Subjective social status and cardiometabolic risk markers in young adults

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ABSTRACT

Background: Low subjective social status (SSS), the perceived status in the social hierarchy, is associated with cardiometabolic risk in middle-aged and older adults. However, most studies are cross-sectional and very little is known about the association in adolescence and young adulthood. The aims of this study were; a) to prospectively investigate the association between SSS at ages 15 and 28 and cardiometabolic risk at age 28–30 and b) to examine if such an association was independent of smoking, physical activity and objective measures of social position.

Methods: The study used questionnaire information at ages 15 and 28 from the West Jutland Cohort Study (N = 3681), health measurements from a sub-sample of the cohort (N = 264, age 28–30, 50% women) and information from population-based national registers. The independent variable was a measure of SSS evaluated by a 10-rung ladder scale and dichotomized at the 25th percentile of data from the cohort study population. The outcome measure was a composite score of cardiometabolic risk including measures of lipids, inflammation, blood pressure and glucose-metabolism. Co-variates included smoking, physical activity, childhood and adulthood objective socioeconomic position. Sex-stratified linear regression analyses were performed to evaluate the associations between SSS and cardiometabolic risk.

Results: In both sexes, low SSS at age 28, but not at age 15, was significantly associated with increased cardiometabolic risk at age 28–30. Neither smoking, physical activity, childhood or adulthood objective socioeconomic position fully explained the associations.

Conclusion: In young adulthood, SSS was inversely related to cardiometabolic risk after accounting for smoking, physical activity and objective measures of socioeconomic position. These findings suggest that SSS could play a role in the social disparities in cardiometabolic risk in addition to traditional measures of socioeconomic position.

1. Introduction

Social disparities in health are well-described across different countries and different diseases (Mackenbach et al., 2008; Adler and Rehkopf, 2008). Some of the most consistent and well-studied outcome measures include cardiometabolic risk markers and cardiometabolic diseases (Kaplan and Keil, 1993; Hostinar et al., 2017; Pollitt et al., 2005). Most of this research examines the effect of different indicators of objective socioeconomic position (SEP) such as income, occupation and educational attainment. However, within recent years, measures of perceived status in the social hierarchy, subjective social status (SSS), and the association with physical health have gained attention (Cundiff and Matthews, 2017).

Animal studies and experimental studies have underlined the importance of status perception in relation to cardiometabolic risk. A study by Pieritz et al. (2016) showed that experimentally manipulated low SSS induced imbalance in the autonomic nervous system represented by heart rate variability. The authors concluded that these findings support a causal role of social status in relation to cardiovascular disease. Furthermore, studies among nonhuman primates found social status differences concerning neurobiological functioning, depressive behaviour and coronary artery calcification (Shively and Day, 2015). In addition, analyses across different countries reveal that a higher degree of national income inequality is related to a higher prevalence of
Cardiometabolic risk factors, morbidity and mortality (Kim et al., 2008). Furthermore, populations with a higher income inequality report more status anxiety, e.g. the feeling of being looked down upon due to job situation or income, than populations with a lower income inequality (Layte and Whelan, 2014). Altogether, this indicates that status perception could provide unique information in order to better understand the social determinants of cardiometabolic risk and increase awareness of potential psychosocial factors influencing disease risk independent of income and education. Observational studies in this research area are sparse and most are cross-sectional and include individuals older than 50 years (Tang et al., 2016). Consequently, a recent meta-analysis by Cundiff et al. calls for prospective studies to evaluate social rank and measures of biology to explore the pathways to disease and thereby draw stronger causal inferences regarding the association between status perception and disease risk (Cundiff and Matthews, 2017). A meta-analysis by Tang et al. (2016) included nine studies and found that lower SSS was associated with significantly increased odds of various cardiometabolic outcomes (coronary artery disease, hypertension, diabetes and dyslipidaemia). All estimates were attenuated after inclusion of objective measures of SEP, however the trends remained consistent.

Various mechanisms have been hypothesized in order to explain the potential association between status perception and cardiometabolic diseases. Most focus has been on the relation between low status perception and psychological distress and further between psychological distress and cardiometabolic diseases (Everson-Rose and Lewis, 2005; Hoebel and Lampert, 2020). These studies indicate that psychological distress and its distal effects could act as an intermediate in the association. Plausible biological mechanisms involve different direct and indirect effects. Direct biological effects include dysfunctional regulation of the hypothalamic-pituitary-adrenal axis and sympathetic predominance of the autonomic nervous system (Everson-Rose and Lewis, 2005; Koban et al., 2021). Indirect effects include harmful coping mechanisms such as smoking, physical inactivity and increased calorie intake, which are all risk factors for cardiometabolic diseases (Cardel et al., 2016; Siqueira et al., 2000; Martins et al., 2021). Additionally, research
suggests a synergistic effect of various biological domains and recommends to incorporate multiple risk markers in the evaluation of early cardiometabolic risk (Huang et al., 2009; Hoogeveen et al., 2020). A simplified model of the potential pathways linking low SSS with cardiometabolic risk is illustrated in Fig. 1.

Previous studies from the West Jutland Cohort Study have found inverse associations between objective measures of childhood SEP and levels of cardiometabolic risk markers such as body mass index, lipids, blood pressure, glucose and low-grade inflammation in young adults (Poulsen et al., 2018; MK. Kempel, TN. Winding, M. Böttcher, JH. Andersen, unpublished data). The primary aim of the current study was to examine if status perception, measured as SSS across two age-points; adolescence and young adulthood (age 15 and 28), was associated with a summary score of multiple cardiometabolic risk markers in young adulthood (age 28–30 years). Secondly, this study aimed to examine if the associations were independent of smoking, physical activity and objective measures of SEP in childhood and adulthood. We hypothesized that there would be an inverse association between SSS and cardiometabolic risk. We further hypothesized that this association would attenuate after inclusion of smoking, physical activity and objective measures of social position.

