BMJ Open

Life stage-specific trends in educational inequalities in health-related quality of life and self-rated health between 2002 and 2016 in Germany – Findings from the German Socioeconomic Panel Study (GSOEP)

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2020-042017
Article Type:	Original research
Date Submitted by the Author:	23-Jun-2020
Complete List of Authors:	Sperlich, Stefanie; Hannover Medical School, Medical Sociology Klar, Marie; Hannover Medical School, Medical Sociology Safieddine, Batoul; Hannover Medical School, Medical Sociology Tetzlaff, Fabian; Hannover Medical School, Medical Sociology Tetzlaff, Juliane; Hannover Medical School, Medical Sociology Geyer, Siegfried; Medizinische Hochschule Hannover, Medical Sociology Unit
Keywords:	EPIDEMIOLOGY, PUBLIC HEALTH, SOCIAL MEDICINE

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Life stage-specific trends in educational inequalities in health-related quality of life and self-rated health between 2002 and 2016 in Germany – Findings from the German Socioeconomic Panel Study (GSOEP)

Stefanie Sperlich[1], Marie Kristin Klar[1], Fabian Tetzlaff[1], Juliane Tetzlaff[1], Batoul Safieddine[1], Siegfried Geyer[1]

[1] Hannover Medical School, Medical Sociology, Hannover, Germany

Corresponding author:
Stefanie Sperlich
Carl-Neuberg Str. 1
30625 Hannover
Tel. 0049 511 532 9310
Fax 0049 511 532 4214
email: Sperlich.Stefanie@mh-hannover.de

Email of the other authors:
marie-k.klar@gmx.de
Safieddine.Batoul@mh-hannover.de
Tetzlaff.Fabian@mh-hannover.de
Tetzlaff.Juliane@mh-hannover.de
Geyer.Siegfried@mh-hannover.de

Word count
Abstract: 285
Manuscript: 4586

ABSTRACT

Objectives While evidence suggests persisting health inequalities, research on whether these trends may vary according to different stages of life has rarely been considered. Against this backdrop, we analyzed life stage-specific trends in educational inequalities in health-related quality of life (HRQOL) and poor self-rated health (SRH) for individuals in 'later working life' (50-64 years), 'young seniors' (65-79 years) and persons of 'old age' (80+ years).

Methods We used survey data from the German Socio-Economic Panel Study comprising the period from 2002 to 2016. The sample consists of 26,074 respondents (160,888 person years) aged 50 years and older. Health was assessed using the mental and physical component summary scale (MCS / PCS) of the HRQOL questionnaire (SF-12v2) and the single item self-rated health. To estimate educational health inequalities, we calculated the regression-based slope index of inequality (SII) and relative index of inequality (RII). Time trends in inequalities were assessed by the inclusion of a two-way interaction term between school education and time.

Results With increasing age, educational inequalities in PCS and poor SRH decreased whereas they rose in MCS. Among young seniors, health inequalities decreased in men (MCS_{SII}=2.76, p<0.05; MCS_{RII}=1.05, p<0.05; PCS_{SII}=2.12, p<0.10; PCS_{RII}=1.05, p<0.10; poor SRH_{SII}=-0.10, p<0.05; poor SRH_{RII}=0.73, p>0.10) and among women for MCS (MCS_{SII}=2.82, p<0.05; MCS_{RII}=1.06, p<0.05). In contrast, health inequalities widened in the 'later working life' among women (PCS_{SII}=-2.98, p<0.01; PCS_{RII}=0.94, p<0.05; poor SRH_{SII}=0.07, p<0.05; poor SRH_{RII}=1.32, p<0.10) while remained largely stable at old age for both genders.

Conclusions We found distinctive patterns of health inequality trends depending on the life stage. Our findings highlight the importance to differentiate between life stages when analyzing the temporal development of health inequality and to pursue research that explores the mechanisms contributing to these differences.

Keywords: health inequality, life stages, trend, temporal change

Strengths and limitations of this study

- This is one of the first studies investigating trends in educational inequalities in HRQOL and poor SRH according to different stages of life
- We used data from a large nationally representative survey, and our study considered trends over a period of 15 years using a validated measure of HRQOL
- The key finding of life stage-specific trends in educational inequality in health are open to different interpretation and might be the result of cohort- as well as period-effects.
- Further studies are warranted in order to replicate our findings and to provide clues to the drivers behind the life stage-specific trends.

INTRODUCTION

Indicators of subjective health like self-rated health (SRH) and health-related quality of life (HRQOL) complement mortality and morbidity as measures used in tracking trends in population health[1]. Previous studies on temporal change in subjective health have shown conflicting results indicating both improvements[2-4] as well as stable trends or even deterioration of self-rated health over time.[5-7] Similarly, recent studies in Germany revealed heterogeneous findings with some suggesting that the prevalence of poor SRH did not change substantially over time[8 9] while others pointing towards enhancements in HRQOL and functional health.[10 11]

The existence of socioeconomic inequalities in mortality and morbidity is well documented[12-14] and the social gradient in health has also been shown to be present for SRH and HRQOL.[15 16] Recent studies from Europe and other western countries indicate that the self-rated health gap between lower and higher socioeconomic status (SES) groups remained largely unchanged or has even widened over time.[17-19] A similar pattern was observed for Germany where trends in self-rated health point towards persisting absolute and relative health inequalities.[8 9 20] The life-course perspective on social inequalities in health suggests that while social disparities persist across the life course, the magnitude of these differences may vary according to the stage in the life phase. Three opposing theoretical perspectives have been proposed about the way in which health inequality may evolve across the life course. The *cumulative advantage/disadvantage hypothesis* claims that the positive effect of SES on health increases over the life course and therefore health inequality would widen at older ages.[21] In contrast, the *status maintenance hypothesis* states that the social health gradient remains largely constant across the life course since the social positions attained in early adulthood do not substantially change in later life.[22] Finally, the *age-as-leveler hypothesis* posits that health inequality decreases at older ages due to different factors such as the selection of more healthy people due to mortality.[23] Previous studies revealed contradictory findings supporting the cumulative advantage/disadvantage hypothesis,[24 25] as well as the status maintenance[25 26] and the age-as-leveler[27] assumptions.

Whereas numerous studies on social inequalities in health have adopted a life course approach[28 29], a life stage-specific perspective on determinants of health inequalities has so far been neglected. In one of the few existing studies, San Sebastian et al.[30] analyzed the effects of social determinants in health at four different life stages. They found that the effects of specific adversities depend on the life course stage and concluded that life course needs to be

taken into consideration for tackling health inequalities. In a similar vein, recent studies suggest that the temporal trends in SRH and functional disability also differ according to the life stage considered.[31-35] Previous research on trends in social inequality in health has mainly focused on the entire adult population and has not adequately taking into consideration that health trends may vary across different stages of life. Using this as a starting-point, the aim of this study was to analyze time trends in educational inequalities in HRQOL and poor SRH for individuals in their 'later working life' (50-64 years), 'young seniors' (65-79 years) and persons of 'old age' (80+ years). In more detail, the study was guided by the following research questions:

1. Does the extent of educational inequalities in HRQOL and poor SRH vary between different life stages?
2. How are HRQOL and poor SRH evolving over time in each of the life stages according to educational level?
3. Are there diverging trends of educational inequalities in health for the different life stages?

METHODS

Our paper follows the "Strengthening the Reporting of Observational Studies in Epidemiology (STROBE)" guidelines.[36]

Data source

This study is based on data from the German Socio-Economic Panel Study (GSOEP V.31). The GSOEP is the largest representative annual survey of German individuals based on a random sample of private households. Conducted from 1984 onwards the study covers nearly 11,000 households and 30,000 individuals each year. The GSOEP population is regularly updated with new survey samples to account for changes in the German population and for compensating loss-to-follow-up. Data were collected using different questionnaires for individuals, households or specific subgroups by face-to-face interviews. Further information on GSOEP can be derived from Frick et al.[37] The information used for this study includes school education, income, marital status, nationality as well as SRH and HRQOL as health outcomes. While SRH was assessed annually, HRQOL has been measured every two years since 2002. We focused on men and women aged 50 and above since limitations in physical wellbeing are rare in younger subjects.

For the physical and the mental components of HRQOL, in total 23,878 respondents (11,553 men / 12,325 women) were observed 81,676 times (39,159 men / 42,517 women) between 2002 and 2016, corresponding to an average participation in 3.4 waves (min. = 1/ max. = 8). With respect to SRH, a total of 26,074 respondents (12,665 men / 13,409 women) were observed 160,888 times (77,028 men / 83,860 women), corresponding to an average participation in 6.1 waves in men and 6.3 in women (min. = 1/ max. = 15). According to our life stage-approach, we assigned the population to three different life stages, namely 'later working life' (50-64 years), 'young seniors' (65-79 years) and 'old age' (80+ years). We used cross-sectional weights which are assumed to produce a nationally representative sample.[38] The proportion of missing values varied between 0 and 2.6%. Respondents with missing information were excluded from analysis (Table 1).

Measures

Self-rated health (SRH)

SRH is one of the most frequently used health measures in public health and has been proved to be a reliable indicator of healthcare services utilization[39], functional limitations[40] and mortality.[39 41] In our study, SRH was measured by the question "How would you assess your current state of health?" comprising the five response categories: 'very good', 'good', 'satisfactory', 'poor' and 'bad'. The responses were dichotomized into 'poor health' (last two categories) and better health (first three categories).

Health-related quality of life (HRQOL)

HRQOL is a multidimensional concept that incorporates physical, emotional and social dimensions of health.[42] In this study, HRQOL was assessed using a slightly modified version of the second version of the 12-Item Short Form Health Survey (SF-12v.2).[43] The SF-12v.2 includes 12 items making up eight scales: physical functioning, role limitations due to physical problems, bodily pain, general health, vitality, social functioning, role limitation due to emotional problems and perceived mental health. Based on these items a physical component summary (PCS) score and a mental component summary (MCS) score were calculated. Values are standardized to a national norm (GSOEP population in 2004) ranging from 0 to 100 points with a mean of 50 points and a standard deviation of 10 points. A higher score corresponds to a better health status.

Education

Educational level was classified into 'low', 'intermediate' and 'high' according to the number of years of schooling. All individuals with a maximum of nine years of schooling (secondary education) were assigned to the low educational group that includes also subjects without school leaving certificate. The intermediate education group consists of those with 10 years of schooling corresponding to a comprehensive school certificate. Subjects with at least twelve years' schooling were assigned to the high educational group corresponding to German secondary school leaving certificate. For analyzing time trends, these educational groups were transformed into cumulative rank probabilities (ridit scores).

Time trend

Changes in SRH and HRQOL between 2002 and 2016 were assessed by a continuous time-trend variable with a range of 0 to 1 for the entire study period. The first year of observation (2002) is coded as 0 and the last year (2016) as 1, with the years in between getting fractional values according to the following formula: [(year-2002) / (2016-2002)].

Confounders

Socio-demographic characteristics such as migration background, marital status and income level might be correlated with health outcomes as well as educational level. Shift in the compositions of these factors due to selective panel attrition might by a possible source of bias for the magnitude of health trends observed. Hence, in all analyses we adjusted for nationality, marital status and equivalized net income. To take account of possible shifts in age composition over time within the three life stages, we additionally adjusted for age in each of the models.

Statistical analysis

We performed logistic and linear regression models to test for time-effects on poor SRH and HRQOL, respectively. We accommodated the statistical dependence among the repeated observations by calculating population-averaged effects using generalized equation estimating (GEE) for logistic and linear regression.[44] We used this regression technique since our aim was to analyze population-averaged and not subject-specific time-effects which would be more accurately estimated by random-effect models.[45] In addition to odds ratios (OR) we

reported predicted means and probabilities (margins at means) giving the time trends a more substantial interpretation.

We calculated the Relative Index of Inequality (RII) and the Slope Index of Inequality (SII) as recommended by Mackenbach and Kunst.[46] These indices are both regression-based and take the entire distribution of a socio-economic variable as well as the size of the socio-economic groups into account. In our study, the RII can be interpreted as the estimated ratio (poor SRH: prevalence ratio, HRQOL: ratio of mean values) between subjects with the lowest and those with the highest educational level. In contrast, the SII quantifies the magnitude of absolute health inequality and can be interpreted as the difference in the prevalence (poor SRH) or in the mean (HRQOL) between individuals at the top and bottom of the educational hierarchy. To calculate RII and SII, the educational groups of each survey year and for each stage of life (separated for men and women) were transformed into cumulative rank probabilities ('ridit scores') ranging from 0 (highest level of education) to 1 (lowest level of education). For computing the ridit-scores, population weights were employed to match the official population statistics. As proposed, we used a logarithmic link function to calculate the RII and an identity link function to calculate the SII by using clustered variance estimators.[46] Temporal trends in educational inequalities were assessed by the inclusion of a two-way interaction term between educational levels (ridit-score) and the time-trend variable. The models were adjusted for possible confounders (see above) and the main effects of education and time. For MCS and PCS where higher scores reflect better health, values of RII <1 and SII <0 indicate widening educational inequalities while RII >1 and SII >0 point to decreasing inequalities over time. The opposite interpretation applies for poor SRH where RII >1 and SII >0 indicate increasing health inequality over time. All analyses were performed with STATA v13.1.

RESULTS

The weighted sample characteristics, separated by time periods, are presented in Table 1. Between 2002 and 2016, the proportion of subjects with low educational attainment decreased while the proportions of those with higher educational levels increased. The distribution of age, gender, income, nationality and cohabitation remained largely stable over time.

