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Intelligence and obesity during the obesity epidemic

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Several studies conducted during the last 50 years have shown that lower intelligence is associated with a higher body mass index (BMI). During this period, the prevalence of obesity and overweight has increased considerably. We investigated whether this increase has altered the relation between intelligence and BMI by studying two cohorts of 419,319 conscripts, born 1939–1959 and 1983–2001, examined in the same geographical districts in Denmark. While the prevalence of obesity increased from 0.8% in the early to 6.7% in the late cohort, the two cohorts showed essentially the same pattern of relations between intelligence test scores (ITS), prevalence of obesity and overweight (including obesity), and BMI. The prevalence of obesity and overweight and BMI was higher at any ITS value in the late than in the early cohort, but inversely associated with ITS in both cohorts. The ITS displayed inverse J-shaped associations with BMI, with ITS peaking around a BMI of 20 kg/m^2 and declining with higher BMI, although with a somewhat steeper decline in the early than in the late cohort. Thus, irrespective of the increase in prevalence of obesity and overweight and in BMI, the pattern of inverse relations between intelligence and higher BMI levels was maintained.

Multiple studies conducted over the last five decades have shown an inverse relation between intelligence and higher levels of body mass index (BMI, kg/m^2), resulting in higher prevalence of obesity (defined as BMI $\geq$ 30.0 kg/m^2) among people with low intelligence or, conversely, lower intelligence among people with obesity[1–17]. During this period, the prevalence of obesity has increased considerably in many countries, referred to as a global obesity epidemic[18,19]. This raises the question of whether the relation of intelligence with BMI and obesity, has changed during this period. Data available in Denmark on young men examined for their suitability for military service allowed us to address this question[20,21].

Previous studies of data on Danish conscripts born before 1960 showed that intelligence had an inverse J-shaped association with BMI, with lower intelligence observed at higher BMI levels[2,3]. These older data suggested that the difference in intelligence between young men with and without obesity declined as the prevalence of obesity increased[2]. A study of the conscripts born 1955–1984 and examined in another part of Denmark also suggested a weakening of the intelligence-BMI relation during the later years[13]. This may suggest that the inverse relation between intelligence and high BMI is a characteristic of a relatively small group of people with a particular type of obesity before the epidemic, whereas the larger group of people with another common type of obesity, constituting the obesity epidemic, may not show this relation. If so, the increasing prevalence of obesity in the population may imply that people with higher intelligence levels have developed obesity and thereby weakened the relation in the later cohorts as compared to the earlier ones. However, the previous Danish studies were based on rather limited sample sizes.

We investigated whether the increase in the prevalence of obesity and overweight (including obesity) has altered the relation between intelligence test scores (ITS) and BMI in two Danish cohorts of young men born between 1939–1959 ('the early cohort', n = 258,882) and 1983–2001 ('the late cohort', n = 162,250), who were examined before a conscription board in the same districts[20,21]. Specifically, we assessed, within each of these cohorts, how prevalence of obesity and overweight and BMI associates with ITS, and, vice versa, how ITS associates with BMI across the BMI range, and whether these relations, including the previously observed non-linearity, have changed between the two cohorts.

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Results

The mean BMI and SD was higher in the late than in the early cohort (mean (SD), of the early cohort, 21.7 (2.5), and of the late cohort 23.5 (3.9)), and the prevalence of obesity among the young men was markedly higher in the late cohort (6.7%) than in the early cohort (0.8%) as was prevalence of overweight (7.9% versus 21.3%). The mean ITS in the late cohort was slightly higher with a lower SD than in the early cohort (mean (SD), of the early cohort, 39.4 (12.2), and of the late cohort, 41.1 (9.3)). As shown in Fig. S1A and B, the distributions differ notably. The ITS distribution in the early cohort exhibits greater left-sided skewness and higher kurtosis than the late cohort, while the BMI distribution shows less right-sided skewness in the early cohort than in the late cohort.

Prevalence of obesity and overweight as a function of intelligence

The prevalence of obesity clearly declined across quartiles of ITS in both cohorts, while the prevalence level was higher in the late than in the early cohort across all the ITS quartiles (Table 1). The logistic model of odds of presence of obesity as a function of ITS revealed a monotonic inverse associations (Table S2). This is illustrated in Fig. 1, which shows the predicted prevalence of obesity by ITS and highlights the substantially higher prevalence across the ITS range in the late cohort than in the early cohort. The inverse association measured by odds ratios of obesity prevalence with ITS was not statistically different between the two cohorts (Table S2, extended model). The added quadratic and cubic terms, including interactions with the cohort variable, to the logistic regression model, were not statistically significant, wherefore they were not included in the final model (Tables S2, main and extended models). The corresponding analysis of overweight are shown in Table S3 and the graphical representation in Fig. 2. A slight non-linear relationship was probed by significant quadratic and cubic terms of ITS, but there were no significant interactions of these terms with the cohort variable.