2. Methods

2.1. Design, study population and data sources

The current study was a prospective study using participants from a sub-sample (n = 264, 50% women) of the ongoing West Jutland Cohort Study (N = 3681). The aim of the cohort study was to investigate health inequities over the life course. Details about the recruitment process of the entire study population and the sub-sample have been described previously (Winding et al., 2014; Kempel et al., 2021). In brief, the West Jutland Cohort consists of all individuals born in 1989 and living in a specific county of Western Denmark when the study was initiated in 2004. All cohort members received a comprehensive questionnaire in 2004 (age 15) concerning various aspects of psychological, social and physical health. Round four of the cohort study was conducted in 2017 (age 28) and included an invitation to a clinical health examination to evaluate early risk markers of cardiometabolic diseases. Respondents who indicated interest in the health examination were randomly invited within six stratified groups based on sex and latest self-reported height and weight (body mass index <25, 25–30 and >30 kg/m²) until a total of 264 participants were included. A flowchart of the study population and response rates in 2004 and 2017 are presented in Fig. 2. All questionnaire- and clinical data were linked with population-based register data on the research servers of Statistics Denmark using the civil registration number assigned to all Danish citizens (Laugesen et al., 2021). Below, the assessment of the variables included in the current study will be described. Furthermore, an overview of the description, categorization and data sources of each variable are offered in appendix, Table A1.

2.2. Exposure, subjective social status (SSS)

SSS was assessed using the MacArthur Scale of Subjective Social Status-Youth Version which is a pictorial 10-rung ladder asking the respondents to place themselves/their families on a ladder step based on perceived social status (Adler et al., 2000; Goodman et al., 2001). The scale ranged from 1 to 10 with higher values indicating higher perceived social status. Inspired by prior studies, we decided to categorize SSS to facilitate the interpretation of the results (Perreira et al., 2018; McClain et al., 2021; Chen et al., 2012). Also, like in other studies some of the ladder scores included very few participants and the categorization thus facilitates more stable estimates (Hu et al., 2005). We choose to base the categorization on population-specific data in order to examine the impact of those perceiving themselves in the very bottom of the social hierarchy and the remaining participants in this specific society. As no consensus about thresholds was available, we dichotomized the scale into low and high based on the sex-stratified 25th percentiles of the entire West Jutland Cohort Study population. The dichotomization resulted in low SSS (ladder step 1–5) and high SSS (ladder step 6–10) for both sexes.

2.3. Outcome, cardiometabolic risk markers

Information about cardiometabolic risk markers was collected at a clinical health examination in 2018–2019 (age 28–30) by trained nurses using standardized operating procedures. The clinical health examination has been described in details previously (Kempel et al., 2021). Following the approach in previous studies investigating cardiometabolic risk in young age, we used multiple biomarkers obtained from fasting blood samples to create a continuous score of cardiometabolic risk (Winning et al., 2016; Non et al., 2014; Kamel et al., 2018). The nine biomarkers covered four biological domains; Inflammation (High-sensitive CRP, Interlukin-6 and Fibrinogen), lipids (Tri-glycerides and inverse values of High-density lipoprotein cholesterol), blood pressure (systolic and diastolic blood pressure) and glucose-metabolism (Glucose and Insulin). All nine biomarkers were standardized for each sex separately and sample-weights were applied to account for the sampling by body mass index. Initially, the mean value of each biological domain was calculated. Afterwards, a summary score of cardiometabolic risk (CMR) was created by standardizing the mean value of all four biological domains. Higher scores indicated higher cardiometabolic risk.

2.4. Covariates

We included childhood socioeconomic position (SEP), adulthood SEP, smoking and physical activity as co-variates in the analyses.

2.4.1. Socioeconomic position

Two indicators of childhood SEP were used; educational level of the mother and household income (Galobardes et al., 2006). Information about educational level of the mother (at age 14 of the participant) was obtained from Statistics Denmark using educational registers and categorized into high, middle and low (>13 years, 11–13 years and ≤10 years of completed school) (Jensen and Rasmussen, 2011). Information about household income was obtained from Statistics Denmark using the Income Statistics Register (Baadsgaard and Quitzau, 2011). Household income was defined as annual equalised disposable income which is a weighted variable taking the size and distribution of the family into account. We used information across five years when the participant was 11–15 years old and calculated an average of the period if information for at least three years was available. Adulthood SEP was indicated by educational level of the participant at age 28 and was obtained from Statistics Denmark using educational registers and categorized into high, middle and low (>13 years, 11–13 years and ≤10 years of completed school) (Jensen and Rasmussen, 2011).

2.4.2. Health behaviour

Information about health behaviour included measures of physical activity and smoking status. Information about physical activity was obtained from questionnaires at ages 15 and 28. Physical activity was categorised into level 0–5 with higher levels indicating more physical activity each week (None, ½ hour, 1 h, 2–3 h, 4–6 h and >7 h). Information about smoking status was obtained from the questionnaire at age 15 and from a questionnaire at the clinical health examination at age 28–30. Smoking was dichotomized into ever (former/current) and never.

2.5. Statistical analyses

All analyses were conducted on the research servers of Statistics
Prior to analyses normality within each stratum was evaluated by visual plots. Cohen’s $d$ was used to describe the effect size by the standardized mean difference in cardiometabolic risk score across strata of SSS.

We performed hierarchical linear regression analyses to evaluate the associations between SSS and the cardiometabolic risk score. Model 1 was a simple linear regression estimating the association between SSS and CMR. Model 2 included physical activity and smoking status. Model 3 included physical activity, smoking status and childhood SEP. Model 4 included physical activity, smoking status and adulthood SEP. All regression analyses were evaluated by visual plots. Cohen’s $d$ was used to describe the effect size by the standardized mean difference in cardiometabolic risk score across strata of SSS.