Women as compared with men reported consistently lower levels of MCS and PCS as well as higher proportions of poor SRH at almost each time point (Figure 1 and 2). Subjects in the later working life showed the highest levels of PCS and lowest proportions of poor SRH. Health status for these indicators gradually declined in the subsequent life stages with poorest

subjective health observed at old age. In contrast, for MCS similar age dependency was not found in both genders.

The extent of educational inequalities in HRQOL and SRH according to life stages

Educational inequalities in mean scores of PCS and proportions of poor SRH to the disadvantage of lower educated subjects were observed for both genders and all life stages considered. These inequalities were most pronounced in later working life and declined with age. In contrast, educational disparities for MCS in both genders were not significant in later working life but increased with age (Table 2).

Health trends in different life stages according to educational level

Among men in the later working life hardly any significant temporal health change was observed in any of the educational groups. The only exception was that MCS significantly improved by 1.01 points ($p<0.05$) among men with high educational attainment (Table 3 and Figure 1). Stronger temporal fluctuations in MCS and PCS were observed in the life stage of old age, however, no systematic linear health trend was found in any of the educational groups. By contrast, health in the life stage of young seniors improved more strongly in low educated as compared with high educated men. This was observed for all of the three health indicators considered. For example, among low educated men MCS and PCS increased by 1.82 points ($p<0.001$) and 1.56 points ($p<0.01$), respectively, while no significant improvements were found among high educated men (Table 3). Similar, in men with low educational level, odds of poor SRH reduced by 31% ($p<0.001$) while declined only by 26% ($p<0.01$) in their high educated counterparts. Among women, a similar pattern was found, indicating that subjective health in young seniors increased more pronounced in those with low as compared to higher educational attainment (Table 3). In later working life, by contrast, PCS and SRH deteriorated among low educated women while remained largely stable for the higher educated ones. At this life stage, PCS declined by 1.65 points ($p<0.001$) in low educated women while slightly improved by 0.36 points ($p>0.05$) in women with high education. Similarly, odds of poor SRH increased by 33% (OR=1.33; $p<0.05$) in low educated women while marginally decreased by 3% (OR=0.97; $p>0.05$) for the high educated ones. Like in men, at old age no systematic linear health trend was found in any of the educational groups.

Life stage-specific trends in relative (RII) and absolute (SII) educational inequalities

Corresponding to the results of Table 3, no significant change in educational inequalities in health was found among men in later working life and old age (Table 4). In contrast, educational inequalities decreased over time among young seniors. As indicated by the significant interaction terms (MCS_{RII} = 1.05 / PCS_{RII} = 1.05), HRQOL improved more strongly in the lowest as compared with the highest educational group. Expressed in absolute terms (SII), educational inequalities between the lowest and the highest educational group were reduced by 2.76 and 2.12 points for MCS and PCS, respectively. The same pattern was found for poor SRH where the opposite interpretation applies (RII < 1 and SII < 0 indicating reduction of health inequality), reaching statistical significance for SII only.

Educational inequalities among 'young seniors' also decreased in women. However, this was restricted to MCS where absolute differences between the highest and lowest educational group were reduced by 2.82 points over time. In accordance with the results of Table 3, the contrary pattern was found in the life stage of 'later working life' where educational inequality in women increased in relative and absolute terms for PCS and poor SRH. Similar to men, no significant change in educational inequalities was observed for the life stage of 'old age'.

DISCUSSION

The aim of this study was to analyze trends in educational inequalities in HRQOL and poor SRH between 2002 and 2016 in the life stages of 'later working life' (50-64 years), 'young seniors' (65-79 years) and 'old age' (80+ years). First, we found that educational inequalities in poor SRH and in the physical component of HRQOL decreased with subsequent life stages while the opposite applied to the mental component of HRQOL. Our findings suggest that the way in which health inequality evolves across the life stages depend on the health indicator considered. This corresponds to previous studies who found different patterns of health inequalities across ages for different health indicators.[25 47 48] Our main finding was that the temporal development of health inequality differed according to the stage of life. While among young seniors health inequalities declined for both genders, a significant increase was found among women in later working life.

The extent of educational inequalities in HRQOL and SRH according to different life stages

In the life stage of 'later working life' no educational inequalities were found for MCS in both genders. This is in line with the finding by Moor et al.[8] who likewise found no social gradient in MCS among subjects aged 30 to 49 years. They supposed that this may due to the specific

life phase in which career building coincide with family demands, affecting subjects of all educational levels and thus equalizing educational differences in HRQOL with respect to mental health. Our findings indicate that educational inequalities in MCS to the disadvantage of lower educated subjects first emerged at retirement age, supporting the assumption that during working life, the mental health component of HRQOL is strongly influenced by work-related demands and time constraints acting independently of educational attainment. Furthermore, our results suggest that high educated women may benefit more from retirement age which supports the cumulative advantage/disadvantage hypothesis claiming that the positive effect of socioeconomic status on health increases over the life course. In contrast, we found educational inequalities in the physical health component of HRQOL as well as in poor SRH to be strongest in the later working life and declining with age. This finding supports the age-as-leveler hypothesis positing that health inequality decreases at older ages. One possible explanation for declining educational inequalities over the life stages in physical health could be that biological frailty in older age may contribute to an intensified health decline of individuals with high SES leading to a reduction of health inequalities. In addition, retirement might bring an end to inequalities in the work context with respect to work-related physical strain. Finally, with age increasing mortality selection in the general population as well as selective panel attrition may have contributed to the selection of more healthy individuals with the consequence that the association between education and health appeared to be weaker at older ages.

Life stage-specific trends in educational health inequalities

Previous studies suggest that health inequalities remain stable or even widen over time. Hu et al.[17] analyzing trends in socioeconomic inequalities in 17 European countries found that absolute inequalities in SRH remained unchanged while relative inequalities increased between 1990 and 2010. Lahelma et al.[19] (2019) reported that educational inequalities in SRH in Finland largely remained constant between 1979 and 2014. In the same way, the study by Hanibuchi et al.[18] revealed stable trends in socioeconomic inequalities in SRH in Japan between 2000 and 2010. Analyzing trends in quality-adjusted life expectancy between 2001 and 2011 for the Netherlands, Gheorghe et al.[49] summarized that the largest increases were found for the higher educated individuals resulting in a widening health gap by education. Previous studies conducted in Germany yielded comparable results. For example, Lampert et al.[16] found increasing income inequalities in the prevalence of poor SRH between 1994 and 2014. Based on the data of repeated cross-sectional surveys between 2003 and 2012, the study

by Wachtler et al.[9] revealed stable absolute and relative inequalities in SRH between 2003 and 2012. However, most of the cited studies are based on the entire adult population ranging in age between 25 and 69 years. When considering individuals of all ages, we likewise found educational inequalities in health to be largely stable over time. However, the differentiated analysis according to life stages revealed distinctive patterns of health inequality trends. The study by Granström et al.[50] is one of the few that adopted an life stage-specific view on health inequality trends. Their findings indicate that the increase in health inequality among women was mainly due to growing inequalities in early adulthood between 25 and 34 years of age. The findings of our study on subjects aging 50 years and older revealed a reduction of educational health inequality in the life stage of young seniors, holding for both genders. In contrast, health inequalities in later working life widened among women and remained largely stable for both genders at old age.

Explaining life stage-specific health inequality trends

In medical sociological research, it has been established to distinguish between material, psychosocial and behavioral pathways in explaining social inequalities in health.[51-53] While the material explanation refers to structural living conditions, the psychosocial pathway includes a wide range of social and personal resources as well as psychosocial stressors. Finally, the behavioral explanation considers a variety of health-related behaviors that are strongly linked with the material and psychosocial pathway.[54] In order to explain trends in health inequality, a dynamic perspective on these explanations need to be employed that take medical, demographic, social and economic change into account. This approach represents a substantial challenge since health inequalities are not a consequence of one or a few determinants but rather the result of the contribution of a number of interacting influencing factors. The significance of a life-stage specific approach arises from this fact that the consequences of medical and social change may have different implications according to people's phase in life. For example, the decline in health inequality among young seniors as found in our study might be attributed to medical progress in the prevention and treatment of diseases that appears to be particularly relevant at this life stage where chronic conditions gained in importance. While medical advances bring benefit to all educational groups, lower educated persons may benefit more as they are more vulnerable to chronic conditions what might partly explain the reduction of health inequality at this age. In the same way, the increase in work-related stress in recent years in Germany[33] does not apply to retired persons, which might partly explain the greater health improvement among young seniors as found in a

previous study.[34] The same reasoning may apply to the reduction of the educational health gap among young seniors found in this study. Seen from that perspective, educational differences in subjective health may decrease at this age as retirement bring an end to the unequal work-related burden caused by socially stratified working conditions that might have become even harder for low educated individuals. In contrast, changes in employment rates over the last decades might have contributed to the increasing health inequalities among women in later working life. In a previous study we found an overall increase in women's perceived rates of good self-rated health at this age that was more pronounced as compared with men.[34] Following the idea by Aguilar-Palacio et al.[55] it was postulated that the increasing presence of women in the labor force might have contributed to the reduction of the gender gap in SRH. The finding of our study suggests that not all women benefited equally from the increase in employment rates. It might be possible that higher educated women have benefited more as their working activities provide higher levels of autonomy and rewards which proved to be significant health-promoting resources.[56 57] Conversely, employment may pose higher burdens to low educated women that would explain the rise in health inequalities found among women of later working life. In addition to these explanations, different trends in health-related behaviors might have contributed to the life stage-specific trends in health inequality. For example, recent findings suggest that probability of obesity increased particularly for younger cohorts while the rise was less pronounced among older cohorts.[58 59] Finally, it is worth noting that while the educational expansion over the past decades has affected all ages, the implications might have been very different depending on the life stage. While today low educated individuals in Germany represent a minority among younger cohorts, they are still forming the majority of older cohorts.[60] Hence, low educated individuals in younger ages may increasingly form a vulnerable subgroup with a high health-risk which is not the case for the elderly. These varying implications of the educational expansion for different cohorts need to be considered when exploring life stage-specific trends in health inequality.

Strength and limitations

The strength of this study is the large sample size representing the German population and allowing for stratification according to gender and different stages of life. We used different indicators of subjective health giving the findings a more substantial interpretation. In addition, we used established instruments to ensure high construct validity for measuring subjective health. We enhanced the validity of trend analysis by using measures of both

absolute and relative health inequalities. We performed further time trend analyses not adjusting for potential confounders and found the time trends determined to be very robust.

However, this study has also limitations worth noting. Even though sampling weights were used, the existence of sampling bias cannot be completely ruled out since a full match of the official population statistics is not absolutely guaranteed. Selection bias could be due to the exclusion of the institutionalized population as well as persons who could not participate in the survey for health reasons. Furthermore, there is a possible existence of a reporting bias since the outcome and the independent variables are self-reported. As Moor et al.[8] pointed out, the effect size in the extent of health inequalities depends on the cut-off point chosen for the categorization of poor health. They conducted a sensitivity analysis, in which 'satisfactory' was part of the reference category 'good health' as it was in this study. Compared with the alternative in which 'satisfactory' was part of the category 'rather poor health', they found the relative risk in low educated people to assess their health as poor to be higher while the absolute difference revealed to be smaller. This finding suggests that the results obtained depend on the way of classification poor health, indicating that the generalizability of our study results may be limited. In addition, our key finding of life stage-specific trends in educational health inequality cannot be clearly attributed to either cohort- or period-effects. While sociological literature considers a cohort-effect as the sum of all unique exposures experienced by the cohort from birth, a period-effect result from external factors that equally affect all age groups at a particular calendar time.[61] In our study, we found subjective health steadily improving particularly among lower educated young seniors not fitting in with the idea of an exclusive cohort- or period-effect. Instead our results speak in favor of a gradual transition that might be better described with the continuing progress of social and economic change that may have different implications depending on the stage of people's lives. This idea corresponds better to the conceptualization of age, period and cohort in epidemiology where a cohort-effect is an effect modification due to a period effect that is differentially experienced through age-specific exposure or susceptibility to that event or cause.[62] In this study, we focused on life stage-specific rather than age-specific effects in order to emphasize that social and demographic change may have altered people's living conditions differently depending on their stage in the life course and the specific psychosocial resources and burdens associated therewith. Lastly, since the observation period of 15 years in our study is relatively short, conclusions about the further development of health inequality in different life stages cannot be derived from our findings. In particular it is not foreseeable

whether the positive trend of narrowed health inequality among young seniors, if confirmed in further studies, will continue in the future.

Conclusions

We found distinctive patterns of health inequality trends in different life stages with educational health disparities declining among young seniors and rising among women in later working life. The results emphasize the need for a life stage-approach for analyzing health inequality trends in order to capture varying effects of social change on different life stages. Moving from the description to the explanation of health trends would be an important next step to develop targeted political interventions aiming at tackling inequality in health.

Competing interests

None declared.

Ethics

Ethics Board approval was not required as we only conducted analyses of completely anonymized SOEP-datasets.

Funding statement

This paper was supported by the DFG (German Research Foundation), grant number GE 1167/15-1.

Competing interest statement

All authors have read and understood the BMJ Group policy on declaration of interests and declared that they have no conflict of interest.

Ethical approval

Approval from the ethics committee is not required as this study using pre-existing and de-identified data.

Patient consent for publication

Not required.