BMI as a function of intelligence

While there were distinct differences in mean BMI between the early and the late cohorts, there were only minor differences in mean BMI across quartiles of ITS within each cohort with the highest BMI values among men in the lowest quartiles of ITS (Table 2). However, in the multiple regression model, the relationship appeared more complex and non-linear, probed with both squared and cubic functions of ITS, and with significant differences observed between cohorts (Table S4, both main and extended models). This complexity reflects the specific joint distributions of ITS and BMI, which are further addressed below in the context of ITS as a function of BMI. The graphical representation of the model showed the generally higher predicted level of BMI at any level of ITS in the late than in the early cohort, and with a decline in predicted BMI with higher ITS in the late cohort, but less clear so in the early cohort (Fig. 3).

Intelligence as a function of BMI

Mean ITS was highest among those with normal weight, slightly lower in those with underweight, lower among those with overweight, and even lower among those with obesity (Table 3). The parameters capturing the non-linearity of the ITS as a function of BMI are shown in Table S5 and graphically represented in Fig. 4. The multiple regression analysis performed on both cohorts together showed that inclusion of quadratic and cubic functions of BMI in the regression model improved the model fit, and, moreover, there were significant interactions between the BMI variables and the cohort variable. Translated to the graphical form, the model showed the generally higher predicted ITS for any given level of BMI, and an inverse J-shaped association of mean ITS as a function of BMI in both the early and the late cohorts with predicted ITS peaking at around a BMI of 20 kg/m^2, and with a monotonic decrease at higher BMI levels until a BMI of around 38 kg/m^2. At BMI values above that level, the association weakened, but the confidence limits also became broader, reflecting the smaller sample size

	The early cohort			The late cohort		
	Prevalence of obesity			Prevalence of obesity		
	N total	N BMI ≥ 30.0	% BMI ≥ 30.0 (95% CI)	N total	N BMI ≥ 30.0	% BMI ≥ 30.0 (95% CI)
Quartile categorized intelligence test score						
ITS score ≤ 31	68,333	871	1.27 (1.19; 1.36)	41,091	4007	9.75 (9.46; 10.04)
ITS score 32–40	62,755	529	0.84 (0.77; 0.91)	46,005	3090	6.72 (6.49; 6.95)
ITS score 41–48	63,110	428	0.68 (0.61; 0.74)	35,268	1987	5.63 (5.39; 5.87)
ITS score ≥ 49	64,684	347	0.54 (0.48; 0.59)	39,886	1749	4.38 (4.18; 4.59)
Total	258,882	2175	0.84 (0.80; 0.88)	162,250	10,833	6.68 (6.56; 6.80)
Geographical district						
Metropolitan	204,785	1751	0.86 (0.82; 0.89)	120,026	7071	5.89 (5.76; 6.02)
Provincial	52,288	399	0.76 (0.69; 0.84)	42,224	3762	8.91 (8.64; 9.18)
Missing	1813	–	–	–	–	–

Table 1. Descriptive statistics of the early (born 1939–1959) and late (born 1983–2001) cohorts. Number and percentage (with 95% confidence intervals (CI)) of total population categorized as obese (body mass index ≥ 30.0) stratified by quartiles of intelligence test score and geographical district and presented separately for the early and the late cohorts.