Denmark using Stata software version 16.1 (Statacorporation, College Station, Texas). Based on previous research in this area we conducted sex-stratified analyses (McClain et al., 2021). Initially, the correlation between the measures of SSS at age 15 and 28 of the entire cohort study population with available data was evaluated by Spearman’s correlation. Afterwards, descriptive statistics of childhood SEP, adulthood SEP, health behaviour and cardiometabolic risk score, stratified on SSS at age 15 and 28, were presented. Values across strata were compared using Pearson’s chi-squared for categorical variables and two sample t-test for continuous variables. Prior to analyses normality within each stratum was evaluated by visual plots. Cohen’s $d$ was used to describe the effect size by the standardized mean difference in cardiometabolic risk score across strata of SSS.

### Table 1
Descriptive statistics of participants by the level of subjective social status.

| Subjective Social Status | Age 15 | | | Age 28 | | |
|--------------------------|-------|---|---|-------|---|---|
|                          | Girls | Boys | | Women | Men | |
| Total, n (%)             | 131   | 129 | 132 | 132   | 132 | 132 |
| Ladder score, Mean (SD)  | 4.6 (0.7) | 4.2 (1.1) | 4.2 (1.0) | 4.2 (1.0) | 4.2 (1.0) | 4.2 (1.0) |
| Educational level of the mother, n (%) | 128 | 129 | 129 | 129 | 129 | 129 |
| High                     | 4 (22) | 6 (30) | 5 (24) | 4 (19) | 4 (16) | 4 (16) |
| Middle                   | 10 (56) | 4 (20) | 12 (57) | 4 (19) | 11 (44) | 11 (44) |
| Low                      | 4 (22) | 10 (50) | 4 (19) | 31 (29) | 10 (40) | 10 (40) |
| Childhood household income, Mean (SD) | 127 | 129 | 128 | 129 | 129 | 129 |
|                           | 39,207 | 37,575 | 36,757 | 37,575 | 37,575 | 37,575 |

P < 0.05 comparing high with low are marked with bold text. P-values are from Pearson’s chi-squared test and t-test for categorical and continuous measures, respectively.

* To ensure confidentiality of participants this variable is categorized based on recommended levels for adolescents (1 h/day) and adults (0.5 h/day), respectively in Table 1. **Standardized values, with sample-weights applied. *** Evaluated by Cohen’s $d$.

NA, not available due to confidentiality of the participants.

### Table 2
The association between subjective social status and cardiometabolic risk score in young adulthood.

|                      | Age 15 | | | Age 28 | | |
|----------------------|-------|---|---|-------|---|---|
|                      | Girls | Boys | | Women | Men | |
| Total                | 131   | 129 | 132 | 132   | 132 | 132 |
| Effect Size          | 0.36  | 0.00 | 0.86 | 0.73  | 0.86 | 0.86 |
| (Cardiometabolic risk score)** | -0.14; (-0.47; (0.38; (0.28; (1.33; (1.77) |

Model 1: Crude estimates (higher values indicate higher cardiometabolic risk).
Model 2: Model 1 + smoking and physical activity at age 15 and 28, respectively.
Model 3a: Model 2 + educational level of the mother.
Model 4a: Model 3a + adult educational level.
Model 3b: Model 2 + childhood household income.
Model 4b: Model 3b + adult educational level.

All estimates are presented with 95% confidence intervals. P < 0.05 compared to “high” are marked with bold text.
weighted to account for the sampling probability in the six stratified groups (by sex and body mass index). The models were checked by post estimation plots of the residuals.

3. Results

Sex-stratified correlations of SSS measured at age 15 and age 28 were rather weak with a Spearman’s rho of 0.20 for women and 0.19 for men. Descriptive statistics by exposure level are shown in Table 1. Male participants with higher childhood SEP, indicated by educational level of the mother, on average scored higher SSS at both age-points. Female participants with higher childhood SEP, indicated by household income, on average scored higher SSS at age 15. No differences in childhood SEP were seen among female participants comparing those with high and low SSS at age 28. There were positive associations between adult educational level and SSS among female participants at both age-points and among male participants at age 28. No significant differences in the level of physical activity were observed at any age-point across strata of SSS. However, female participants with low SSS at age 28 on average smoked more than female participants with high SSS. No differences in cardiometabolic risk score were observed across strata of SSS measured at age 15. However, at age 28, participants with low SSS on average had higher cardiometabolic risk scores compared to participants with high SSS with an estimated effect size of 0.86 (0.38; 1.33) and 0.73 (0.28; 1.17) for women and men, respectively.

Table 2 presents the results from the linear regression analyses. Statistical details about each model are presented in appendix Tables A2–A5. Regardless of sex, no statistically significant associations were observed between SSS measured at age 15 and the cardiometabolic risk scores. However, in girls, there was a tendency towards an inverse association between SSS and cardiometabolic risk. In both sexes, we found statistically significant inverse associations between SSS measured at age 28 and the cardiometabolic risk scores in the crude model 1. The associations were not affected by adjustment of smoking, physical activity and childhood SEP in model 2 and 3. A minor attenuation of the estimates was seen in model 4b among women when further adjusting for adult educational level. The estimates remained largely unaffected among men; however the confidence intervals became wider.

4. Discussion

In this study, we found that lower social status perception at age 28, but not age 15, was associated with increased cardiometabolic risk at age 28–30 in both sexes. The associations at age 28 remained largely unaffected when smoking, physical activity and childhood SEP was taken into account and was slightly attenuated after inclusion of objective measures of adulthood SEP.

These findings are consistent with previous studies reporting that status perception in adulthood is related to cardiometabolic risk independently of objective measures (Tang et al., 2016). The findings are further in line with results from the Jackson Heart Study (N = 1724, mean age 53.4 (± 11.8)) reporting that the inverse association between status perception and metabolic syndrome severity was independent of lifestyle factors (Cardel et al., 2020). As opposed to this, a recent prospective study of a national sample of people ≥ 50 years from The English Longitudinal Study of Ageing (N = 9972) found that unhealthy behaviours to some extent explained the inverse association between status perception and cardiovascular mortality (Demakakos et al., 2018). The difference concerning adjustment by health behaviour might be explained by dissimilarities in the outcome measures, the age of the study participants and the fact that the English Longitudinal Study of Ageing also adjusted for body mass index. Conversely, in line with the current and other studies, the association was only slightly affected by adjustment for objective measures of SEP.