Author Contributions

SS has made substantial contributions to the concept and design and conducted the statistical analyses. BS, FT, JT, MKK and SG participated in the design of the study and helped to draft the manuscript. They have also been involved in revising the manuscript critically for important intellectual content. All authors read and approved the final manuscript.

Data availability statement

The raw data were drawn from the German Socio-Economic Panel Study (GSOEP 21 V.31). The datasets used are available from the corresponding author on reasonable request. German data privacy laws necessitate that all users sign a data user contract with DIW Berlin.

REFERENCES

1. Bombak AE. Self-rated health and public health: a critical perspective. *Front Public Health* 2013;1:15-15. doi: 10.3389/fpubh.2013.00015
2. Parker MG, Thorslund M. Health trends in the elderly population: getting better and getting worse. *Gerontologist* 2007;47(2):150-8. doi: 10.1093/geront/47.2.150 [published Online First: 2007/04/19]
3. Roqué IFM, Salvà A, Bolíbar I, et al. [Trends in self-perceived health and chronic disability in the elderly Spanish population: evolution between years 1993 and 2006]. *Med Clin (Barc)* 2012;139(7):284-9. doi: 10.1016/j.medcli.2011.06.021 [published Online First: 2011/10/22]
4. Põld M, Pärna K, Ringmets I. Trends in self-rated health and association with socioeconomic position in Estonia: data from cross-sectional studies in 1996-2014. *Int J Equity Health* 2016;15(1):200. doi: 10.1186/s12939-016-0491-9 [published Online First: 2016/12/10]
5. Zack MM, Moriarty DG, Stroup DF, et al. Worsening trends in adult health-related quality of life and self-rated health-United States, 1993-2001. *Public Health Rep* 2004;119(5):493-505. doi: 10.1016/j.phr.2004.07.007 [published Online First: 2004/08/18]
6. Galenkamp H, Braam AW, Huisman M, et al. Seventeen-year time trend in poor self-rated health in older adults: changing contributions of chronic diseases and disability. *Eur J Public Health* 2013;23(3):511-7. doi: 10.1093/eurpub/cks031 [published Online First: 2012/04/12]
7. Mairey I, Bjerregaard P, Brønnum-Hansen H. Gender difference in health expectancy trends in Greenland. *Scand J Public Health* 2014;42(8):751-8. doi: 10.1177/1403494814550174 [published Online First: 2014/09/28]
8. Moor I, Günther S, Knöchelmann A, et al. Educational inequalities in subjective health in Germany from 1994 to 2014: a trend analysis using the German Socio-Economic Panel study (GSOEP). *BMJ Open* 2018;8(6):e019755. doi: 10.1136/bmjopen-2017-019755 [published Online First: 2018/06/10]
9. Wachtler B, Hoebel J, Lampert T. Trends in socioeconomic inequalities in self-rated health in Germany: a time-trend analysis of repeated cross-sectional health surveys between 2003 and 2012. *BMJ Open* 2019;9(9):e030216. doi: 10.1136/bmjopen-2019-030216 [published Online First: 2019/09/29]
10. Ellert U, Kurth B-M. Gesundheitsbezogene Lebensqualität bei Erwachsenen in Deutschland: Robert Koch-Institut, 2013.
11. Trachte F, Sperlich S, Geyer S. [Compression or expansion of morbidity? Development of health among the older population]. *Z Gerontol Geriatr* 2015;48(3):255-62. doi: 10.1007/s00391-014-0644-7 [published Online First: 2014/05/02]
12. Marmot M, Bell R. Social inequalities in health: a proper concern of epidemiology. *Ann Epidemiol* 2016;26(4):238-40. doi: 10.1016/j.annepidem.2016.02.003 [published Online First: 2016/04/17]
13. Marmot M. The Health Gap: The Challenge of an Unequal World: the argument. *Int J Epidemiol* 2017;46(4):1312-18. doi: 10.1093/ije/dyx163 [published Online First: 2017/09/25]
14. Bopp M, Mackenbach JP. [Death is a respecter of persons : 30 years of research comparing European countries regarding social inequality in mortality]. *Z Gerontol Geriatr* 2019;52(2):122-29. doi: 10.1007/s00391-019-01530-6 [published Online First: 2019/03/16]
15. Mackenbach JP, Stirbu I, Roskam AJ, et al. Socioeconomic inequalities in health in 22 European countries. *N Engl J Med* 2008;358(23):2468-81. doi: 10.1056/NEJMsa0707519 [published Online First: 2008/06/06]
16. Lampert T, Schmidtke C, Borgmann L-S, et al. Subjektive Gesundheit bei Erwachsenen in Deutschland. *Journal of Health Monitoring* 2018(3):64--71. doi: http://dx.doi.org/10.17886/RKI-GBE-2018-068
17. Hu Y, van Lenthe FJ, Borsboom GJ, et al. Trends in socioeconomic inequalities in self-assessed health in 17 European countries between 1990 and 2010. *J Epidemiol Community Health* 2016;70(7):644-52. doi: 10.1136/jech-2015-206780 [published Online First: 2016/01/21]

18. Hanibuchi T, Nakaya T, Honjo K. Trends in socioeconomic inequalities in self-rated health, smoking, and physical activity of Japanese adults from 2000 to 2010. *SSM Popul Health* 2016;2:662-73. doi: 10.1016/j.ssmph.2016.09.002 [published Online First: 2016/09/09]
19. Lahelma E, Pietiläinen O, Pentala-Nikulainen O, et al. 36-year trends in educational inequalities in self-rated health among Finnish adults. *SSM Popul Health* 2019;9:100504-04. doi: 10.1016/j.ssmph.2019.100504
20. Hoebel J, Kuntz B, Moor I, et al. Post-millennial trends of socioeconomic inequalities in chronic illness among adults in Germany. *BMC Res Notes* 2018;11(1):200. doi: 10.1186/s13104-018-3299-4 [published Online First: 2018/03/28]
21. Ferraro KF, Shippee TP. Aging and cumulative inequality: how does inequality get under the skin? *Gerontologist* 2009;49(3):333-43. doi: 10.1093/geront/gnp034 [published Online First: 2009/04/21]
22. Pampel FC, Hardy M. Status Maintenance and Change during Old Age*. *Social Forces* 1994;73(1):289-314. doi: 10.1093/sf/73.1.289
23. George LK. The Life Course Perspective. In: Gu D, Dupre ME, eds. Encyclopedia of Gerontology and Population Aging. Cham: Springer International Publishing 2019:1-9.
24. Andrea E. Willson, Kim M. Shuey, Glen H. Elder J. Cumulative Advantage Processes as Mechanisms of Inequality in Life Course Health. *American Journal of Sociology* 2007;112(6):1886-924. doi: 10.1086/512712
25. Leopold L, Engelhartdt H. Education and physical health trajectories in old age. Evidence from the Survey of Health, Ageing and Retirement in Europe (SHARE). *International Journal of Public Health* 2013;58(1):23-31. doi: 10.1007/s00038-012-0399-0
26. Schöllgen I, Huxhold O, Tesch-Römer C. Socioeconomic status and health in the second half of life: findings from the German Ageing Survey. *European Journal of Ageing* 2010;7(1):17-28. doi: 10.1007/s10433-010-0140-x
27. Herd P. Do Functional Health Inequalities Decrease in Old Age?:Educational Status and Functional Decline Among the 1931-1941 Birth Cohort. *Research on Aging* 2006;28(3):375-92. doi: 10.1177/0164027505285845
28. Pavalko EK, Caputo J. Social Inequality and Health Across the Life Course. *American Behavioral Scientist* 2013;57(8):1040-56. doi: 10.1177/0002764213487344
29. Larson K, Russ SA, Kahn RS, et al. Health Disparities: A Life Course Health Development Perspective and Future Research Directions. In: Halfon N, Forrest CB, Lerner RM, et al., eds. Handbook of Life Course Health Development. Cham: Springer International Publishing 2018:499-520.
30. San Sebastian M, Hammarström A, Gustafsson PE. Socioeconomic inequalities in functional somatic symptoms by social and material conditions at four life course periods in Sweden: a decomposition analysis. *BMJ Open* 2015;5(8):e006581. doi: 10.1136/bmjopen-2014-006581
31. Johansson SE, Midlöv P, Sundquist J, et al. Longitudinal trends in good self-rated health: effects of age and birth cohort in a 25-year follow-up study in Sweden. *Int J Public Health* 2015;60(3):363-73. doi: 10.1007/s00038-015-0658-y [published Online First: 2015/02/05]
32. Clause-Verdreau AC, Audureau É, Leplège A, et al. Contrasted trends in health-related quality of life across gender, age categories and work status in France, 1995-2016: repeated population-based cross-sectional surveys using the SF-36. *J Epidemiol Community Health* 2019;73(1):65-72. doi: 10.1136/jech-2018-210941 [published Online First: 2018/10/12]
33. Wolff JK, Nowossadeck S, Spuling SM. Altern nachfolgende Kohorten gesünder? Selbstberichtete Erkrankungen und funktionale Gesundheit im Kohortenvergleich. In: Mahne K, Wolff JK, Simonson J, et al., eds. Altern im Wandel: Zwei Jahrzehnte Deutscher Alterssurvey (DEAS). Wiesbaden: Springer Fachmedien Wiesbaden 2017:125-38.
34. Sperlich S, Tetzlaff J, Geyer S. Trends in good self-rated health in Germany between 1995 and 2014: do age and gender matter? *Int J Public Health* 2019;64(6):921-33. doi: 10.1007/s00038-019-01235-y [published Online First: 2019/03/29]

35. Beller J, Miething A, Regidor E, et al. Trends in grip strength: Age, period, and cohort effects on grip strength in older adults from Germany, Sweden, and Spain. *SSM - Population Health* 2019;9:100456. doi: https://doi.org/10.1016/j.ssmph.2019.100456
36. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *J Clin Epidemiol* 2008;61(4):344-9. doi: 10.1016/j.jclinepi.2007.11.008 [published Online First: 2008/03/04]
37. Frick J, Schupp J, Wagner G. The German Socio-Economic Panel Study (SOEP)—Scope, evolution and enhancements. *Schmollers Jahrbuch : Journal of Applied Social Science Studies / Zeitschrift für Wirtschafts- und Sozialwissenschaften* 2007;127:139-69. doi: 10.2139/ssrn.1028709
38. Goebel J, Grabka MM, Liebig S, et al. The German Socio-Economic Panel (SOEP). 2019;239(2):345. doi: https://doi.org/10.1515/jbnst-2018-0022
39. DeSalvo KB, Fan VS, McDonell MB, et al. Predicting mortality and healthcare utilization with a single question. *Health Serv Res* 2005;40(4):1234-46. doi: 10.1111/j.1475-6773.2005.00404.x [published Online First: 2005/07/22]
40. Idler EL, Russell LB, Davis D. Survival, Functional Limitations, and Self-rated Health in the NHANES I Epidemiologic Follow-up Study, 1992. *American Journal of Epidemiology* 2000;152(9):874-83. doi: 10.1093/aje/152.9.874
41. Jylhä M. What is self-rated health and why does it predict mortality? Towards a unified conceptual model. *Soc Sci Med* 2009;69(3):307-16. doi: 10.1016/j.socscimed.2009.05.013 [published Online First: 2009/06/13]
42. Bullinger M, Quitmann J. Quality of life as patient-reported outcomes: principles of assessment. *Dialogues Clin Neurosci* 2014;16(2):137-45. [published Online First: 2014/08/26]
43. Nübling M, Andersen H, Mühlbacher A, et al. Computation of Standard Values for Physical and Mental Health Scale Scores Using the SOEP Version of SF12v2. *Schmollers Jahrbuch : Journal of Applied Social Science Studies / Zeitschrift für Wirtschafts- und Sozialwissenschaften* 2007;127(1):171-82.
44. Liang K-Y, Zeger SL. Longitudinal data analysis using generalized linear models. *Biometrika* 1986;73(1):13-22. doi: 10.1093/biomet/73.1.13
45. Hu FB, Goldberg J, Hedeker D, et al. Comparison of Population-Averaged and Subject-Specific Approaches for Analyzing Repeated Binary Outcomes. *American Journal of Epidemiology* 1998;147(7):694-703. doi: 10.1093/oxfordjournals.aje.a009511
46. Mackenbach JP, Kunst AE. Measuring the magnitude of socio-economic inequalities in health: an overview of available measures illustrated with two examples from Europe. *Soc Sci Med* 1997;44(6):757-71. doi: 10.1016/s0277-9536(96)00073-1 [published Online First: 1997/03/01]
47. Bardel A, Wallander MA, Wallman T, et al. Age and sex related self-reported symptoms in a general population across 30 years: Patterns of reporting and secular trend. *PLoS One* 2019;14(2):e0211532. doi: 10.1371/journal.pone.0211532 [published Online First: 2019/02/05]
48. Asada Y, Hurley J, Grignon M, et al. Health inequalities and inequities by age: Stability for the Health Utilities Index and divergence for the Frailty Index. *SSM - Population Health* 2018;5:17-32. doi: https://doi.org/10.1016/j.ssmph.2018.04.002
49. Gheorghe M, Wubulihasimu P, Peters F, et al. Health inequalities in the Netherlands: trends in quality-adjusted life expectancy (QALE) by educational level. *Eur J Public Health* 2016;26(5):794-99. doi: 10.1093/eurpub/ckw043 [published Online First: 2016/04/17]
50. Granström F, Molarius A, Garvin P, et al. Exploring trends in and determinants of educational inequalities in self-rated health. *Scand J Public Health* 2015;43(7):677-86. doi: 10.1177/1403494815592271 [published Online First: 2015/07/04]