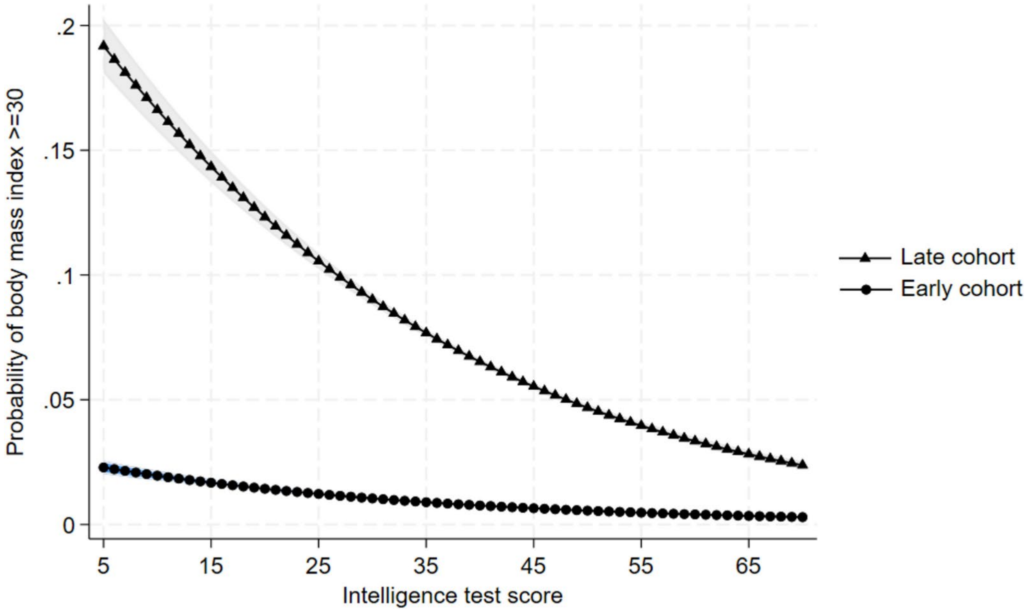

Fig. 1. Predictions of body mass index ≥ 30.0 kg/m^2 as a function of intelligence test score separately for the early (born 1939–1959) and late (born 1983–2001) cohorts. The graph is based on a logistic regression model that include birth year, geographical district, and height, with confidence intervals indicated by the grey zone around the estimates. For details of the model structure, see 'Extended model' in Table S2.

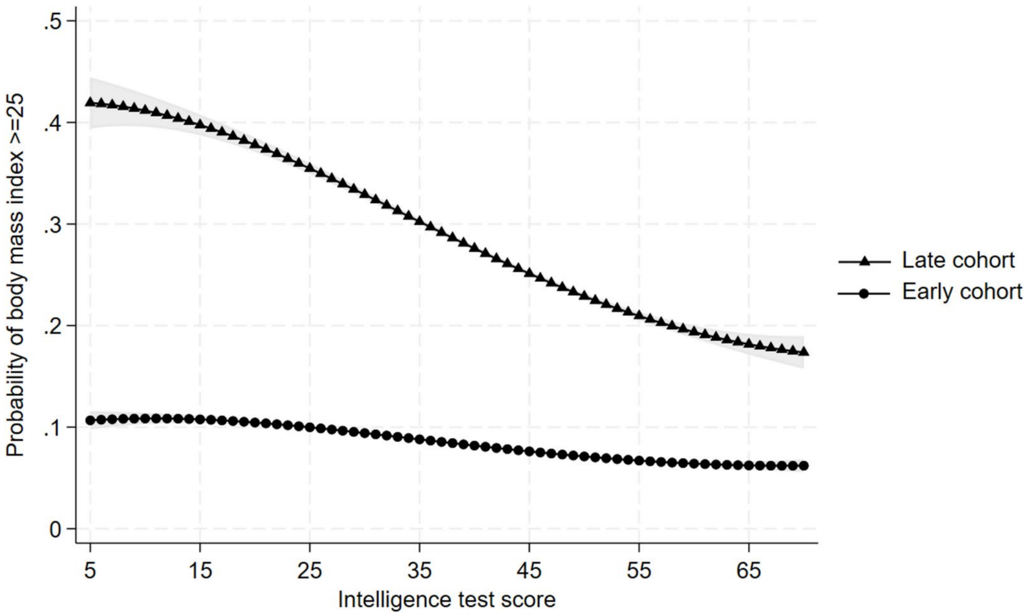

Fig. 2. Predictions of body mass index ≥ 25.0 kg/m^2 as a function of intelligence test score separately for the early (born 1939–1959) and late (born 1983–2001) cohorts. The graph is based on a logistic regression model that include birth year, geographical district, and height, with confidence intervals indicated by the grey zone around the estimates. For details of the model structure, see 'Extended model' in Table S3.

at these values. However, the shape of the curves was somewhat different with less steep decline of ITS by higher BMI values above the peak value in the late cohort than in the early cohort.

Discussion

Despite the considerable increase in the prevalence of obesity, it remained monotonically and inversely associated with intelligence, with no differences in the association as measured by odds ratios between the two cohorts. The analyses of prevalence of overweight (including obesity) showed essentially the same picture, although less

	The early cohort				The late cohort			
			Body mass index				Body mass index	
	N	Percent %	Mean (95% CI)	SD	N	Percent %	Mean (95% CI)	SD
Quartile categorized intelligence test score								
ITS score ≤ 31	68,333	26.4	21.80 (21.78; 21.82)	2.7	41,091	25.3	24.83 (23.96; 24.04)	4.4
ITS score 32–40	62,755	24.2	21.71 (21.68; 21.72)	2.5	46,005	28.4	23.59 (23.56; 23.64)	3.9
ITS score 41–48	63,110	24.4	21.60 (21.58; 21.62)	2.4	35,268	21.7	23.32 (23.26; 23.34)	3.7
ITS score ≥ 49	64,684	25.0	21.59 (21.58; 21.62)	2.3	39,886	24.6	23.02 (22.97; 23.03)	3.5
Total	258,882	100	21.70 (21.69; 21.71)	2.5	162,250	100	23.50 (23.48; 23.52)	3.9
Geographical district								
Metropolitan	204,785	79.1	21.60 (21.59; 21.61)	2.5	120,026	74.0	23.30 (23.28; 23.32)	3.8
Provincial	52,288	20.2	22.01 (21.98; 22.02)	2.40	42,224	26.0	24.00 (23.96; 24.04)	4.2
Missing	1813	0.7	–	–	–	–	–	–

Table 2. Descriptive statistics of the early (born 1939–1959) and late (born 1983–2001) cohorts. Men body mass index (with 95% confidence intervals (CI)) by intelligence test score categorized in quartiles and categorized covariates separately for the early and the late cohorts.