A number of studies suggest that individuals experiencing status inferiority might engage in activities to increase energy stores in order to cope with a potential future lack of resources (Cardel et al., 2016; Dharunhar, 2016). This includes health behaviours to alter the energy balance toward a positive level. An experimental study supports this by showing that individuals placed lowest in the social hierarchy in a manipulated setting have increased calorie intake as compared to those placed highest in the hierarchy (Cardel et al., 2016). In the present study we do not have knowledge about the calorie intake of the participants. However, physical activity and smoking did not explain the overall association and focusing only on these traditional risk factors does therefore not seem sufficient. If increased calorie intake is a downstream effect of perceived low social status, this could be included in research analyses in order to better understand the indirect pathways from SSS to disease. Similarly, another explanation of the association is the status anxiety mentioned in the introduction. If the feeling of being looked down upon mediates the association this would be important knowledge for public health initiatives. The prevalence of cardiometabolic diseases is higher in countries with a higher degree of national income inequality (Kim et al., 2008). However, differences in cardiometabolic risk and all-cause mortality across objective measures of SEP are also apparent in rather egalitarian societies such as the Nordic countries with low relative income inequality measured by the Gini coefficient (OEC, 2021; Sundhedsstyrelsen, 2020; Mackenbach, 2017). In these countries absolute disparities in lack of material resources and food supply are minor and do not seem to sufficiently explain the total effects of SEP on health. Furthermore, a very recent review evaluated the association between income inequality and adult mental health (Tibber et al., 2021). The study finds that higher income inequality is associated with poorer mental health. Given these findings the observed association between SSS and cardiometabolic risk in a Danish welfare society might seem surprising. Since SSS is a relative measure, the social comparison underlying SSS could potentially be conceptualized differently in Denmark compared to countries with greater income inequality. The minor attenuation after inclusion of objective measures of SEP in the analyses of the current study suggest that status perception indeed contributes with other aspects of social position in relation to cardiometabolic risk. One explanation could be that status perception captures the individual level of social position initiating pathophysiological cascades rather than the somewhat general categorization of objectively measured SEP on the societal level. E.g. status perception might summarize the overall life circumstances relative to other people including multiple psychological-social factors such as occupation, educational level, social cohesion, self-esteem, and social network which are all correlated with health outcomes (Havranek et al., 2015). Singh-Manoux and colleagues from the British Whitehall II study suggest that SSS involves the “cognitive averaging of standard markers of socioeconomic position, while taking into account one’s assessment of current and future prospects” (Singh-Manoux et al., 2003). This definition is supported by a recent study from the Brazilian Longitudinal Study of Adult Health which included 15,105 civil servants from six Brazilian states (Ferreira et al., 2018). The study showed that SSS in adulthood was a result of complex developmental processes including various family and individual indicators of SEP across the life course. This might also add to the explanation of the observed difference in the association between SSS and cardiometabolic risk across the two age-points in the current study. E.g. the measure at age 28 might be an accumulation of earlier experiences and thus a more robust indicator in relation to cardiometabolic risk compared to the measure at age 15. Another explanation could be the different grounds on which the individual bases their perception in the social hierarchy at the two age-points. E.g. the period between age 15 and age 28 could be seen as a period of transition from mainly being influenced and dependent on parental environment in adolescence towards establishment of own family, profession, values and position in the society in young adulthood. Alternatively, overall difficulties in assessment of societal status perception at age 15 could induce bias towards the null due to random measurement error of the exposure (Weinberg et al., 1994). Additional analyses examining the association between status...
perception in the school class rather than the society at age 15 in the current study, did not change the estimates substantially (results in appendix Tables A6 and A7). The rather low correlation between SSS measured at age 15 and age 28 further highlights that status perception is dynamic and thus potentially feasible for intervention. Additionally, as no strong long-term effects of SSS measured at age 15 were evident in the current study, it would be of interest for future studies to examine the changes in SSS over the life course and the association with cardiometabolic risk as well as the association between adolescent SSS and adolescent cardiometabolic risk.

Our study found stronger associations between SSS and cardiometabolic risk among young women compared to men. This is in line with a recent study by McClain et al. (2021). The difference might be explained by both psychological and pathophysiological differences between the two sexes. First of all men and women might conceptualise SSS differently (Shaked et al., 2016). Secondly, the impact from low status perception and emotional distress might involve different downstream pathophysiological effects involving neurobiological sex-differences in the limbic system as well as sex-hormonal differences interacting with the HPA-axis (Kloeppe and Yurgelun-Todd, 2001; Pasquali, 2012). The current study underlines the importance of investigating the association sex-stratified and further attention towards understanding the sex-differences are warranted in future studies.

4.1. Strengths and limitations

Some limitations of the current study need to be acknowledged. The study population was an ethnically homogenous population with predominantly Caucasians. This does not allow for stratified groups evaluating non-Caucasians, which in other studies are found of great importance (McClain et al., 2021). Studies in multi-ethnic populations are warranted and researchers should ensure sufficient study-samples in order to explore how ethnicity influences the relationship between SSS and cardiometabolic risk. Another limitation of the current study was the possible effects of attrition and selection that lie in the nature of every cohort study. We were unable to fully account for all factors regarding non-responders which might have biased the results. A prior study from the West Jutland Cohort showed that non-respondents of the questionnaires were more likely to have parents from low SEP (Winding et al., 2014). We do not know if being non-respondent was also associated with SSS and cardiometabolic risk which could bias the results. Respondents of questionnaires often tend to be healthier than non-respondents (Greenberg et al., 2005). If being non-respondent was also associated with low SSS, this could have underestimated the estimates of the current study. Selection based on strata of sex and body mass index into the clinical health examination could also induce bias. However, the selection was conducted randomly within each stratum, and we accounted for the uneven distribution by applying sample-weights to the outcome measure and the regression analyses. Furthermore, supplementary analyses stratified by SSS and sex showed that the participants in the health examination did not differ significantly from other respondents of the questionnaires in 2004 and 2017 with regard to childhood SEP, adulthood SEP, smoking and physical activity (data not shown). We cannot exclude that the observed association between SSS and cardiometabolic risk is affected by reverse causation and prior studies have also emphasized the potential of common method bias, i.e. an underlying shared factor affecting both SSS and the health measure of interest (Singh-Manoux et al., 2005). However, the longitudinal study design with self-reported SSS at age 28 (2017) and the objectively measured cardiometabolic risk at age 28–30 (2018–2019) prior to manifest disease give some reassurance that the observed association is not merely due to reverse causation or common method bias.