51. Duijster D, Oude Groeniger J, van der Heijden GJMG, et al. Material, behavioural, cultural and psychosocial factors in the explanation of socioeconomic inequalities in oral health. *European Journal of Public Health* 2017;28(4):590-97. doi: 10.1093/eurpub/ckx209
52. Khang Y-H, Lynch JW, Yang S, et al. The contribution of material, psychosocial, and behavioral factors in explaining educational and occupational mortality inequalities in a nationally representative sample of South Koreans: Relative and absolute perspectives. *Social Science & Medicine* 2009;68(5):858-66. doi: https://doi.org/10.1016/j.socscimed.2008.12.003
53. van Oort FVA, van Lenthe FJ, Mackenbach JP. Material, psychosocial, and behavioural factors in the explanation of educational inequalities in mortality in the Netherlands. *Journal of Epidemiology and Community Health* 2005;59(3):214-20. doi: 10.1136/jech.2003.016493
54. Moor I, Spallek J, Richter M. Explaining socioeconomic inequalities in self-rated health: a systematic review of the relative contribution of material, psychosocial and behavioural factors. *J Epidemiol Community Health* 2017;71(6):565-75. doi: 10.1136/jech-2016-207589 [published Online First: 2016/09/30]
55. Aguilar-Palacio I, Carrera-Lasfuentes P, Sánchez-Recio R, et al. Recession, employment and self-rated health: a study on the gender gap. *Public Health* 2018;154:44-50. doi: 10.1016/j.puhe.2017.10.013 [published Online First: 2017/12/05]
56. Karasek R, Baker D, Marxer F, et al. Job decision latitude, job demands, and cardiovascular disease: a prospective study of Swedish men. *Am J Public Health* 1981;71(7):694-705. doi: 10.2105/ajph.71.7.694 [published Online First: 1981/07/01]
57. Caman OK, Calling S, Midlöv P, et al. Longitudinal age-and cohort trends in body mass index in Sweden--a 24-year follow-up study. *BMC Public Health* 2013;13:893-93. doi: 10.1186/1471-2458-13-893
58. Reither EN, Hauser RM, Yang Y. Do birth cohorts matter? Age-period-cohort analyses of the obesity epidemic in the United States. *Social science & medicine (1982)* 2009;69(10):1439-48. doi: 10.1016/j.socscimed.2009.08.040 [published Online First: 2009/09/19]
59. Diouf I, Charles MA, Ducimetière P, et al. Evolution of obesity prevalence in France: an age-period-cohort analysis. *Epidemiology* 2010;21(3):360-65. doi: 10.1097/EDE.0b013e3181d5bff5
60. Statistisches Jahrbuch 2019. Deutschland und Internationales www.destatis.de/jahrbuch: Statistisches Bundesamt (Destatis); 2019 [accessed 15. May 2019 2019.
61. Blanchard RD, Bunker JB, Wachs M. Distinguishing aging, period and cohort effects in longitudinal studies of elderly populations. *Socio-Economic Planning Sciences* 1977;11(3):137-46. doi: https://doi.org/10.1016/0038-0121(77)90032-5
62. Keyes KM, Utz RL, Robinson W, et al. What is a cohort effect? Comparison of three statistical methods for modeling cohort effects in obesity prevalence in the United States, 1971-2006. *Soc Sci Med* 2010;70(7):1100-8. doi: 10.1016/j.socscimed.2009.12.018 [published Online First: 2010/02/04]

Table 1: Weighted sample characteristics in % by time period, GSOEP 2002-2016, $n_{observations}$=170,317.

	2002-2006 (n=54,244)	2007-2011 (n=56,299)	2012-2016 (n=59,774)
Sex	%	%	%
Women	54.2	53.7	53.2
Men	45.8	46.3	46.8
Missings (n)	0	0	0
Age groups in years			
50-64	49.2	48.2	50.0
65-79	402	40.0	38.7
80+	10.6	11.8	11.3
missing (n)	0	0	0
School education			
primary / no education	58,5	51,3	43.9
secondary	19,5	23,4	26.2
tertiary	14,6	17,0	19.6
other qualification	7.4	8.3	10.3
missing (n)	1689	1262	1212
Income			
<60%	14.5	15.8	15.3
60% - < 150%	67.5	65.9	65.6
≥ 150 %	18.0	18.3	19.1
missing (n)	16	13	31
Living with partner			
yes	67.8	66.7	66.6
no	32.2	33.3	33.4
missing (n)	0	0	1
Nationality			
German	93.6	92.8	92.8
others	6.4	7.2	7.2
missing (n)	0	0	1

GSOEP: German Socio-Economic Panel; n= number of observations (maximum sample size of annually surveys 2002 to 2016), income: equivalized net income.

Table 2: Educational inequalities in HRQOL (MCS and PCS) and poor SRH in men and women, stratified by life stage, GSOEP 2002-2016

		Men							
		MCS			PCS		Poor SRH		
Life stage	**Education**	**n**	**Coef.**	**95% CI**	**Coef.**	**95% CI**	**OR**	**n**	**95% CI**
all ages	low	13902	**-0.85*****	-1.31- -0.40	**-4.07*****	-4.53 - -361	**1.66*****	30102	1.50 - 1.84
	medium	6857	**-0.48**◊	-0 98 - 0.02	**-2.40*****	-2.88 - -1.92	**1.21****	14604	1.08 - 1.37
	high	8578	1		1		1	17640	
Later working life (50-64 yr.)	low	6050	-0.40	-0.99 - 0.19	**-4.59*****	-5.17 - -4.00	**1.90*****	13042	1.65 - 2.17
	medium	4501	-0.42	-1.01 - 0.18	**-2.70*****	-3.26 - -2.15	**1.28****	9590	1.11 - 1.48
	high	5008	1		1		1	10411	
Young seniors (65-79 yr.)	low	6727	**-1.23*****	-1.89 - -0.57	**-3.49*****	-4.19 - -2.79	**1.51*****	14484	1.30 - 1.75
	medium	2031	-0.25	-1.05-0.55	**-1.89*****	-2.76 - -1.03	1.15	4278	0.96 - 1.39
	high	3140	1		1		1	6244	
Old age (80+ yr.)	low	1125	**-2.25***	-4.14 - -0.36	**-2.29****	-4.01 - -0.57	**1.42***	2576	1.05 - 1.11
	medium	325	-1.42	-3.40 - 0.55	-1.31	-3.42 - 0.79	1.20	736	0.83 - 1.74
	high	430	1		1		1	985	
		Women							
		MCS			PCS		Poor SRH		
Life stage	**Education**	**n**	**Coef.**	**95% CI**	**Coef.**	**95% CI**	**OR**	**n**	**95% CI**
all ages	low	16251	**-1.10*****	-1.64 - -0.57	**-3.31*****	-3.84 - -2.77	**1.56*****	35521	1.40-1.75
	medium	9544	-0.21	-0.74 – 0.33	**-1.76*****	-2.29 - -1.22	**1.19****	20149	1.06-1.34
	high	5970	1		1		1	12599	
Later working life (50-64 yr.)	low	6347	-0.50	-1.16 - 0.17	**-3.67*****	-4.32 - -3.02	**1.54*****	13665	1.34 - 1.76
	medium	6494	0.50	-0.57 - 0.67	**-1.91*****	-2.52 - -1.32	1.10	13609	0.96 - 1.26
	high	4103	1		1		1	8561	
Young seniors (65-79 yr.)	low	7880	**-2.64*****	-3.47 - -1.80	**-3.16*****	-4.08 - -2.24	**1.77*****	17176	1.48 - 2.12
	medium	2590	**-1.04***	-1.97 - -0.12	**-1.81****	-2.83 - -0.78	**1.39****	5519	1.14 - 1.70
	high	1615	1		1		1	3422	
Old age (80+ yr.)	low	2024	**-3.87*****	-5.99 - -1.74	-1.02	-3.00 - 0.96	**1.43***	4680	1.04 - 1.08
	medium	460	-1.65	-4.08 - -0.77	1.54	-0.74 - 3.82	1.08	1021	0.76 - 6.21
	high	252	1		1		1	616	

Adjusted for age, nationality, living with partner and equivalized net income; GSOEP: German Socio-Economic Panel; MCS: Mental Component Summary; PCS: Physical Component Summary; SRH: Self-Rated Health; Coef.: Coefficient; CI: Confidence Interval; ◊ p<0.10, *p<0.05, **p<0.01, ***p<0.001.

Table 3: Time trends in HRQOL (MCS and PCS) and poor SRH in men and women, stratified by life stage and level of education, GSOEP 2002-2016

	Men							
	MCS			PCS		Poor SRH		
Time trend	**n**	**Coeff.**	**95% CI**	**Coeff.**	**95% CI**	**n**	**OR**	**95% CI**
Later working life (50 - 64 yr.)								
Education low	6050	0.79	- 0.16 - 1.74	- 0.68	- 1.63 - 0.27	13042	1.06	0.89 - 1.26
medium	4501	0.21	- 0.90 - 1.33	- 0.75	- 1.79 - 0.30	9590	1.12	0.89 - 1.44
high	5008	**1.01***	0.04 - 1.98	- 0.32	- 1.20 - 0.56	10411	1.00	0.77 - 1.30
Young seniors (65 - 79 yr.)								
Education low	6727	**1.82*****	0.80 - 2.85	**1.56****	0.56 - 2.56	14484	**0.69*****	0.57 - 0.83
medium	2031	**1.85***	0.19 - 3.50	0.33	- 1.33 - 2.00	4278	1.16	0.77 - 1.62
high	3140	0.47	- 0.89 - 1.83	0.53	- 0.87 - 1.93	6244	**0.74**◊	0.53 - 1.08
Old age (80+ yr.)								
Education low	1125	0.63	- 2.31 - 3.57	0.05	- 2.42 - 2.53	2576	0.91	0.61 - 1.35
medium	325	-2.63	- 7.05 - 1.80	2.07	- 2.97 - 7.10	736	1.22	0.56 - 2.65
high	430	2.59	- 1.57 - 6.75	0.89	- 2.79 - 4.57	985	0.56	0.26 - 1.21
	Women							
Time trend	**MCS**			**PCS**		**Poor SRH**		
	n	**Coeff.**	**95% CI**	**Coeff.**	**95% CI**	**n**	**OR**	**95% CI**
Later working life (50 - 64 yr.)								
Education low	6347	0.90	- 0.10 - 1.89	**-1.65****	- 2.65 - 0.66	13665	**1.33***	1.12 - 1.59
medium	6494	0.36	- 0.60 - 1.32	- 0.34	- 1.25 - 0.57	13609	1.04	0.84 - 1.28
high	4103	0.78	- 0.39 - 1.95	0.36	- 0.78 - 1.49	8561	0.97	0.75 - 1.27
Young seniors (65 - 79 yr.)								
Education low	7880	**2.75*****	1.74 - 3.76	**1.30****	0.39 - 2.21	17176	**0.73*****	0.62 - 0.89
medium	2590	0.78	- 0.78 - 2.34	- 0.13	- 1.83 - 1.57	5519	0.83	0.61 - 1.13
high	1615	1.44	- 0.58 - 3.45	**1.97**◊	- 0.01 - 3.94	3422	**0.67**◊	0.43 - 1.03
Old age (80+ yr.)								
Education low	2024	0.77	- 1.33 - 2.87	0.61	- 1.01 - 2.22	4680	0.70	0.53 - 0.94
medium	460	0.04	- 4.62 - 4.71	**3.35**◊	- 0.04 - 6.74	1021	0.75	0.41 - 1.36
high	252	1.57	- 2.80 - 5.95	1.59	- 3.97 - 7.15	616	0.88	0.41 - 1.90

Adjusted for age, nationality, living with partner and equivalized net income; MCS: Mental Component Summary; PCS: Physical Component Summary; SRH: Self-Rated Health; n: number of observations; GSOEP: German Socio-Economic Panel; ◊ p<0.10, *p<0.05, **p<0.01, ***p<0.001

