987 to 2021, overall and by socioeconomic groups. We observed a shift in the distribution curve of BMI to the right illustrated by positive linear slopes for high and low BMI percentiles alike. Additionally, a change in the shape of the BMI distribution was observed with a broader range and lower peak in the most recent survey (also illustrated by steeper slopes for the 90th percentile). The prevalence of obesity in Denmark increased from 6.1% in 1987 to 18.4% in 2021. Thus, the above-described trends indicate that the increased prevalence in obesity may be explained by an increase in BMI among all BMI categories with a somewhat higher increase in the higher BMI categories.

Our findings are in line with international studies [2]. Additionally, specific studies from Norway and the USA showed similar trends [10, 11]. In Norway, a general shift towards higher body weight in all weight categories with larger increases in obesity class I and II was reported [10]. In the USA, changes in median BMI contributed to 75% of the increase in obesity from 1980 to 2000 [11].

Several mechanisms have been proposed to explain the higher increase in BMI in the higher BMI categories. Interaction between the individuals' genetic susceptibility and environmental factors has been suggested by many [12-15]. Additionally, weight bias and discrimination may lead to an increase in hormone levels, including cortisol, food intake and negative emotions, decreased physical activity and, consequently, weight gain [16]. This may potentially be a contributing factor to the increased dispersion in BMI. Thus, in an obesogenic environment, the positive skewing of the distribution curve of BMI (meaning that the tail of a distribution curve is proportionally longer on the right side or the upper end than at the lower end) may increase over time as heavier individuals gain more weight than lighter individuals. However, the increasing BMI dispersion is likely to be multifactorial, and its nature is not yet fully understood.

An important finding was that increases in and dispersion of BMI occurred for all educational groups, although the dispersion over time was larger for individuals with short education, suggesting a trend towards increasing social inequality in BMI. This is consistent with well-known social inequality in the prevalence of obesity in Denmark and comparable populations [17]. The larger increase in BMI among individuals with short education suggests that ongoing inequalities in weight gain will further put lower socioeconomic groups at a higher risk of obesity and its comorbidities. It has been proposed that socioeconomic inequalities in obesity may, to some extent, be explained by different exposure to obesogenic environments, suggesting that low-socioeconomic areas have fewer healthy choices, either in relation to food or physical activity [18, 19]. However, we did not observe large differences in the 10th, 50th or 90th percentile BMI between tertiles of municipality wealth, and no differences were recorded in the dispersion of BMI between tertiles. These findings suggest that social factors, such as educational level, rather than the physical environment, drive the inequality in dispersion of BMI – at least in Denmark. However, it is plausible that inequalities in the environment within municipalities are not captured as they are equalised when measuring municipality wealth on average.

Increasing population BMI with a right shift of the whole distribution has implications for public health and suggests that public health measures to prevent obesity should be targeted at the general population, e.g., by introducing structural public health programmes.

A major strength of this study is that the the Danish National Health and Morbidity Surveys are nationally representative and cover a period of 34 years. However, the response rate has varied across the survey years and overall decreased from 79.9% in 1987 to 45.4% in 2021 [7, 8]. Although the response rates were similar in other studies, they may be influenced by degree of health, including BMI and sociodemographic factors. In the Danish Health and Morbidity Surveys, non-respondents were generally more likely to be young men, have another ethnic background than Danish, be unmarried and have lower socioeconomic status (e.g., educational level and income). Further details have been described elsewhere [7, 8, 20]. To account for this, sampling weights based on sociodemographic information of non-respondents were applied. Previous studies have shown that self-reported information on weight and height have been biased in such way that individuals are likely to overestimate their height and underestimate their weight, resulting in an underestimation of BMI. However, in a Danish validation study with a similar study population and setting as used in this study, the degree of BMI underreporting was found to be low [9]. Also, the applied calibrations have been validated in a sub-sample of 15,692 participants who both filled out questionnaires and participated in a health examination with weight and height measures [9].

The difference in the distribution indicators were not tested for statistical significance as the purpose of this study was to describe distribution trends. How much of the increasing obesity prevalence and mean BMI may be attributed to a right shift and changes in the distribution cannot be concluded. However, we believe quantifying this is less important and that the important finding is that both mechanisms are in play and that the population as a whole is affected by increasing BMI. This is an important consideration when planning public health measures to prevent obesity as such initiatives may include public health measures to the broader public as well measures targeted at individuals in high BMI categories.