Major strengths of the study included the prospective design, the use of high-quality national registers combined with questionnaire information comprising measures of SSS and health behaviour. Furthermore, the age-groups studied were seen as strengths due to the novelty within this area of research. Cardiometabolic diseases primarily occur in middle-aged and older populations. However, subclinical cardiovascular damage and metabolic abnormalities initiate in childhood and youth and track into older age (Zhang et al., 2019; Davis et al., 2001; Berenson, 2002). Given the modifiability of the cardiometabolic risk markers included in the CMR score, investigating the association in young age facilitates potentials for intervention with increased implication throughout the life course prior to manifest disease.

4.2. Conclusion

In conclusion, social status perception at age 28, but not age 15, was inversely associated with overall cardiometabolic risk in young adulthood in both sexes. Neither childhood SEP, adulthood SEP, smoking or physical activity fully explained the overall association. Perceived social status might be able to capture individual aspects of social position as compared to objective measures of SEP and thus provide valuable information within the area of health disparities. If the perception of status inferiority in itself increases cardiometabolic risk in young adulthood, interventions to reduce the effects, including the potential psychosocial consequences of this perception, are needed. Furthermore, social status perception might be easier to intervene upon in a societal setting as compared to objective measures of SEP. This may well include interventions to increase social network, trust and social participation. Furthermore, even though no strong association was found between SSS at age 15 and later cardiometabolic risk, improved focus in childhood could potentially impact status perception across the life course. This however, would need further clarification in future studies.

Ethical statement

The Danish Data Protection Agency and the Regional Committee on Health Research Ethics (no: 1-10-72-400-17) both approved the study. Participants signed a statement of consent prior to the health examination and the study complies with the Helsinki II Declaration.

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CRediT authorship contribution statement

All authors contributed to the conception and design of the study and acquisition of data. All authors contributed to interpretation of data. M KK conducted the analysis and drafted the manuscript. All authors revised the article critically and gave final approval.

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Conflicts of interest

The authors declare no conflict of interest.

Appendix A

See Tables A1–A7.
| Variable                      | Description                                                                 | Categorization       | Source                                      |
|-------------------------------|-----------------------------------------------------------------------------|----------------------|---------------------------------------------|
| **Exposure, Subjective Social Status** | The MacArthur Scale of subjective social status 10-rung pictorial ladder: ‘Think of this ladder as representing where people stand in society. At the top of the ladder are the people who are the best off: those who have the most money, the most education, and the most respected jobs. At the bottom are the people who are the worst off-those who have the least money, least education, and the least respected jobs or no job. Mark your response on the ladder below that best represents where you think you/your family stand in relation to other families in Denmark’. Dichotomized at the 25th percentiles based on the sex-stratified distribution of the entire cohort with available data. | Low High (ref) | Questionnaire at ages 15 and 28 years |
| **Outcome**                   | All biomarkers were obtained between April 2018 and December 2019. Fasting blood samples were drawn from an antecubital vein and stored at minus 80 degrees until analyses when inclusion ended. The mean values of each biological domain was used. | All biomarkers were standardized for each sex separately with mean=0 and standard deviation=1 and evaluated as continuous measures. | Health examination, age 28–30 |
| **Inflammation**              | Interleukin-6 High-sensitive CRP, Fibrinogen                                | –                    | –                                           |
| **Lipids**                    | Triglycerides, Inverse values of High-density lipoprotein cholesterol        | –                    | –                                           |
| **Blood pressure**            | Diastolic blood pressure, Systolic blood pressure (Blood pressure was obtained with a regularly calibrated automatic device after five minutes of rest. Three consecutive measures were recorded and the mean values of the two last readings were used). | –                    | –                                           |
| **Glucose metabolism**        | Glucose, Insulin                                                            | –                    | –                                           |
| **Cardiometabolic risk score**| The mean value of the above mentioned                                       | –                    | –                                           |

| Variable                      | Description                                                                 | Categorization       | Source                                      |
|-------------------------------|-----------------------------------------------------------------------------|----------------------|---------------------------------------------|
| **Covariates**                |                                                                             |                      |                                             |
| Sex                           | Biological sex                                                               | Girl Boy             | The civil registry                          |
| Childhood SEP:                |                                                                             |                      |                                             |
| 1. Educational attainment of the mother | Low: Completed school of the mother (when the participant was 14 years old). Low: ≤ 10 years. Middle: 11–13 years. High: > 13 years. | Low Middle High     | Statistics Denmark 1. Education registers 2. The income register |
| 2. Household income           | Medium: Equivalent disposable household income when the participant was 11–15 years. Based on the OECD modified-scale: The first adult is assigned a weight of one, the subsequent adults > 14 years are assigned the weight of 0.5 and children 0.3. We calculated the average value of the period when data was available from at least three years. | Low Middle High     |                                             |
| Smoking status                | ‘Do you smoke?’ Age: 15: No, never No (but I used to) Yes (not every week) Yes (not every day but every week) Yes (every day) Age 28–30: Yes No, never No (but I used to) | Never Ever (former/current) | Questionnaire at age 15 and 28–30 years |
| Physical activity             | ‘How many hours a week during leisure time do you usually exercise or play sports where you are out of breath or sweating?’ Original categories: None, < ½ hour, 1, 2–3 h, 4–6 h, and 7 h or more (at age 28: 7–10 h and 11 h or more). | Categories 0–5     | Questionnaire at age 15 and 28 years |

*Table A1 (continued)*
### Table A2
The association between subjective social status and cardiometabolic risk score in young adulthood.