Table 4: Trends in relative (RII) and absolute (SII) educational inequalities in HRQOL (MCS and PCS) and poor SRH, stratified by gender and life stage, GSEOP 2002-2016

		n	RII	95% CI	SII	95% CI
Men						
all ages	MCS	35208	1.01	0.98-1.04	0.52	-0.84-1.87
	PCS	35208	1.02	0.99-1.05	0.91	-0.38-2.20
	Poor SRH	69095	0.88	0.69-1.12	-0.03	-0.08-0.03
Later working life (50 - 64 yr.)	MCS	18947	1.00	0.96-1.03	-0.20	-2.04-1.64
	PCS	18947	0.99	0.95-1.03	-0.56	-2.39-1.23
	Poor SRH	37316	1.16	0.80-1.67	0.03	-0.04-0.10
Young Seniors (65-79 yr.)	MCS	13840	**1.05***	1.01-1.10	**2.76***	0.41-5.11
	PCS	13840	**1.05**◊	1.00-1.11	**2.12**◊	-0.3-4.5
	Poor SRH	27028	0.73	0.48-1.13	**-0.10***	-0.19-0.01
Old age (80+yr.)	MCS	2421	1.03	0.91-1.17	1.44	-5.20-5.09
	PCS	2421	0.89	0.77-1.04	-4.71	-10.6-11.6
	Poor SRH	4751	1.08	0.52-2.26	0.06	-0.23-0.34
Women						
		n	**RII**	**95% CI**	**SII**	**95% CI**
all ages	MCS	38229	**1.03***	1.00-1.06	**1.41**◊	-0.03-2.86
	PCS	38229	0.98	0.95-1.01	-0.59	-1.95-0.76
	Poor SRH	75142	0.99	0.80-1.23	0.01	-0.04-0.06
Later working life (50 - 64 yr.)	MCS	20412	1.00	0.97-1.04	0.27	-1.61-2.15
	PCS	20412	**0.94***	0.90-0.98	**-2.98****	-4.86- -1.11
	Poor SRH	40074	**1.32**◊	0.95-1.83	**0.07***	0.00-0.14
Young Seniors (65-79 yr.)	MCS	14371	**1.06***	1.01-1.12	**2.82***	0.16-5-50
	PCS	14371	1.02	0.96-1.09	0.85	-1.82-3.52
	Poor SRH	28179	1.10	0.74-1.63	-0.04	-0.14-0.07
Old age (80+yr.)	MCS	3446	1.03	0.91-1.17	1.19	-5.25-7.63
	PCS	3446	0.97	0.84-1.13	-0.96	-6.63-4.72
	Poor SRH	6889	1.02	0.57-1.22	-0.02	-0.28-0.23

Adjusted for age, nationality, living with partner and equivalised net income; MCS: Mental Component Summary; PCS: Physical Component Summary, SRH: Self-Rated Health; n: number of observations; GSOEP: German Socio-Economic Panel; RII: Relative Index of Inequality, SII: Slope Index of inequality;
◊ p<0.10, *p<0.05, **p<0.01, ***p<0.001

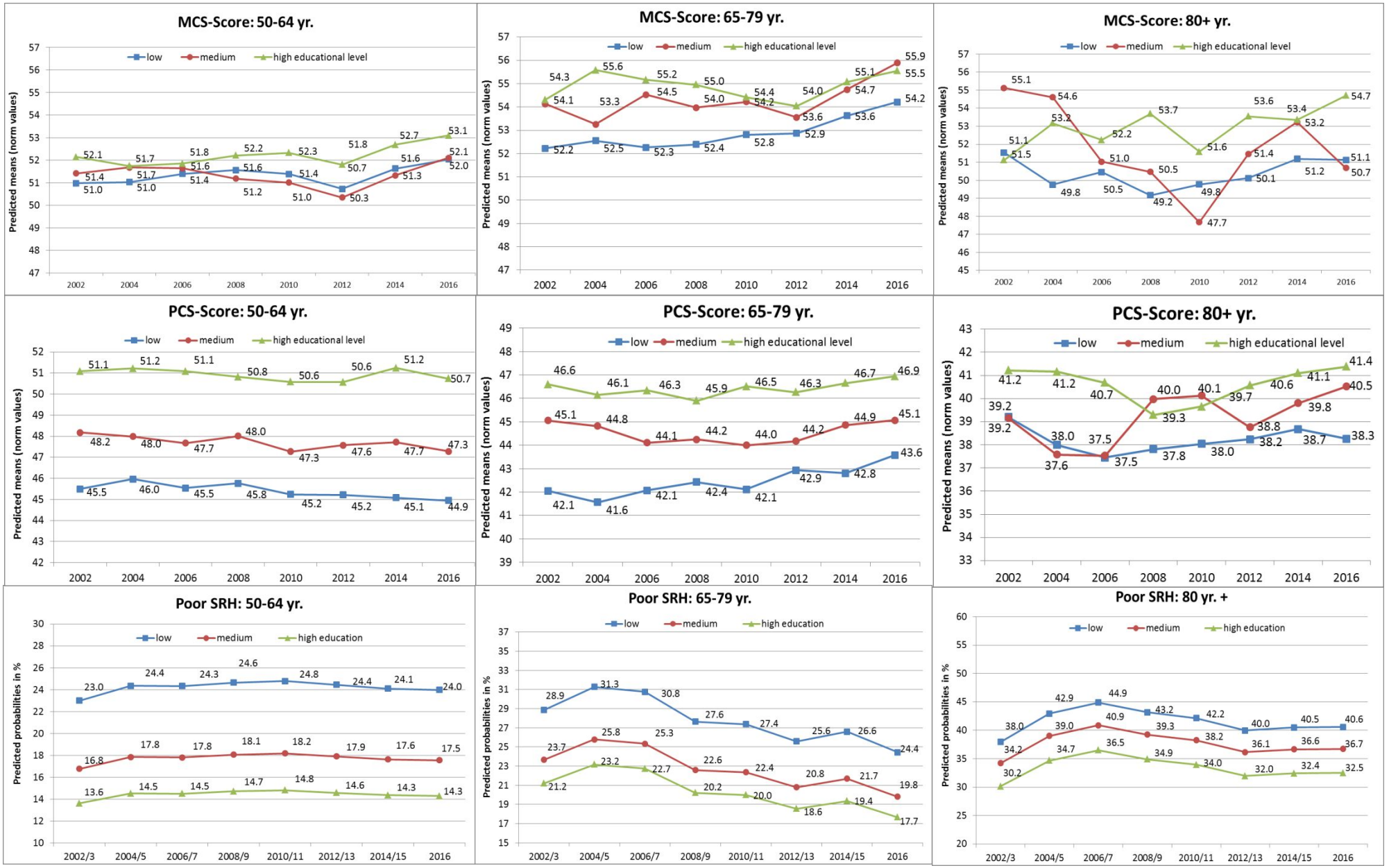

Figure 1: Trends in in HRQOL (MCS / PCS) and poor SRH (predicted means and probabilities) by life stages among **men**.

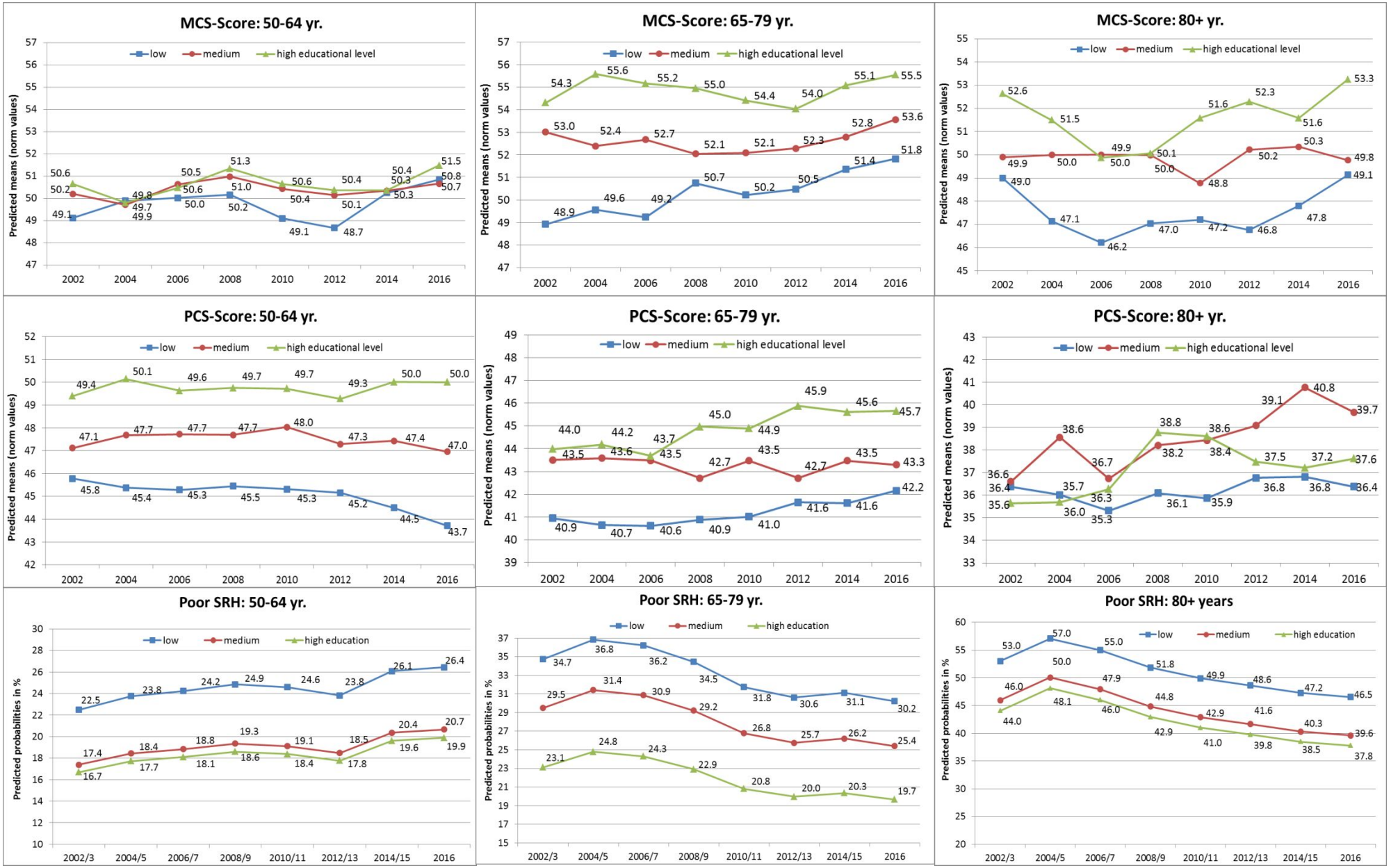

Figure 2: Trends in HRQOL (MCS / PCS) and poor SRH (predicted means and probabilities) by life stages among **women**.

Reporting checklist for cross sectional study.

Based on the STROBE cross sectional guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

Upload your completed checklist as an extra file when you submit to a journal.

In your methods section, say that you used the STROBE cross sectionalreporting guidelines, and cite them as:

von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies.

		Reporting Item	Page Number
Title and abstract			
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	1
Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	#3	State specific objectives, including any prespecified hypotheses	5
Methods			

Study design	#4	Present key elements of study design early in the paper	5
Setting	#5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Eligibility criteria	#6a	Give the eligibility criteria, and the sources and methods of selection of participants.	5
	#7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources / measurement	#8	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. Give information separately for for exposed and unexposed groups if applicable.	6-7
Bias	#9	Describe any efforts to address potential sources of bias	7
Study size	#10	Explain how the study size was arrived at	5
Quantitative variables	#11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	7-8
Statistical methods	#12a	Describe all statistical methods, including those used to control for confounding	7-8
Statistical methods	#12b	Describe any methods used to examine subgroups and interactions	7-8
Statistical methods	#12c	Explain how missing data were addressed	6
Statistical methods	#12d	If applicable, describe analytical methods taking account of sampling strategy	6-7
Statistical methods	#12e	Describe any sensitivity analyses	14

Results			
Participants	#13a	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed. Give information separately for for exposed and unexposed groups if applicable.	"n/a. We did no select participants but used data from the German Socio-Economic Panel Study
Participants	#13b	Give reasons for non-participation at each stage	"n/a, see above"
Participants	#13c	Consider use of a flow diagram	"n/a, see above"
Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable.	8
Descriptive data	#14b	Indicate number of participants with missing data for each variable of interest	Table 1, p.21
Outcome data	#15	Report numbers of outcome events or summary measures. Give information separately for exposed and unexposed groups if applicable.	Figure 1 and 2
Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	p. 7; Tables 2-4; p.14
Main results	#16b	Report category boundaries when continuous variables were categorized	6
Main results	#16c	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	"n/a, see above"
Other analyses	#17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	14
Discussion			

Key results	#18	Summarise key results with reference to study objectives	10
Limitations	#19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	13
Interpretation	#20	Give a cautious overall interpretation considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence.	11-13
Generalisability	#21	Discuss the generalisability (external validity) of the study results	14
Other Information			
Funding	#22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15

Notes:

- 13a: "n/a. We did no select participants but used data from the German Socio-Economic Panel Study
- 13b: "n/a, see above"
- 13c: "n/a, see above"
- 16c: "n/a, see above"
- The STROBE checklist is distributed under the terms of the Creative Commons Attribution License CC-BY. This checklist was completed on 18. June 2020 using https://www.goodreports.org/, a tool made by the EQUATOR Network in collaboration with Penelope.ai

BMJ Open

Life stage-specific trends in educational inequalities in health-related quality of life and self-rated health between 2002 and 2016 in Germany – Findings from the German Socioeconomic Panel Study (GSOEP)

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2020-042017.R1
Article Type:	Original research
Date Submitted by the Author:	30-Dec-2020
Complete List of Authors:	Sperlich, Stefanie; Hannover Medical School, Medical Sociology Klar, Marie; Hannover Medical School, Medical Sociology Safieddine, Batoul; Hannover Medical School, Medical Sociology Tetzlaff, Fabian; Hannover Medical School, Medical Sociology Tetzlaff, Juliane; Hannover Medical School, Medical Sociology Geyer, Siegfried; Medizinische Hochschule Hannover, Medical Sociology Unit
Primary Subject Heading:	Public health
Secondary Subject Heading:	Health policy
Keywords:	EPIDEMIOLOGY, PUBLIC HEALTH, SOCIAL MEDICINE

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Life stage-specific trends in educational inequalities in health-related quality of life and self-rated health between 2002 and 2016 in Germany – Findings from the German Socioeconomic Panel Study (GSOEP)

Stefanie Sperlich[1], Marie Kristin Klar[1], Batoul Safieddine[1], Fabian Tetzlaff[1], Juliane Tetzlaff[1], Siegfried Geyer[1]

[1] Hannover Medical School, Medical Sociology, Hannover, Germany

Corresponding author:
Stefanie Sperlich
Carl-Neuberg Str. 1
30625 Hannover
Tel. 0049 511 532 9310
Fax 0049 511 532 4214
email: Sperlich.Stefanie@mh-hannover.de

Email of the other authors:
marie-k.klar@gmx.de
Safieddine.Batoul@mh-hannover.de
Tetzlaff.Fabian@mh-hannover.de
Tetzlaff.Juliane@mh-hannover.de
Geyer.Siegfried@mh-hannover.de

ABSTRACT

Objectives While evidence suggests persisting health inequalities, research on whether these trends may vary according to different stages of life has rarely been considered. Against this backdrop, we analyzed life stage-specific trends in educational inequalities in health-related quality of life (HRQOL) and poor self-rated health (SRH) for individuals in 'later working life' (50-64 years), 'young seniors' (65-79 years) and persons of 'old age' (80+ years).