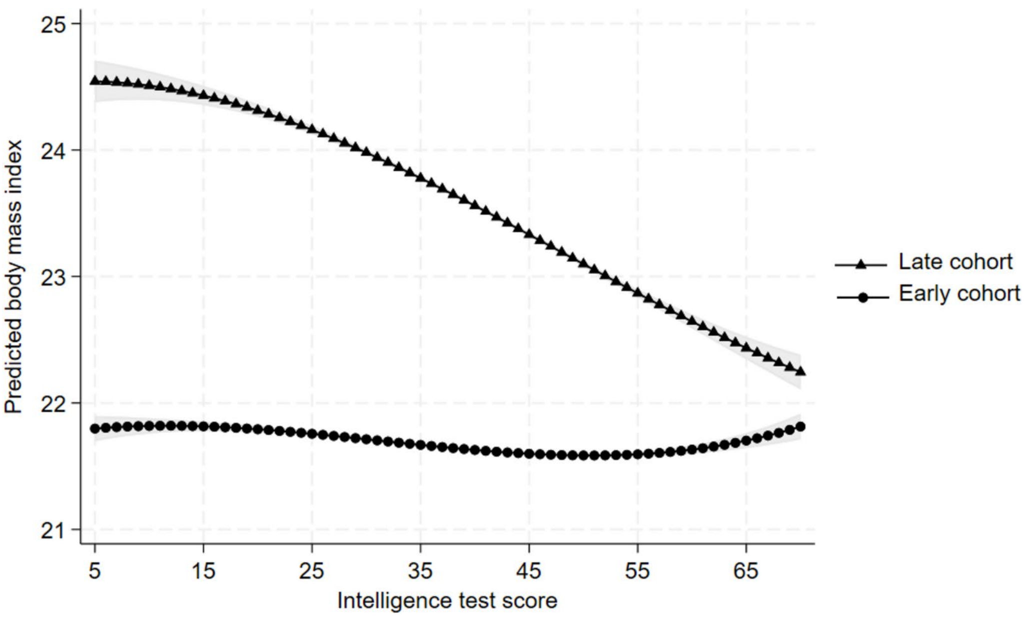

Fig. 3. Body mass index as a function of intelligence test score for the early (born 1939–1959) and late (born 1983–2001) cohorts. The graph is based on a multiple linear regression model, which includes birth year, geographical district, and height, with confidence intervals indicated by the grey zone around the estimates. For details of the model structure, see 'Extended model' in Table S4.

pronounced and with some minor non-linearity similarly present in both cohorts. Analyses across the full ranges of ITS and BMI proved to be more complex, requiring non-linear functions and interactions with the cohort variable. This complexity likely reflects the unique characteristics of the joint distributions of ITS and BMI and their changes over time. Analysing mean BMI as a function of ITS showed a decline in BMI with higher ITS, which was clearly observed in the late cohort, but less pronounced in the early cohort. The previously observed inverse J-shaped relation of ITS as a function of BMI was evident in both the early and the late cohorts. The ITS values were slightly higher in the late cohort than in the early cohort across the range of BMI, peaking in both cohorts around a BMI of 20 kg/m^2. With increasing BMI values above this level, the ITS declined monotonically and almost linearly, but with a somewhat less steep slope in the late than in the early cohort until the decline plateaued at a BMI around 38 kg/m^2. Overall, the mutual explanatory values, as assessed by R-squared, were very small. Thus, the key findings of this study pertain to the upper extreme of the BMI distribution, whereas the central range shows only weak and non-linear relations between intelligence and BMI.