#### Girls, age 15

| Variable                    | Model 1 ($R^2=0.01$) | Model 2 ($R^2=0.09$) | Model 3a ($R^2=0.16$) | Model 3b ($R^2=0.10$) |
|-----------------------------|-----------------------|-----------------------|-----------------------|-----------------------|
|                             | $\beta$ (SE) P        | $\beta$ (SE) P        | $\beta$ (SE) P        | $\beta$ (SE) P        |
| SSS                         |                       |                       |                       |                       |
| High                        | Ref                   | Ref                   | Ref                   | Ref                   |
| Low                         | 0.3 (0.3) 0.202       | 0.5 (0.3) 0.301       | 0.3 (0.3) 0.243       | 0.3 (0.3) 0.360       |
| Physical activity           |                       |                       |                       |                       |
| 0                           | Ref                   | Ref                   | Ref                   | Ref                   |
| 1                           | -0.5 (0.6) 0.412      | -0.4 (0.4) 0.334      | -0.5 (0.6) 0.445      |                       |
| 2                           | -1.2 (0.5) 0.019      | -1.1 (0.3) 0.001      | -1.0 (0.5) 0.050      |                       |
| 3                           | -1.7 (0.5) 0.001      | -1.4 (0.3) 0.000      | -1.6 (0.5) 0.001      |                       |
| 4                           | -1.2 (0.4) 0.007      | -1.0 (0.3) 0.000      |                       | -1.2 (0.5) 0.011      |
| 5                           | -1.6 (0.5) 0.001      | -1.5 (0.3) 0.000      |                       | -1.6 (0.5) 0.001      |
| Smoking                     |                       |                       |                       |                       |
| Never                       | Ref                   | Ref                   | Ref                   | Ref                   |
| Ever                        | 0.0 (0.2) 0.976       | 0.0 (0.1) 0.922       |                       | -0.1 (0.2) 0.587      |
| Mothers education           |                       |                       |                       |                       |
| High                        | Ref                   |                       |                       |                       |
| Average                     | 0.0 (0.2) 0.922       |                       |                       |                       |
| Low                         | 0.5 (0.2) 0.014       |                       |                       |                       |
| Household income            |                       |                       |                       |                       |
|                             | 0.0 (0.0) 0.779       |                       |                       |                       |

Model 1: Crude estimates (higher values indicate higher cardiometabolic risk).
Model 2: Model 1 + smoking and physical activity at age 15.
Model 3a: Model 2 + educational level of the mother.
Model 3b: Model 2 + childhood household income.
SE, Standard Error.

### Table A3
The association between subjective social status and cardiometabolic risk score in young adulthood.

#### Boys, age 15

| Variable                    | Model 1 ($R^2=0.00$) | Model 2 ($R^2=0.06$) | Model 3a ($R^2=0.08$) | Model 3b ($R^2=0.07$) |
|-----------------------------|-----------------------|-----------------------|-----------------------|-----------------------|
|                             | $\beta$ (SE) P        | $\beta$ (SE) P        | $\beta$ (SE) P        | $\beta$ (SE) P        |
| SSS                         |                       |                       |                       |                       |
| High                        | Ref                   | Ref                   | Ref                   | Ref                   |
| Low                         | 0.0 (0.3) 0.982       | 0.1 (0.3) 0.851       | -0.2 (0.3) 0.587      | 0.0 (0.3) 0.921       |
| Physical activity           |                       |                       |                       |                       |
| 0                           | Ref                   | Ref                   | Ref                   | Ref                   |
| 1                           | -2.2 (0.8) 0.006      | -1.4 (0.3) 0.000      | -2.2 (0.8) 0.007      |                       |
| 2                           | -1.7 (0.8) 0.032      | -1.0 (0.4) 0.005      | -1.7 (0.8) 0.035      |                       |
| 3                           | -1.9 (0.8) 0.012      | -1.1 (0.2) 0.000      | -1.9 (0.8) 0.015      |                       |
| 4                           | -1.7 (0.8) 0.028      | -0.9 (0.2) 0.000      | -1.7 (0.8) 0.031      |                       |
| 5                           | -2.0 (0.8) 0.009      | -1.3 (0.2) 0.000      | -1.9 (0.7) 0.011      |                       |
| Smoking                     |                       |                       |                       |                       |
| Never                       | Ref                   | Ref                   | Ref                   | Ref                   |
| Ever                        | -0.2 (0.4) 0.574      | -0.1 (0.3) 0.839      | -0.2 (0.4) 0.562      |                       |
| Mothers education           |                       |                       |                       |                       |
| High                        | Ref                   |                       |                       |                       |
| Average                     | -0.4 (0.2) 0.093      |                       |                       |                       |
| Low                         | 0.2 (0.3) 0.489       |                       |                       |                       |
| Household income            |                       |                       |                       |                       |
|                             | 0.0 (0.0) 0.129       |                       |                       |                       |

Model 1: Crude estimates (higher values indicate higher cardiometabolic risk).
Model 2: Model 1 + smoking and physical activity at age 15.
Model 3a: Model 2 + educational level of the mother.
Model 3b: Model 2 + childhood household income.
SE, Standard Error.
Table A4
The association between subjective social status and cardiometabolic risk score in young adulthood.