Methods We used survey data from the German Socio-Economic Panel Study comprising the period from 2002 to 2016. The sample consists of 26,074 respondents (160,888 person years) aged 50 years and older. Health was assessed using the mental and physical component summary scale (MCS / PCS) of the HRQOL questionnaire (SF-12v2) and the single item self-rated health. To estimate educational health inequalities, we calculated the regression-based slope index of inequality (SII) and relative index of inequality (RII). Time trends in inequalities were assessed by the inclusion of a two-way interaction term between school education and time.

Results With increasing age, educational inequalities in PCS and poor SRH decreased whereas they rose in MCS. Over time, health inequalities decreased in men aged 65-79 years (MCS_{SII}=2.76, 95%CI 0.41-5.11; MCS_{RII}=1.05, 95%CI 1.01-1.10; PCS_{SII}=2.12, 95%CI -0.27-4.51; PCS_{RII}=1.05, 95%CI 1.01-1.10; poor SRH_{SII}=-0.10, 95%CI -0.19-0.01; poor SRH_{RII}=0.73, 95%CI 0.48-1.13) and among women of that age for MCS (MCS_{SII}=2.82, 95%CI 0.16-5.50; MCS_{RII}=1.06, 95%CI 1.01-1.12). In contrast, health inequalities widened in the 'later working life' among women (PCS_{SII}=-2.98, 95%CI -4.86- -1.11; PCS_{RII}=0.94, 95%CI 0.90-0.98; poor SRH_{SII}=0.07, 95%CI 0.00-0.14) while remained largely stable at old age for both genders.

Conclusions We found distinctive patterns of health inequality trends depending on gender and life stage. Our findings suggest to adopt a differentiated view on health inequality trends and to pursue research that explores their underlying determinants.

Keywords: health inequality, life stages, trend, temporal change

Strengths and limitations of this study

- This is one of the first studies investigating trends in educational inequalities in HRQOL and poor SRH according to different stages of life
- We used data from a large nationally representative survey, and our study considered trends over a period of 15 years using a validated measure of HRQOL
- The key finding of life stage-specific trends in educational inequality in health are open to different interpretation and might be the result of cohort- as well as period-effects.
- Further studies are warranted in order to replicate our findings and to provide clues to the drivers behind the life stage-specific trends.

INTRODUCTION

Indicators of subjective health like self-rated health (SRH) and health-related quality of life (HRQOL) complement mortality and morbidity as measures used in tracking trends in population health[1]. Previous studies on temporal change in subjective health have shown conflicting results indicating both improvements[2-4] as well as stable trends or even deterioration of self-rated health over time.[5-7] Similarly, recent studies in Germany revealed heterogeneous findings with some suggesting that the prevalence of poor SRH did not change substantially over time[8 9] while others pointing towards enhancements in HRQOL and functional health.[10 11]

The existence of socioeconomic inequalities in mortality and morbidity is well documented[12-14] and the social gradient in health has also been shown to be present for SRH and HRQOL.[15 16] Recent studies from Europe and other western countries indicate that the self-rated health gap between lower and higher socioeconomic status (SES) groups remained largely the same or has even widened over time. For instance, Hu et al.[17], who analyzed trends in socioeconomic inequalities in 17 European countries, found that absolute inequalities in SRH remained unchanged while relative inequalities increased between 1990 and 2010. Lahelma et al.[18] reported that educational inequalities in SRH in Finland largely remained constant between 1979 and 2014. Similarly, the study by Hanibuchi et al.[19] revealed stable trends in socioeconomic inequalities in SRH in Japan between 2000 and 2010. Analyzing trends in quality-adjusted life expectancy between 2001 and 2011 for the Netherlands, Gheorghe et al.[20] summarized that the largest increases were found for higher educated individuals, which resulted in a widening health gap by education. A similar pattern was observed for Germany where Lampert et al.[16] found increasing income inequalities in the prevalence of poor SRH between 1994 and 2014. Based on the data of repeated cross-sectional surveys between 2003 and 2012, the study by Wachtler et al.[9] revealed stable absolute and relative inequalities in SRH between 2003 and 2012.

The life-course perspective on social inequalities in health suggests that while social disparities persist across the life course, the magnitude of these differences may vary according to the stage in the life phase. Three opposing theoretical perspectives have been proposed about the way in which health inequality may evolve across the life course. The *cumulative advantage/disadvantage hypothesis* claims that the positive effect of SES on health increases over the life course and therefore health inequality would widen at older ages.[21] In contrast, the *status maintenance hypothesis* states that the social health gradient

remains largely constant across the life course since the social positions attained in early adulthood do not substantially change in later life.[22] Finally, the *age-as-leveler hypothesis* posits that health inequality decreases at older ages due to different factors such as the selection of more healthy people due to mortality.[23] Previous studies revealed contradictory findings supporting the cumulative advantage/disadvantage hypothesis,[24 25] as well as the status maintenance[25 26] and the age-as-leveler[27] assumptions.

Whereas numerous studies on social inequalities in health have adopted a life course approach[28 29], a life stage-specific perspective on determinants of health inequalities has so far been neglected. In one of the few existing studies, San Sebastian et al.[30] analyzed the effects of social determinants in health at four different life stages. They found that the effects of specific adversities depend on the life course stage and concluded that life course needs to be taken into consideration for tackling health inequalities. In a similar vein, recent studies suggest that the temporal trends in SRH and functional disability also differ according to the life stage considered.[31-35]

In medical sociological research, it has been established to distinguish between material, psychosocial and behavioral pathways in explaining social inequalities in health.[36-38] While the material explanation refers to structural living conditions, the psychosocial pathway includes a wide range of social and personal resources as well as psychosocial stressors. Finally, the behavioral explanation considers a variety of health-related behaviors that are strongly linked with the material and psychosocial pathway.[39] In order to explain trends in health inequality, a dynamic perspective on these explanations needs to be employed that take medical, demographic, social and economic change into account. This approach represents a substantial challenge since health inequalities are the result of a number of interacting factors. In addition, a life-stage specific approach would appear appropriate as the consequences of medical and social change may have different implications according to people's phase in life. However, research on whether trends in health inequalities may vary according to different stages of life is still rare. Using this as a starting-point, the aim of this study was to analyze life stage-specific time trends in educational inequalities in HRQOL and poor SRH for individuals in 'later working life' (50-64 years), among 'young seniors' (65-79 years) and persons of 'old age' (80+ years). We focused on life stage-specific rather than age-specific effects in order to emphasize that social and demographic change may have altered people's living conditions differently depending on their stage in the life course and the specific

psychosocial resources and burdens associated therewith. In more detail, the study was guided by the following research questions:

1. Does the extent of educational inequalities in HRQOL and poor SRH vary between different life stages?
2. How are HRQOL and poor SRH evolving over time in each of the life stages according to educational level?
3. Are there diverging trends of educational inequalities in health for the different life stages?

METHODS

Our paper follows the "Strengthening the Reporting of Observational Studies in Epidemiology (STROBE)" guidelines.[40]

Data source

This study is based on data from the German Socio-Economic Panel Study (GSOEP V.31). The GSOEP is the largest representative annual survey of German individuals based on a random sample of private households. Conducted from 1984 onwards the study covers nearly 11,000 households and 30,000 individuals each year. The GSOEP population is regularly updated with new survey samples to account for changes in the German population and for compensating loss-to-follow-up. Data were collected using different questionnaires for individuals, households or specific subgroups by face-to-face interviews. Further information on GSOEP can be derived from Frick et al.[41] The information used for this study includes school education, income, marital status, nationality as well as SRH and HRQOL as health outcomes. While SRH was assessed annually, HRQOL has been measured every two years since 2002. We focused on men and women aged 50 and above since limitations in physical wellbeing are rare in younger subjects.

For the physical and the mental components of HRQOL, in total 23,878 respondents (11,553 men / 12,325 women) were observed 81,676 times (39,159 men / 42,517 women) between 2002 and 2016, corresponding to an average participation in 3.4 waves (min. = 1/ max. = 8). With respect to SRH, a total of 26,074 respondents (12,665 men / 13,409 women) were observed 160,888 times (77,028 men / 83,860 women), corresponding to an average participation in 6.1 waves in men and 6.3 in women (min. = 1/ max. = 15). We used cross-sectional weights which are assumed to produce a nationally representative sample.[42] The

proportion of missing values varied between 0 and 2.6%. Respondents with missing information were excluded from analysis (Table 1).

Life stage-approach

According to our life stage-approach, we assigned the population to three different life stages, namely 'later working life' (50-64 years), 'young seniors' (65-79 years) and 'old age' (80+ years).

Patient and public involvement

The study is based on anonymized data from the German Socio-Economic Panel Study that is conducted by the German Institute for Economic Research (DIW). No patients were involved in the design of the study, nor were they involved in the recruitment to and the conduct of the study. In addition, no consent to participate was required and there are no plans to disseminate the results of the research to study participants.

Measures

Self-rated health (SRH)

SRH is one of the most frequently used health measures in public health and has been proved to be a reliable indicator of healthcare services utilization[43], functional limitations[44] and mortality.[43 45] In our study, SRH was measured by the question "How would you assess your current state of health?" comprising the five response categories: 'very good', 'good', 'satisfactory', 'poor' and 'bad'. The responses were dichotomized into 'poor health' (last two categories) and better health (first three categories).

Health-related quality of life (HRQOL)

HRQOL is a multidimensional concept that incorporates physical, emotional and social dimensions of health.[46] In this study, HRQOL was assessed using a slightly modified version of the second version of the 12-Item Short Form Health Survey (SF-12v.2).[47] The SF-12v.2 includes 12 items making up eight scales: physical functioning, role limitations due to physical problems, bodily pain, general health, vitality, social functioning, role limitation due to emotional problems and perceived mental health. Based on these items a physical component summary (PCS) score and a mental component summary (MCS) score were calculated. Values are standardized to a national norm (GSOEP population in 2004) ranging

from 0 to 100 points with a mean of 50 points and a standard deviation of 10 points. A higher score corresponds to a better health status.

Education

Educational level was classified into 'low', 'intermediate' and 'high' according to the number of years of schooling. All individuals with a maximum of nine years of schooling (secondary education) were assigned to the low educational group that includes also subjects without a school leaving certificate due to early school leaving. The intermediate education group consists of those with 10 years of schooling corresponding to a comprehensive school certificate. Subjects with at least twelve years' schooling were assigned to the high educational group corresponding to German secondary school leaving certificate. For analyzing time trends, these educational groups were transformed into cumulative rank probabilities (ridit scores).

Time trend

Changes in SRH and HRQOL between 2002 and 2016 were assessed by a continuous time-trend variable with a range of 0 to 1 for the entire study period. The first year of observation (2002) is coded as 0 and the last year (2016) as 1, with the years in between getting fractional values according to the following formula: [(year-2002) / (2016-2002)].

Confounders

Socio-demographic characteristics such as migration background, marital status and income level might be correlated with health outcomes as well as educational level. Shift in the compositions of these factors due to selective panel attrition might by a possible source of bias for the magnitude of health trends observed. Hence, in all analyses we adjusted for nationality, marital status and equivalized net income. To take account of possible shifts in age composition over time within the three life stages, we additionally adjusted for age in each of the models.

Statistical analysis

We performed logistic and linear regression models to test for time-effects on poor SRH and HRQOL, respectively. We accommodated the statistical dependence among the repeated observations by calculating population-averaged effects using generalized equation estimating (GEE) for logistic and linear regression.[48] We used this regression technique since our aim was to analyze population-averaged and not subject-specific time-effects which would be

more accurately estimated by random-effect models.[49] In addition to odds ratios (OR) we reported predicted means and probabilities (margins at means) giving the time trends a more substantial interpretation.