Strengths and limitations

A major strength of the present study was the inclusion of two large cohorts representing most of the young men examined in the defined geographical district during the two time periods[20,21]. The large sample sizes allowed

	The early cohort				The late cohort			
			Intelligence test score				Intelligence test score	
	N	Percent %	Mean (95% CI)	SD	N	Percent %	Mean (95% CI)	SD
WHO categorized body mass index (BMI)								
Underweight, BMI < 18.5	17,509	6.8	39.23 (38.96; 39.50)	12.1	7619	4.7	40.93 (40.71; 41.15)	9.7
Normal weight, BMI 18.5–24.9	218,767	84.5	39.62 (39.55; 39.69)	12.2	109,251	67.3	41.76 (41.71; 41.82)	9.1
Overweight, BMI 25.0–29.9	20,431	7.9	37.81 (37.68; 37.94)	12.4	34,547	21.3	40.07 (39.97; 40.17)	9.3
Obesity, BMI ≥ 30.0	2175	0.8	35.09 (34.56; 35.62)	12.5	10,833	6.7	38.18 (38.00; 38.37)	9.8
Total	258,882	100	39.41 (39.35; 39.47)	12.2	162,250	100	41.12 (41.21; 41.32)	9.3
Geographical district								
Metropolitan	204,785	79.1	40.04 (39.97; 40.11)	12.2	120,026	74.0	41.26 (41.21; 41.32)	9.3
Provincial	52,288	20.2	37.08 (36.96; 37.20)	12.1	42,224	26.0	40.72 (40.63; 40.81)	9.1
Missing	1813	0.7	–	–	–	–	–	–

Table 3. Descriptive statistics of the early (born 1939–1959) and late (born 1983–2001) cohorts. Mean intelligence test score (with 95% confidence intervals (CI)) by body mass index (categorized according to W.H.O. criteria) and geographical district separately for the early and the late cohorts.

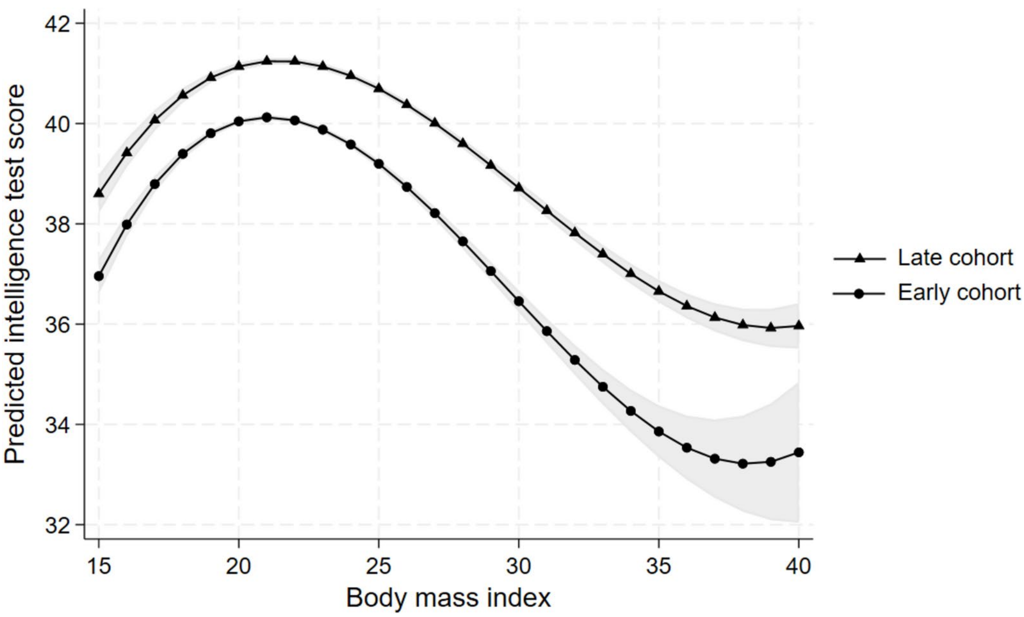

Fig. 4. Intelligence test score as a function of body mass index for the early (born 1939–1959) and late (born 1983–2001) cohorts. The graph is based on a multiple linear regression model, which includes birth year, geographical district, and height, with confidence intervals indicated by the grey zone around the estimates. For details of the model structure, see 'Extended model' in Table S5.

for reasonable and reliable estimates of the relations in the upper extreme of the BMI distribution, although the uncertainty of these estimates naturally increases at higher BMI levels, more so in the early than in the late cohort. Another strength was the objective measurement of height and weight, alongside the consistent assessment of intelligence using the same test administered at approximately the same ages across cohorts, making it possible to perform presumably valid comparisons of the two cohorts. Although BMI reflects the sum of relative weights of several body compartments, there is a general agreement about its utility as a proxy measure of the relative size of the body fat mass, especially at population levels, which is reflected in the use of BMI by WHO as tool to define overweight and obesity (see Methods) and its use in numerous population studies. The high correlation of the intelligence test used in this study with the internationally generally applied Wechsler Adult Intelligence Scale documents its validity (see Methods).