| Variable | Women, age 28 |
|----------|---------------|
|          | Model 1 ($R^2=0.08$) | Model 2 ($R^2=0.13$) | Model 3a ($R^2=0.19$) | Model 4a ($R^2=0.30$) | Model 3b ($R^2=0.14$) | Model 4b ($R^2=0.30$) |
|          | $\beta$ (SE) | $P$ | $\beta$ (SE) | $P$ | $\beta$ (SE) | $P$ | $\beta$ (SE) | $P$ | $\beta$ (SE) | $P$ | $\beta$ (SE) | $P$ |
| SSS      | High         | Ref | Ref | Ref | Ref | Ref | Ref | Ref | Ref | Ref | Ref | Ref |
|          | Low          | 1.0 (0.3) | 0.003 | 0.9 (0.3) | 0.004 | 1.1 (0.3) | 0.001 | 0.9 (0.3) | 0.004 | 0.8 (0.3) | 0.019 | 0.7 (0.3) | 0.040 |
| Physical activity | 0 | Ref | Ref | Ref | Ref | Ref | Ref | Ref | Ref | Ref | Ref | Ref |
|          | 1 | 0.3 (0.4) | 0.437 | 0.4 (0.4) | 0.315 | 0.2 (0.4) | 0.546 | 0.4 (0.4) | 0.398 | 0.1 (0.4) | 0.893 |
|          | 2 | -0.4 (0.3) | 0.287 | -0.1 (0.4) | 0.769 | -0.4 (0.3) | 0.259 | -0.5 (0.4) | 0.231 | -0.8 (0.4) | 0.063 |
|          | 3 | -0.1 (0.3) | 0.646 | 0.0 (0.3) | 0.908 | -0.2 (0.3) | 0.490 | -0.3 (0.4) | 0.480 | -0.5 (0.4) | 0.191 |
|          | 4 | -0.2 (0.3) | 0.556 | 0.0 (0.4) | 0.984 | -0.1 (0.3) | 0.684 | -0.3 (0.4) | 0.460 | -0.5 (0.4) | 0.273 |
|          | 5 | -0.5 (0.4) | 0.180 | -0.3 (0.4) | 0.507 | -0.6 (0.4) | 0.143 | -0.7 (0.4) | 0.144 | -0.6 (0.4) | 0.144 |
| Smoking  | Never        | Ref | Ref | Ref | Ref | Ref | Ref | Ref | Ref | Ref | Ref | Ref |
|          | Ever         | 0.0 | 0.904 | -0.2 (0.2) | 0.384 | -0.3 (0.2) | 0.192 | 0.1 (0.2) | 0.663 | -0.1 (0.2) | 0.539 |
| Mothers education | High | Ref | Ref |
|          | Average Low | -0.3 (0.2) | 0.097 | -0.4 (0.2) | 0.147 | -0.4 (0.2) | 0.147 | -0.3 (0.2) | 0.147 | -0.3 (0.2) | 0.147 |
| Adult education | High | Ref | Ref |
|          | Average Low | 0.2 (0.2) | 0.100 | 0.2 (0.2) | 0.100 | 0.2 (0.2) | 0.100 | 0.2 (0.2) | 0.100 | 0.2 (0.2) | 0.100 |
| Household income | 0.0 (0) | 0.522 | 0.0 (0) | 0.756 |

Model 1: Crude estimates (higher values indicate higher cardiometabolic risk).
Model 2: Model 1 + smoking and physical activity at age 28.
Model 3a: Model 2 + educational level of the mother.
Model 4a: Model 3a + adult educational level.
Model 3b: Model 2 + childhood household income.
Model 4b: Model 3b + adult educational level.
SE, Standard Error.

Table A5
The association between subjective social status and cardiometabolic risk score in young adulthood.

| Variable | Men, Age 28 |
|----------|-------------|
|          | Model 1 ($R^2=0.06$) | Model 2 ($R^2=0.15$) | Model 3a ($R^2=0.18$) | Model 4a ($R^2=0.20$) | Model 3b ($R^2=0.15$) | Model 4b ($R^2=0.18$) |
|          | $\beta$ (SE) | $P$ | $\beta$ (SE) | $P$ | $\beta$ (SE) | $P$ | $\beta$ (SE) | $P$ | $\beta$ (SE) | $P$ |
| SSS      | High | Ref | Ref | Ref | Ref | Ref | Ref | Ref | Ref | Ref | Ref | Ref |
|          | Low | 0.6 (0.3) | 0.025 | 0.6 (0.3) | 0.092 | 0.7 (0.4) | 0.063 | 0.6 (0.4) | 0.092 | 0.6 (0.3) | 0.096 | 0.5 (0.3) | 0.124 |
| Physical activity | 0 | Ref | Ref | Ref | Ref | Ref | Ref | Ref | Ref | Ref | Ref | Ref |
|          | 1 | 0.0 (0.4) | 0.997 | -0.2 (0.4) | 0.512 | -0.3 (0.4) | 0.284 | 0.0 (0.4) | 0.956 | -0.2 (0.4) | 0.621 |
|          | 2 | -0.4 (0.3) | 0.238 | -0.3 (0.3) | 0.332 | -0.3 (0.3) | 0.332 | -0.3 (0.3) | 0.226 | -0.4 (0.3) | 0.254 |
|          | 3 | -0.3 (0.3) | 0.277 | -0.3 (0.3) | 0.301 | -0.3 (0.3) | 0.247 | -0.3 (0.3) | 0.283 | -0.3 (0.3) | 0.189 |
|          | 4 | -0.5 (0.3) | 0.154 | -0.6 (0.3) | 0.067 | -0.6 (0.3) | 0.059 | -0.5 (0.3) | 0.155 | -0.5 (0.3) | 0.128 |
|          | 5 | -0.9 (0.3) | 0.007 | -0.9 (0.3) | 0.013 | -0.9 (0.3) | 0.010 | -0.9 (0.3) | 0.006 | -1.0 (0.3) | 0.004 |
| Smoking  | Never        | Ref | Ref | Ref | Ref | Ref | Ref | Ref | Ref | Ref | Ref | Ref |
|          | Ever         | 0.2 (0.2) | 0.197 | 0.2 (0.2) | 0.174 | 0.2 (0.2) | 0.212 | 0.2 (0.2) | 0.184 | 0.2 (0.2) | 0.253 |
| Mothers education | High | Ref | Ref |
|          | Average Low | -0.3 (0.2) | 0.180 | -0.4 (0.2) | 0.095 | -0.1 (0.2) | 0.682 | -0.1 (0.2) | 0.682 |
| Adult education | High | Ref | Ref |
|          | Average Low | 0.6 (0.4) | 0.111 | 0.6 (0.4) | 0.111 | 0.6 (0.4) | 0.111 | 0.6 (0.4) | 0.111 |
| Household income | 0.0 (0.1) | 0.797 | 0.0 (0.0) | 0.077 |