We calculated the Relative Index of Inequality (RII) and the Slope Index of Inequality (SII) as recommended by Mackenbach and Kunst.[50] These indices are both regression-based and take the entire distribution of a socio-economic variable as well as the size of the socio-economic groups into account. In our study, the RII can be interpreted as the estimated ratio (poor SRH: prevalence ratio, HRQOL: ratio of mean values) between subjects with the lowest and those with the highest educational level. In contrast, the SII quantifies the magnitude of absolute health inequality and can be interpreted as the difference in the prevalence (poor SRH) or in the mean (HRQOL) between individuals at the top and bottom of the educational hierarchy. In order to calculate RII and SII, the educational groups of each survey year and for each stage of life (separated for men and women) were transformed into cumulative rank probabilities ('ridit scores') ranging from 0 (highest level of education) to 1 (lowest level of education). For computing the ridit-scores, population weights were employed to match the official population statistics. As proposed, we used a logarithmic link function to calculate the RII and an identity link function to calculate the SII by using clustered variance estimators.[50] Temporal trends in educational inequalities were assessed by the inclusion of a two-way interaction term between educational levels (ridit-score) and the time-trend variable. The models were adjusted for possible confounders (see above) and the main effects of education and time. For MCS and PCS where higher scores reflect better health, values of RII <1 and SII <0 indicate widening educational inequalities while RII >1 and SII >0 point to decreasing inequalities over time. The opposite interpretation applies for poor SRH where RII >1 and SII >0 indicate increasing health inequality over time. All analyses were performed with STATA v13.1.

RESULTS

The weighted sample characteristics, separated by time periods, are presented in Table 1. Between 2002 and 2016, the proportion of subjects with low educational attainment decreased while the proportions of those with higher educational levels increased. The distribution of age, gender, income, nationality and cohabitation remained largely stable over time.

Women as compared with men reported consistently lower levels of MCS and PCS as well as higher proportions of poor SRH at almost each time point (Figure 1 and 2). Men and women in the later working life both showed the highest levels of PCS and lowest proportions of poor

SRH. Health status for these indicators gradually declined in the subsequent life stages with poorest subjective health observed at old age. For both genders, in contrast, levels of MCS were lowest in the later working life and tended to improve with age.

The extent of educational inequalities in HRQOL and SRH according to life stages

Educational inequalities in mean scores of PCS and proportions of poor SRH to the disadvantage of lower educated subjects were observed for both genders and all life stages considered. These inequalities were most pronounced in later working life and declined with age. In contrast, for both men and women, educational disparities in MCS were not significant in later working life but widened with age (Table 2).

Health trends in different life stages according to educational level

Among men in the later working life hardly any significant temporal health change was observed in any of the educational groups. The only exception was that MCS significantly improved by 1.01 points (95%CI 0.04 to 1.98, $p<0.05$) among highly educated men (Table 3 and Figure 1). Stronger temporal fluctuations in MCS and PCS were observed in the life stage of old age, however, no systematic linear health trend was found in any of the educational groups. By contrast, health in the life stage of young seniors improved more strongly in low educated as compared with highly educated men. This was observed for all of the three health indicators considered. For example, among low educated men MCS and PCS increased by 1.82 points (95%CI 0.80 to 2.85, $p<0.001$) and 1.56 points (95%CI 0.56 to 2.56, $p<0.01$), respectively, while no significant improvements for MCS and PCS were found among highly educated men (Table 3). Similar, in men with low educational level, odds of poor SRH reduced by 31% (OR=0.69, 95%CI 0.57 to 0.83, $p<0.001$) while declined only by 26% (OR=0.74, 95%CI 0.53 to 1.08, $p<0.10$) in their high educated counterparts.

Among women, a similar pattern was found, indicating that subjective health in young seniors increased more pronounced in those with low as compared to higher educational attainment (Table 3). In later working life, by contrast, PCS and SRH deteriorated among low educated women while remained largely stable for the higher educated ones. At this life stage, PCS declined by 1.65 points (95%CI -2.65 to -0.66, $p<0.001$) in low educated women while slightly improved by 0.36 points (95%CI -0.78 to 1.49, $p>0.10$) in women with high education. In addition, odds of poor SRH increased by 33% (OR=1.33; 95%CI 1.12 to 1.59, $p<0.05$) in low educated women while marginally decreased by 3% (OR=0.97; 95%CI 0.75 to 1.27, $p>0.10$) for the high educated ones. Similarly to the results of their male counterparts,

no systematic linear health trend was found among old age women in any of the educational groups.

Life stage-specific trends in relative (RII) and absolute (SII) educational inequalities

In terms of relative (RII) and absolute (SII) educational inequalities, no significant temporal change in HRQOL and SRH was found among men in later working life as well as in old age (Table 4). In contrast, educational inequalities decreased over time among male young seniors. As indicated by the significant interaction terms (MCS_{RII} = 1.05, 95%CI 1.01 to 1.10, $p<0.05$ / PCS_{RII} = 1.05, 95%CI 1.00 to 1.11, $p<0.10$), HRQOL improved more strongly in the lowest as compared with the highest educational group. Expressed in absolute terms (SII), educational inequalities between low and highly educated men were reduced by 2.76 points (95%CI 0.41 to 5.11, $p<0.05$) for MCS and 2.12 points (95%CI -0.27 to 4.51, $p<0.10$) for PCS. The same pattern was found for poor SRH where the opposite interpretation applies (RII < 1 and SII < 0 indicating reduction of health inequality), reaching statistical significance for SII only.

Educational inequalities among 'young seniors' also decreased in women. However, this was restricted to MCS where absolute differences between the highest and lowest educational group were reduced over time by 2.82 points (95%CI 0.16 to 5.50, $p<0.05$). The contrary pattern was found in the life stage of 'later working life' where educational inequality in women increased in relative and absolute terms for PCS and poor SRH. Similar to men, no significant change in educational inequalities was observed for the life stage of 'old age'.

DISCUSSION

The aim of this study was to analyze trends in educational inequalities in HRQOL and poor SRH between 2002 and 2016 in the life stages of 'later working life' (50-64 years), 'young seniors' (65-79 years) and 'old age' (80+ years). First, we found that educational inequalities in poor SRH and in the physical component of HRQOL decreased with subsequent life stages while the opposite applied to the mental component of HRQOL. Our findings suggest that the way in which health inequality evolves across the life stages depend on the health indicator considered. This corresponds to previous studies who found different patterns of health inequalities across ages for different health indicators.[25 51 52] Our main finding was that the temporal development of health inequality differed according to the stage of life. While among young seniors health inequalities declined for both genders, a significant increase was found among women in later working life.

The extent of educational inequalities in HRQOL and SRH according to different life stages

In the life stage of 'later working life' no educational inequalities were found for MCS in both genders. This is in line with the finding by Moor et al.[8] who likewise found no social gradient in MCS among subjects aged 30 to 49 years. They supposed that this may due to the specific life phase in which career building coincide with family demands, affecting subjects of all educational levels and thus equalizing educational differences in HRQOL with respect to mental health. Our findings indicate that educational inequalities in MCS to the disadvantage of lower educated subjects first emerged at retirement age, supporting the assumption that during working life, the mental health component of HRQOL is strongly influenced by work-related demands and time constraints acting independently of educational attainment. Furthermore, our results suggest that high educated women may benefit more from retirement age which supports the cumulative advantage/disadvantage hypothesis claiming that the positive effect of socioeconomic status on health increases over the life course. In contrast, we found educational inequalities in the physical health component of HRQOL as well as in poor SRH to be strongest in the later working life and declining with age. This finding supports the age-as-leveler hypothesis positing that health inequality decreases at older ages. One possible explanation for declining educational inequalities over the life stages in physical health could be that biological frailty in older age may contribute to an intensified health decline of individuals with high SES leading to a reduction of health inequalities. In addition, retirement might bring an end to inequalities in the work context with respect to work-related physical strain. Finally, with age increasing mortality selection in the general population as well as selective panel attrition may have contributed to the selection of more healthy individuals with the consequence that the association between education and health appeared to be weaker at older ages.

Life stage-specific trends in educational health inequalities

Previous research on trends in health inequalities has mainly focused on the entire adult population and has not adequately taking into consideration that health trends may vary across different stages of life. In line with this research, we found educational inequalities in health to be largely stable over time when considering individuals of all ages. However, the differentiated analysis according to life stages revealed distinctive patterns of health inequality trends. The study conducted by Granström et al.[53] is one of the few that adopted a life stage-specific view on health inequality trends. Their findings indicate that the increase in

health inequality among women was mainly due to growing inequalities in early adulthood between 25 and 34 years of age. The findings of our study on subjects aging 50 years and older revealed a reduction of educational health inequality in the life stage of young seniors, holding for both genders. In contrast, health inequalities in later working life widened among women and remained largely stable for both genders at old age. These findings support the assumption that the consequences of medical and social change may have different implications according to people's phase in life. For example, the decline in health inequality among young seniors as found in our study might be attributed to medical progress in the prevention and treatment of diseases that appears to be particularly relevant at this life stage where chronic conditions gained in importance. While medical advances bring benefit to all educational groups, lower educated persons may benefit more as they are more vulnerable to chronic conditions what might partly explain the reduction of health inequality at this age. In the same way, the increase in work-related stress in recent years in Germany[33] does not apply to retired persons, which might partly explain the greater health improvement among young seniors as found in a previous study.[34] The same reasoning may apply to the reduction of the educational health gap among young seniors found in this study. Seen from that perspective, educational differences in subjective health may decrease at this age as retirement bring an end to the unequal work-related burden caused by socially stratified working conditions that might have become even harder for low educated individuals. In contrast, changes in employment rates over the last decades might have contributed to the increasing health inequalities among women in later working life. In a previous study we found an overall increase in women's perceived rates of good self-rated health at this age that was more pronounced as compared with men.[34] Following the idea by Aguilar-Palacio et al.[54] it was postulated that the increasing presence of women in the labor force might have contributed to the reduction of the gender gap in SRH. The finding of this study suggests that not all women benefited equally from the increase in employment rates. It might be possible that higher educated women have benefited more as their working activities provide higher levels of autonomy and rewards which proved to be significant health-promoting resources.[55 56] Conversely, employment may pose higher burdens to low educated women that would explain the rise in health inequalities found among women of later working life. In addition to these explanations, different trends in health-related behaviors might have contributed to the life stage-specific trends in health inequality. For example, recent findings suggest that probability of obesity increased particularly for younger cohorts while the rise was less pronounced among older ones.[57 58] Finally, it is worth noting that while the educational expansion over the

past decades has affected all ages, the implications might have been very different depending on the life stage. While today low educated individuals in Germany represent a minority among younger cohorts, they are still forming the majority of older cohorts.[59] Hence, low educated individuals in younger ages may increasingly form a vulnerable subgroup with a high health-risk which is not the case for the elderly. These varying implications of the educational expansion for different cohorts need to be considered when exploring life stage-specific trends in health inequality.

Strength and limitations

The strength of this study is the large sample size representing the German population allowing for stratification according to gender and different stages of life. We used different indicators of subjective health giving the findings a more substantial interpretation. In addition, we used established instruments to ensure high construct validity for measuring subjective health. We enhanced the validity of trend analysis by using measures of both absolute and relative health inequalities. We performed further time trend analyses not adjusting for potential confounders and found the time trends determined to be very robust.

However, this study has also limitations worth noting. Even though sampling weights were used, the existence of sampling bias cannot be completely ruled out since a full match of the official population statistics is not absolutely guaranteed. Selection bias could be due to the exclusion of the institutionalized population as well as persons who could not take part in the survey for health reasons. Furthermore, there is a possible existence of a reporting bias since the outcome and the independent variables are self-reported.

As Moor et al.[8] pointed out, the effect size in the extent of health inequalities depends on the cut-off point chosen for the categorization of poor health. They conducted a sensitivity analysis, in which 'satisfactory' was part of the reference category 'good health' as it was in this study. Compared with the alternative in which 'satisfactory' was part of the category 'rather poor health', they found the relative risk in low educated people to assess their health as poor to be higher while the absolute difference revealed to be smaller. This finding suggests that the results obtained depend on the way of classification poor health, indicating that the generalizability of our study results may be limited.

In addition, our key finding of life stage-specific trends in educational health inequality cannot be clearly attributed to either cohort- or period-effects. While sociological literature considers a cohort-effect as the sum of all unique exposures experienced by the cohort from

birth, a period-effect result from external factors that equally affect all age groups at a particular calendar time.[60] In our study, we found subjective health steadily improving particularly among lower educated young seniors not fitting in with the idea of an exclusive cohort- or period-effect. Instead, our results speak in favor of a gradual transition that might be better described with the continuing progress of social and economic change that may have different implications depending on the stage of people's lives.

Lastly, since the observation period of 15 years in our study is relatively short, conclusions about the further development of health inequality in different life stages cannot be derived from our findings. In particular, it is not foreseeable whether the positive trend of narrowed health inequality among young seniors, if confirmed in further studies will continue in the future.

Conclusions

We found distinctive patterns of health inequality trends in HRQOL and SRH for different life stages and according to gender. While educational disparities declined among young seniors in both genders, they widened in later working life exclusively among women. The results emphasize the need for a life stage-approach when analyzing health inequality trends in order to capture varying effects of social change on different life stages. In addition, our findings suggest that social change may have different implications for men and women, indicating that gender is another core inequality dimension that may interact with life stage and social status. Moving from the description to the explanation of health trends would be an important next step to develop targeted political interventions aiming at tackling inequality in health. For this purpose it would beneficial to adopt an intersectional framework that includes age, gender and social status as interconnected and time-varying dimensions of health inequalities.

Competing interests

None declared.

Ethics

Ethics Board approval was not required as we only conducted analyses of completely anonymized SOEP-datasets.

Funding statement

This paper was supported by the DFG (German Research Foundation), grant number GE 1167/15-1.

Competing interest statement

All authors have read and understood the BMJ Group policy on declaration of interests and declared that they have no conflict of interest.

Ethical approval

Approval from the ethics committee is not required as this study using pre-existing and de-identified data.