CONCLUSIONS

We observed a shift to the right in the BMI distribution curve from 1987 to 2021 with gradually higher values in all BMI percentiles and in all socioeconomic strata. Thus, our results show that, generally, everyone in the Danish population is gaining weight. Continued monitoring of population BMI trends is needed for identification, implementation and evaluation of public health policies and evidence-based interventions.

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Accepted 11 August 2023

Conflicts of interest none. Disclosure forms provided by the authors are available with the article at ugeskriftet.dk/dmj

Cite this as Dan Med J 2023;70(10):A03230139

Supplementary https://content.ugeskriftet.dk/sites/default/files/2023-08/a03230139-supplementary.pdf

REFERENCES

1. Janssen F, Bardoutsos A, Vidra N. Obesity prevalence in the long-term future in 18 European countries and in the USA. Obes Facts. 2020;13(5):514-27.
2. NCD Risk Factor Collaboration (NCD-RisC). Heterogeneous contributions of change in population distribution of body mass index to change in obesity and underweight. Elife. 2021;10:e60060.
3. Razak F, Subramanian SV, Sarma S et al. Association between population mean and distribution of deviance in demographic surveys from 65 countries: cross sectional study. BMJ. 2018;362:k3147.
4. Rose G, Day S. The population mean predicts the number of deviant individuals. BMJ. 1990;301(6759):1031-4.
5. Wagner KJP, Boing AF, Cembranel F et al. Change in the distribution of body mass index in Brazil: analysing the interindividual inequality between 1974 and 2013. J Epidemiol Community Health. 2019;73(6):544-8.
6. Penman AD, Johnson WD. The changing shape of the body mass index distribution curve in the population: implications for public health policy to reduce the prevalence of adult obesity. Prev Chronic Dis. 2006;3(3):A74.
7. Ekholm O, Hesse U, Davidsen M et al. The study design and characteristics of the Danish national health interview surveys. Scand J Public Health. 2009;37(7):758-65.

8. Jensen HAR, Ekholm O, Davidsen M et al. The Danish health and morbidity surveys: study design and participant characteristics. BMC Med Res Methodol. 2019;19(1):91.
9. Neermark S, Holst C, Bisgaard T et al. Validation and calibration of self-reported height and weight in the Danish Health Examination Survey. Eur J Public Health. 2019;29(2):291-6.
10. Midthjell K, Lee CMY, Langhammer A et al. Trends in overweight and obesity over 22 years in a large adult population: the HUNT Study, Norway. Clin Obes. 2013;3(1-2):12-20.
11. Helmchen LA, Henderson RM. Changes in the distribution of body mass index of white US men, 1890-2000. Ann Hum Biol. 2004;31(2):174-81.
12. Brandkvist M, Bjørngaard JH, Ødegård RA et al. Quantifying the impact of genes on body mass index during the obesity epidemic: longitudinal findings from the HUNT Study. BMJ. 2019;366:l4067.
13. Jackson SE, Llewellyn CH, Smith L. The obesity epidemic - nature via nurture: a narrative review of high-income countries. SAGE Open Med. 2020;8:2050312120918265.
14. Rohde K, Keller M, la Cour Poulsen L et al. Genetics and epigenetics in obesity. Metabolism. 2019;92:37-50.
15. Hemmingsson E, Nowicka P, Ulijaszek S et al. The social origins of obesity within and across generations. Obes Rev. 2023;24(1):e13514.
16. Major B, Tomiyama AJ, Hunger JM. The negative and bidirectional effects of weight stigma on health. In: Major B, Dovidio JF, Link BG, eds. The Oxford handbook of stigma, discrimination, and health. Oxford University Press, 2018.
17. Magnusson M, Sørensen TIA, Olafsdottir S et al. Social inequalities in obesity persist in the Nordic region despite its relative affluence and equity. Curr Obes Rep. 2014;3(1):1-15.
18. Hilmers A, Hilmers DC, Dave J. Neighborhood disparities in access to healthy foods and their effects on environmental justice. Am J Public Health. 2012;102(9):1644-54.
19. Cohen DA, Han B, Nagel CJ et al. The first national study of neighborhood parks: implications for physical activity. Am J Prev Med. 2016;51(4):419-26.
20. Kjøller M, Thoning H. Characteristics of non-response in the Danish health interview surveys, 1987-1994. Eur J Public Health. 2005;15(5):528-35.