The cross-sectional study design poses limitations in the assessment of temporality of the evolvement of the intelligence-BMI relations within each cohort, but the comparison of the two cohorts, exhibiting distinct differences in BMI distributions, may allow elucidation of the changes in the mutual relationships. The proportion of men exempted from the conscript examinations due to disqualifying conditions—possibly implying extreme values of ITS and/or BMI—was slightly higher in the late cohort than in the early cohort, which may have biased the comparison, possibly in the direction of weakening the associations in the late compared with the early cohort. Likewise, other differences in population composition and characteristics between the two cohorts could bias the comparisons. Obviously, there were major changes in the Danish society from the period of the early to the late cohort, likely contributing to the increases in ITS, BMI, and obesity prevalence, possibly confounding their observed relationships. However, the finding of almost stable relations between ITS and BMI, despite these societal changes, is remarkable by itself. Thus, we find it unlikely that such societal changes would have made the relations between ITS, BMI and obesity prevalence more similar than they would have been without these concomitant changes. Finally, the focus on only Danish men and lack of women in the cohorts limit the conclusions to the Danish men.

Comparison with previous studies

Whereas several previous studies have suggested, albeit with different strength, that obesity associates with low cognitive ability[1–17], the consistent, distinct, monotonic inverse relation across the ITS range within the two cohorts during the development of the obesity epidemic has not been previously demonstrated. Our finding of an inverse J-shaped relation between BMI and intelligence in the early cohort born between 1939 and 1959 replicates the finding by Teasdale and colleagues on an overlapping sample of Danish conscripts born between 1947 and 1958[3]. Investigation of a smaller cohort of Danish conscripts born 1955, 1965–1969, 1970–1979, and 1980–1984, and examined in another part of Denmark found a similar inverse J-shaped BMI-intelligence relation in the two earliest cohorts, but surprisingly, an almost linear and less steep inverse relation in the two later cohorts[13]. In our larger cohort including men born 1983–2001, we found that the inverse J-shape was maintained, although somewhat weakened. Inconsistencies with previous studies may be due to their smaller sample sizes, necessarily capturing mainly the weaker relations within the central part of the BMI distribution. Moreover, the inverse J-shape of the ITS as a function of BMI implies that the assessment of that relation in linear regressions of ITS on BMI or BMI on ITS are inadequate.

Interpretation of the findings

The question concerning which causal mechanisms may generate the observed relations of intelligence with BMI is complex by implying general questions about determinants of both BMI and intelligence and about their possible uni- or bi-directional mutual interactions and underlying common roots (horizontal and vertical pleiotropy), which may exhibit heterogeneity across the range of BMI with apparently distinct processes in the upper range of overweight and obesity. While the results of the present study and similar previous studies cannot answer these questions, the current results may allow exclusion of some of the possible underlying causal relationships as less likely. Thus, despite the persisting and obviously strong inverse association of obesity prevalence with intelligence, the overall increase in intelligence between the two cohorts implies that the increase in obesity prevalence cannot be attributed to a declining intelligence. This indicates that the effect of cognitive ability on the risk of obesity is independent of other factors that must be behind the increase in the obesity prevalence. Conversely, the findings are not supporting a major influence of obesity development on intelligence, since it increases despite the rise in BMI and obesity prevalence. This aligns with previous prospective studies suggesting that intelligence may determine the later individual risk of obesity rather than the other way round[4–11].

The complex role of educational level, including its likely interactive relations to both BMI, obesity, and intelligence and the genetic, familial, and socioeconomic background[1–17,22–26], clearly need to be integrated in a comprehensive causal modelling of the relations. However, acknowledging the limitations of the information available to this study, such modelling falls outside the scope of our study. While the present study addressed the intelligence-BMI relationships at the beginning of adult life, the impact of cognitive ability on body weight changes in later adult life appeared limited[4,15,27,28]. On the other hand, further considerations and studies of how these relationships come about during childhood, including the possible mediating role of education and hence the opportunities to modify the relations, are needed.

In conclusion, whereas the evolvement of the obesity epidemic in the population of Danish young men was accompanied by a minor general increase in intelligence, the prevalence of obesity remains strongly and inversely associated with intelligence throughout its range. The previously observed inverse J-shaped association of intelligence as a function of BMI with markedly lower scores at higher BMI, was maintained albeit somewhat weakened. The findings suggest that the relation reflects underlying body processes linking cognitive processes and obesity development that appear to be independent of and resistant to the societal changes. Elucidation of the origin and mechanisms of the persisting inverse relation between intelligence and obesity may be relevant in understanding the processes driving the obesity epidemic, and thereby inform public health strategies aiming at mitigating the obesity epidemic.