Model 1: Crude estimates (higher values indicate higher cardiometabolic risk).
Model 2: Model 1 + smoking and physical activity at age 28.
Model 3a: Model 2 + educational level of the mother.
Model 4a: Model 3a + adult educational level.
Model 3b: Model 2 + childhood household income.
Model 4b: Model 3b + adult educational level.
SE, Standard Error.
Table A6
The association between subjective social status in school and cardiometabolic risk score in young adulthood.

| Variable          | Girls, age 15, school |          |          |          |          |          |          |
|-------------------|-----------------------|----------|----------|----------|----------|----------|----------|
|                   | Model 1 ($R^2=0.02$) | Model 2 ($R^2=0.12$) | Model 3a ($R^2=0.18$) | Model 3b ($R^2=0.12$) |
|                   | β (SE) P              | β (SE) P | β (SE) P | β (SE) P | β (SE) P |
| SSS-school        |                       |          |          |          |          |          |          |
| High              | Ref                   | Ref      | Ref      | Ref      | Ref      |          |          |
| Low               | 0.3 (0.2) 0.111       | 0.5 (0.2) 0.048 | 0.5 (0.2) 0.243 | 0.4 (0.2) 0.094 |
| Physical activity |                       |          |          |          |          |          |          |
| 0                 | Ref                   | Ref      | Ref      | Ref      | Ref      |          |          |
| 1                 | -0.5 (0.6) 0.411      | -0.4 (0.4) 0.318 | -0.4 (0.6) 0.469 |          |          |          |          |
| 2                 | -1.2 (0.5) 0.015      | -1.1 (0.3) 0.000 | -1.0 (0.5) 0.042 |          |          |          |          |
| 3                 | -1.8 (0.5) 0.000      | -1.6 (0.3) 0.000 | -1.7 (0.5) 0.000 |          |          |          |          |
| 4                 | -1.3 (0.4) 0.005      | -1.1 (0.3) 0.000 | -1.2 (0.5) 0.009 |          |          |          |          |
| 5                 | -1.7 (0.5) 0.001      | -1.5 (0.3) 0.000 | -1.6 (0.5) 0.001 |          |          |          |          |
| Smoking           |                       |          |          |          |          |          |          |
| Never             | Ref                   | Ref      | Ref      | Ref      | Ref      |          |          |
| Ever              | 0.2 (0.2) 0.512       | 0.2 (0.2) 0.506 | 0.0 (0.2) 0.099 |          |          |          |          |
| Mothers education |                       |          |          |          |          |          |          |
| High              | Ref                   |          |          |          |          |          |          |
| Average           |                      |          |          |          |          |          |          |
| Low               |                      |          |          |          |          |          |          |
| Household income  |                      |          |          |          |          |          |          |
|                   |                      |          |          |          |          | 0.0 (0.0) 0.535 |          |

Model 1: Crude estimates (higher values indicate higher cardiometabolic risk).
Model 2: Model 1 + smoking and physical activity at age 15.
Model 3a: Model 2 + educational level of the mother.
Model 3b: Model 2 + childhood household income.
SE, Standard Error.

Table A7
The association between subjective social status in school and cardiometabolic risk score in young adulthood.

| Variable          | Boys, age 15, school |          |          |          |          |          |          |
|-------------------|----------------------|----------|----------|----------|----------|----------|----------|
|                   | Model 1 ($R^2=0.00$) | Model 2 ($R^2=0.06$) | Model 3a ($R^2=0.07$) | Model 3b ($R^2=0.07$) |
|                   | β (SE) P              | β (SE) P | β (SE) P | β (SE) P | β (SE) P |
| SSS-school        |                       |          |          |          |          |          |          |
| High              | Ref                   |          |          |          |          |          |          |
| Low               | 0.1 (0.3) 0.772       | 0.0 (0.3) 0.949 | 0.0 (0.3) 0.884 | 0.0 (0.3) 0.889 |
| Physical activity |                       |          |          |          |          |          |          |
| 0                 | Ref                   |          |          |          |          |          |          |
| 1                 | -2.2 (0.8) 0.006      | -1.4 (0.3) 0.000 | -2.2 (0.8) 0.006 |          |          |          |          |
| 2                 | -1.7 (0.8) 0.030      | -1.0 (0.4) 0.015 | -1.7 (0.8) 0.031 |          |          |          |          |
| 3                 | -1.9 (0.8) 0.012      | -1.1 (0.3) 0.001 | -1.9 (0.8) 0.013 |          |          |          |          |
| 4                 | -1.7 (0.8) 0.028      | -0.9 (0.3) 0.009 | -1.7 (0.7) 0.029 |          |          |          |          |
| 5                 | -2.0 (0.7) 0.007      | -1.3 (0.3) 0.000 | -1.9 (0.7) 0.008 |          |          |          |          |
| Smoking           |                       |          |          |          |          |          |          |
| Never             | Ref                   |          |          |          |          |          |          |
| Ever              | -0.2 (0.4) 0.613      | -0.1 (0.4) 0.823 | -0.2 (0.4) 0.597 |          |          |          |          |
| Mothers education |                       |          |          |          |          |          |          |
| High              | Ref                   |          |          |          |          |          |          |
| Average           |                      |          |          |          |          |          |          |
| Low               |                      |          |          |          |          |          |          |
| Household income  |                      |          |          |          |          | 0.0 (0.0) 0.129 |          |

Model 1: Crude estimates (higher values indicate higher cardiometabolic risk).
Model 2: Model 1 + smoking and physical activity at age 15.
Model 3a: Model 2 + educational level of the mother.
Model 3b: Model 2 + childhood household income.
SE, Standard Error.

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