Materials and methods

Study populations

The present study was based on two separate cohorts of Danish conscripts, the early cohort derived from the Danish Conscription Database and the late cohort derived from the Danish Conscription Registry[20,21]. In Denmark, all men are required by law to appear before a conscript board for a physical and cognitive examination around age 18 years, and the examination must be completed before they turn 27 years. A small proportion of men are exempted from the examination due to disqualifying diseases (e.g., type 1 diabetes or epilepsy) rendering them unfit for military service. The examination includes assessments of height, weight, and intelligence testing, providing the BMI and ITS data. Figure 5 shows the selection of cohort members to the present study, which included 258,882 men from the early cohort and 162,250 men from the late cohort, in total 421,132, which in the eventual analyses were reduced to 419,319 individuals because of missing information on geographical district in 1813 individuals (Tables 1, 2 and 3).

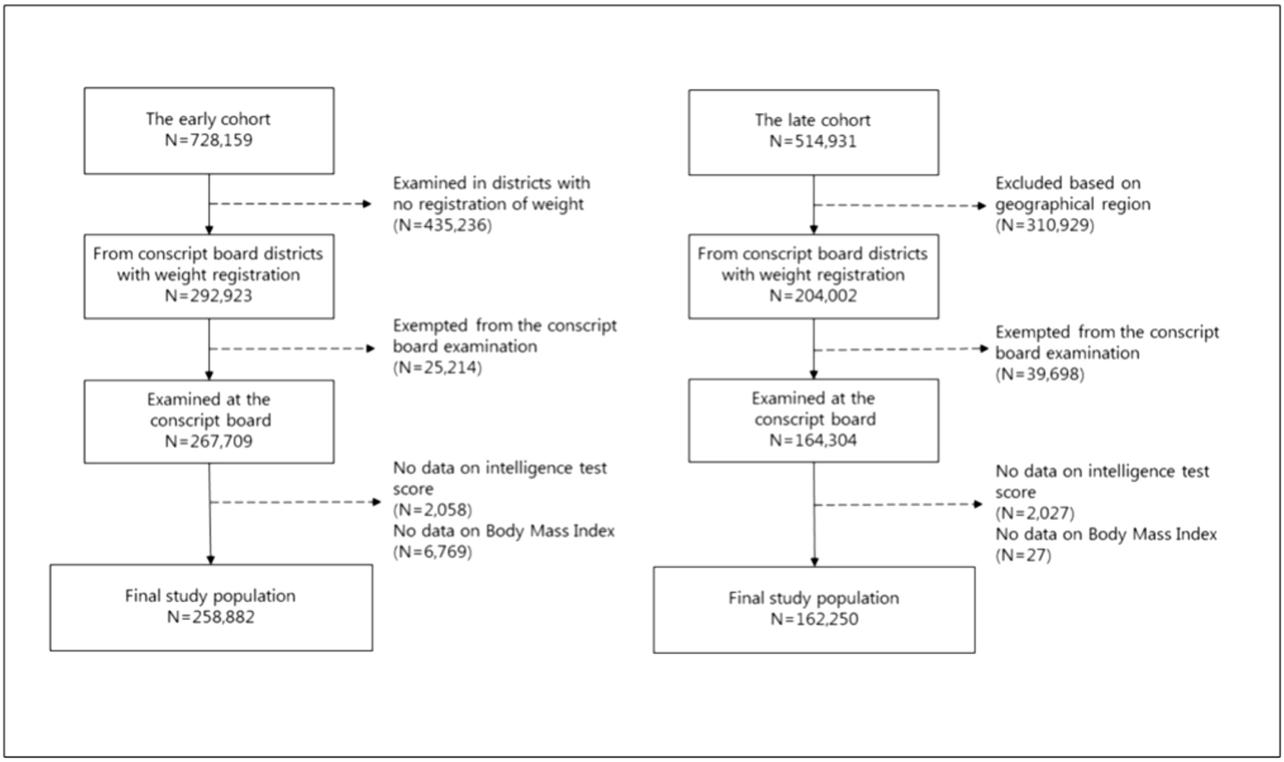

Fig. 5. Flow chart presenting the selection of Danish young conscripts to the early (born 1939–1959) and late (born 1983–2001) cohorts.

The early cohort

The early cohort comprises information from examination of 728,159 Danish men, who appeared before the Danish conscription boards from 1957 through 1984, and hence predominantly were born from 1939 through 1959. In this period, Denmark was divided in seven conscription board districts, but routine weighing differed by district and across the period. Only two districts had a systematic registration of weight across the entire period, namely District 1 (metropolitan district), covering greater Copenhagen and the northern part of Sjælland (Zealand), and District 3 (provincial district), covering Fyn (Funen), adjacent islands and a minor part of Jylland (Jutland). A total of 435,236 (59.8%) men were thus excluded because they were examined in districts with no or only ad hoc registration of weight. Furthermore, 25,214 (3.5%) were exempted from the examination, and 8827 (1.2%) men were excluded due to missing data on either ITS (n = 2058) or BMI (n = 6769 men) leaving a final study population of 258,882 men in the early cohort.

The late cohort

The late cohort includes data from 514,931 conscripts examined from 2006 through 2019, who were predominantly born from 1983 through 2001. For this cohort, weighing was carried out and registered across all of Denmark, but because both BMI and ITS differ between districts, we aimed at ensuring geographical concordance with the early cohort by identifying and selecting only those who were living in the districts previously covered by conscription board Districts 1 (metropolitan district) and 3 (provincial district). Thereby we excluded 310,929 (60.4%) men who were living in areas covered by conscription board Districts 2, 4, 5, 6, and 7. A total of 39,698 (7.7%) men were exempted from the examination, and 2054 (0.4%) men were excluded due to missing information on either ITS (n = 2027) or BMI (n = 27) resulting in a final study population of 162,250 men in the late cohort.

Body mass index

At the conscription board examination, height was measured without shoes and to the nearest centimetre and weight was measured wearing only underwear and to the nearest kilogram. BMI was calculated as weight in kilograms divided by the square of height in meters (kg/m^2) and analysed as a continuous and rounded variable. Furthermore, the BMI variable was categorized according to WHO weight status categories (Table 1) and categorized into dichotomous variables indicating presence or absence of obesity and overweight (including obesity).

Intelligence test score

Intelligence was assessed at the conscription board examination by an intelligence test called the 'Børge Priens Prøve'[29], which has been in use unchanged since the examinations in 1957. It is a time-limited test comprising four subtests: letter matrices (19 items), verbal analogies (24 items), number series (17 items), and geometric figures (18 items). The number of correct answers is summed into a total score within a range of 0–78, which was analysed as a continuous variable. Furthermore, to estimate prevalence and mean BMI across ITS, the ITS variable was categorized into quartiles (Table 2). The total test score has been shown to correlate substantially (r = 0.82) with the full-scale Wechsler Adult Intelligence Scale IQ score[30], the most widely used individual test of intelligence. Information on the individual subtest scores was not available.

Covariates

As potential confounders of the relation between BMI and intelligence within each cohort, we considered birth year[31–34], geographical district (metropolitan district; provincial district)[2,35], and height[36].

Statistical analysis

Cohort characteristics were analysed using descriptive statistics (Tables 1, 2, 3, and Table S1).

In view of the previous studies, also those based on Danish conscription data[2,3,13], and the initial empirical scrutiny of the joint distributions of ITS and BMI, we decided to use a modelling strategy allowing for non-linear functions of these variables by inclusion of quadratic and cubic terms when assessing BMI and ITS as function of ITS and BMI, respectively.

Logistic regression analyses were performed with BMI as the dependent variable when categorized by obesity as 0 = BMI < 30.0 kg/m^2 and 1 = BMI ≥ 30.0 kg/m^2 and by overweight (including obesity) as 0 = BMI < 25.0 kg/m^2 and 1 = BMI ≥ 25.0 kg/m^2 and with the continuous ITS as the independent variable. The two cohorts were analysed together in one model. The modelling included ITS as squared and cubic functions with a hierarchical stepwise inclusion of the non-linear terms. The covariates birth year (centred within cohorts), geographical district, and height were additionally added. The difference between the two cohorts was assessed adding main effects of the cohorts (with the early cohort assigned as reference, coded 1, and the late cohort coded 2) and interaction terms with all other variables. The interaction terms for the covariates were included for all three covariates in one model, the extended model. The models were reduced by removing components that were statistically insignificant in both the main and the extended model. The final extended model (Tables S2 and S3) was graphed as the probabilities (with 95% confidence intervals) of having a BMI of ≥ 30.0 kg/m^2 and a BMI of ≥ 25.0 kg/m^2 as functions of ITS separately for the early and the late cohorts (Figs. 1 and 2).

Multiple linear regression analyses were performed for BMI as a function of ITS and for ITS as a function of BMI, including the early and late cohorts together. Both linear, quadratic, and cubic terms of ITS and BMI, respectively, were included in a hierarchical stepwise model building, as well as the covariates, birth year (centred within cohorts), geographical district, and height as linear variables. To assess the difference between the two cohorts, the models included the cohorts (with the early cohort assigned as reference, coded 1 and the late cohort coded 2) as main effect together with interaction terms with all other variables. The models were reduced by removing components that were statistically insignificant in both models. The final extended models (Tables S4 and S5) were graphed as predicted BMI and ITS (with 95% confidence intervals) as function of ITS and BMI, respectively (Figs. 3 and 4).

All analyses were performed using STATA version 18.

Data availability

Inquiries about secure access to data in accordance with the Danish Data Protection Agency guidelines should be directed to Merete Osler, email: merete.osler@regionh.dk.

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Competing interests

The authors declare no competing interests.

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