Author Contributions

SS has made substantial contributions to the concept and design and conducted the statistical analyses. BS, FT, JT, MKK and SG participated in the design of the study and helped to draft the manuscript. They have also been involved in revising the manuscript critically for important intellectual content. All authors read and approved the final manuscript.

Data availability statement

The raw data were drawn from the German Socio-Economic Panel Study (GSOEP 21 V.31). The datasets used are available from the corresponding author on reasonable request. German data privacy laws necessitate that all users sign a data user contract with DIW Berlin.

REFERENCES

1. Bombak AE. Self-rated health and public health: a critical perspective. *Frontiers in public health* 2013;1:15-15. doi: 10.3389/fpubh.2013.00015
2. Parker MG, Thorslund M. Health trends in the elderly population: getting better and getting worse. *Gerontologist* 2007;47(2):150-8. doi: 10.1093/geront/47.2.150 [published Online First: 2007/04/19]
3. Roqué IFM, Salvà A, Bolíbar I, et al. [Trends in self-perceived health and chronic disability in the elderly Spanish population: evolution between years 1993 and 2006]. *Med Clin (Barc)* 2012;139(7):284-9. doi: 10.1016/j.medcli.2011.06.021 [published Online First: 2011/10/22]
4. Põld M, Pärna K, Ringmets I. Trends in self-rated health and association with socioeconomic position in Estonia: data from cross-sectional studies in 1996-2014. *Int J Equity Health* 2016;15(1):200. doi: 10.1186/s12939-016-0491-9 [published Online First: 2016/12/10]
5. Zack MM, Moriarty DG, Stroup DF, et al. Worsening trends in adult health-related quality of life and self-rated health-United States, 1993-2001. *Public Health Rep* 2004;119(5):493-505. doi: 10.1016/j.phr.2004.07.007 [published Online First: 2004/08/18]
6. Galenkamp H, Braam AW, Huisman M, et al. Seventeen-year time trend in poor self-rated health in older adults: changing contributions of chronic diseases and disability. *Eur J Public Health* 2013;23(3):511-7. doi: 10.1093/eurpub/cks031 [published Online First: 2012/04/12]
7. Mairey I, Bjerregaard P, Brønnum-Hansen H. Gender difference in health expectancy trends in Greenland. *Scand J Public Health* 2014;42(8):751-8. doi: 10.1177/1403494814550174 [published Online First: 2014/09/28]
8. Moor I, Günther S, Knöchelmann A, et al. Educational inequalities in subjective health in Germany from 1994 to 2014: a trend analysis using the German Socio-Economic Panel study (GSOEP). *BMJ Open* 2018;8(6):e019755. doi: 10.1136/bmjopen-2017-019755 [published Online First: 2018/06/10]
9. Wachtler B, Hoebel J, Lampert T. Trends in socioeconomic inequalities in self-rated health in Germany: a time-trend analysis of repeated cross-sectional health surveys between 2003 and 2012. *BMJ Open* 2019;9(9):e030216. doi: 10.1136/bmjopen-2019-030216 [published Online First: 2019/09/29]
10. Ellert U, Kurth B-M. Gesundheitsbezogene Lebensqualität bei Erwachsenen in Deutschland: Robert Koch-Institut, 2013.
11. Trachte F, Sperlich S, Geyer S. [Compression or expansion of morbidity? Development of health among the older population]. *Z Gerontol Geriatr* 2015;48(3):255-62. doi: 10.1007/s00391-014-0644-7 [published Online First: 2014/05/02]
12. Marmot M, Bell R. Social inequalities in health: a proper concern of epidemiology. *Ann Epidemiol* 2016;26(4):238-40. doi: 10.1016/j.annepidem.2016.02.003 [published Online First: 2016/04/17]
13. Marmot M. The Health Gap: The Challenge of an Unequal World: the argument. *Int J Epidemiol* 2017;46(4):1312-18. doi: 10.1093/ije/dyx163 [published Online First: 2017/09/25]
14. Bopp M, Mackenbach JP. [Death is a respecter of persons : 30 years of research comparing European countries regarding social inequality in mortality]. *Z Gerontol Geriatr* 2019;52(2):122-29. doi: 10.1007/s00391-019-01530-6 [published Online First: 2019/03/16]

15. Mackenbach JP, Stirbu I, Roskam AJ, et al. Socioeconomic inequalities in health in 22 European countries. *N Engl J Med* 2008;358(23):2468-81. doi: 10.1056/NEJMsa0707519 [published Online First: 2008/06/06]
16. Lampert T, Schmidtke C, Borgmann L-S, et al. Subjektive Gesundheit bei Erwachsenen in Deutschland. *Journal of Health Monitoring* 2018(3):64--71. doi: http://dx.doi.org/10.17886/RKI-GBE-2018-068
17. Hu Y, van Lenthe FJ, Borsboom GJ, et al. Trends in socioeconomic inequalities in self-assessed health in 17 European countries between 1990 and 2010. *J Epidemiol Community Health* 2016;70(7):644-52. doi: 10.1136/jech-2015-206780 [published Online First: 2016/01/21]
18. Lahelma E, Pietiläinen O, Pentala-Nikulainen O, et al. 36-year trends in educational inequalities in self-rated health among Finnish adults. *SSM - population health* 2019;9:100504-04. doi: 10.1016/j.ssmph.2019.100504
19. Hanibuchi T, Nakaya T, Honjo K. Trends in socioeconomic inequalities in self-rated health, smoking, and physical activity of Japanese adults from 2000 to 2010. *SSM Popul Health* 2016;2:662-73. doi: 10.1016/j.ssmph.2016.09.002 [published Online First: 2016/09/09]
20. Gheorghe M, Wubulihasimu P, Peters F, et al. Health inequalities in the Netherlands: trends in quality-adjusted life expectancy (QALE) by educational level. *Eur J Public Health* 2016;26(5):794-99. doi: 10.1093/eurpub/ckw043 [published Online First: 2016/04/17]
21. Ferraro KF, Shippee TP. Aging and cumulative inequality: how does inequality get under the skin? *Gerontologist* 2009;49(3):333-43. doi: 10.1093/geront/gnp034 [published Online First: 2009/04/21]
22. Pampel FC, Hardy M. Status Maintenance and Change during Old Age*. *Social Forces* 1994;73(1):289-314. doi: 10.1093/sf/73.1.289
23. George LK. The Life Course Perspective. In: Gu D, Dupre ME, eds. Encyclopedia of Gerontology and Population Aging. Cham: Springer International Publishing 2019:1-9.
24. Andrea E. Willson, Kim M. Shuey, Glen H. Elder J. Cumulative Advantage Processes as Mechanisms of Inequality in Life Course Health. *American Journal of Sociology* 2007;112(6):1886-924. doi: 10.1086/512712
25. Leopold L, Engelhardt H. Education and physical health trajectories in old age. Evidence from the Survey of Health, Ageing and Retirement in Europe (SHARE). *International Journal of Public Health* 2013;58(1):23-31. doi: 10.1007/s00038-012-0399-0
26. Schöllgen I, Huxhold O, Tesch-Römer C. Socioeconomic status and health in the second half of life: findings from the German Ageing Survey. *European Journal of Ageing* 2010;7(1):17-28. doi: 10.1007/s10433-010-0140-x
27. Herd P. Do Functional Health Inequalities Decrease in Old Age?:Educational Status and Functional Decline Among the 1931-1941 Birth Cohort. *Research on Aging* 2006;28(3):375-92. doi: 10.1177/0164027505285845
28. Pavalko EK, Caputo J. Social Inequality and Health Across the Life Course. *American Behavioral Scientist* 2013;57(8):1040-56. doi: 10.1177/0002764213487344
29. Larson K, Russ SA, Kahn RS, et al. Health Disparities: A Life Course Health Development Perspective and Future Research Directions. In: Halfon N, Forrest CB, Lerner RM, et al., eds. Handbook of Life Course Health Development. Cham: Springer International Publishing 2018:499-520.
30. San Sebastian M, Hammarström A, Gustafsson PE. Socioeconomic inequalities in functional somatic symptoms by social and material conditions at four life course periods in Sweden: a decomposition analysis. *BMJ Open* 2015;5(8):e006581. doi: 10.1136/bmjopen-2014-006581

31. Johansson SE, Midlöv P, Sundquist J, et al. Longitudinal trends in good self-rated health: effects of age and birth cohort in a 25-year follow-up study in Sweden. *Int J Public Health* 2015;60(3):363-73. doi: 10.1007/s00038-015-0658-y [published Online First: 2015/02/05]
32. Clause-Verdreau AC, Audureau É, Leplège A, et al. Contrasted trends in health-related quality of life across gender, age categories and work status in France, 1995-2016: repeated population-based cross-sectional surveys using the SF-36. *J Epidemiol Community Health* 2019;73(1):65-72. doi: 10.1136/jech-2018-210941 [published Online First: 2018/10/12]
33. Wolff JK, Nowossadeck S, Spuling SM. Altern nachfolgende Kohorten gesünder? Selbstberichtete Erkrankungen und funktionale Gesundheit im Kohortenvergleich. In: Mahne K, Wolff JK, Simonson J, et al., eds. Altern im Wandel: Zwei Jahrzehnte Deutscher Alterssurvey (DEAS). Wiesbaden: Springer Fachmedien Wiesbaden 2017:125-38.
34. Sperlich S, Tetzlaff J, Geyer S. Trends in good self-rated health in Germany between 1995 and 2014: do age and gender matter? *Int J Public Health* 2019;64(6):921-33. doi: 10.1007/s00038-019-01235-y [published Online First: 2019/03/29]
35. Beller J, Miething A, Regidor E, et al. Trends in grip strength: Age, period, and cohort effects on grip strength in older adults from Germany, Sweden, and Spain. *SSM - Population Health* 2019;9:100456. doi: https://doi.org/10.1016/j.ssmph.2019.100456
36. Duijster D, Oude Groeniger J, van der Heijden GJMG, et al. Material, behavioural, cultural and psychosocial factors in the explanation of socioeconomic inequalities in oral health. *European Journal of Public Health* 2017;28(4):590-97. doi: 10.1093/eurpub/ckx209
37. Khang Y-H, Lynch JW, Yang S, et al. The contribution of material, psychosocial, and behavioral factors in explaining educational and occupational mortality inequalities in a nationally representative sample of South Koreans: Relative and absolute perspectives. *Social Science & Medicine* 2009;68(5):858-66. doi: https://doi.org/10.1016/j.socscimed.2008.12.003
38. van Oort FVA, van Lenthe FJ, Mackenbach JP. Material, psychosocial, and behavioural factors in the explanation of educational inequalities in mortality in the Netherlands. *Journal of Epidemiology and Community Health* 2005;59(3):214-20. doi: 10.1136/jech.2003.016493
39. Moor I, Spallek J, Richter M. Explaining socioeconomic inequalities in self-rated health: a systematic review of the relative contribution of material, psychosocial and behavioural factors. *J Epidemiol Community Health* 2017;71(6):565-75. doi: 10.1136/jech-2016-207589 [published Online First: 2016/09/30]
40. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *J Clin Epidemiol* 2008;61(4):344-9. doi: 10.1016/j.jclinepi.2007.11.008 [published Online First: 2008/03/04]
41. Frick J, Schupp J, Wagner G. The German Socio-Economic Panel Study (SOEP)—Scope, evolution and enhancements. *Schmollers Jahrbuch : Journal of Applied Social Science Studies / Zeitschrift für Wirtschafts- und Sozialwissenschaften* 2007;127:139-69. doi: 10.2139/ssrn.1028709
42. Goebel J, Grabka MM, Liebig S, et al. The German Socio-Economic Panel (SOEP). 2019;239(2):345. doi: https://doi.org/10.1515/jbnst-2018-0022
43. DeSalvo KB, Fan VS, McDonell MB, et al. Predicting mortality and healthcare utilization with a single question. *Health Serv Res* 2005;40(4):1234-46. doi: 10.1111/j.1475-6773.2005.00404.x [published Online First: 2005/07/22]

44. Idler EL, Russell LB, Davis D. Survival, Functional Limitations, and Self-rated Health in the NHANES I Epidemiologic Follow-up Study, 1992. *American Journal of Epidemiology* 2000;152(9):874-83. doi: 10.1093/aje/152.9.874
45. Jylhä M. What is self-rated health and why does it predict mortality? Towards a unified conceptual model. *Soc Sci Med* 2009;69(3):307-16. doi: 10.1016/j.socscimed.2009.05.013 [published Online First: 2009/06/13]
46. Bullinger M, Quitmann J. Quality of life as patient-reported outcomes: principles of assessment. *Dialogues Clin Neurosci* 2014;16(2):137-45. [published Online First: 2014/08/26]
47. Nübling M, Andersen H, Mühlbacher A, et al. Computation of Standard Values for Physical and Mental Health Scale Scores Using the SOEP Version of SF12v2. *Schmollers Jahrbuch : Journal of Applied Social Science Studies / Zeitschrift für Wirtschafts- und Sozialwissenschaften* 2007;127(1):171-82.
48. Liang K-Y, Zeger SL. Longitudinal data analysis using generalized linear models. *Biometrika* 1986;73(1):13-22. doi: 10.1093/biomet/73.1.13
49. Hu FB, Goldberg J, Hedeker D, et al. Comparison of Population-Averaged and Subject-Specific Approaches for Analyzing Repeated Binary Outcomes. *American Journal of Epidemiology* 1998;147(7):694-703. doi: 10.1093/oxfordjournals.aje.a009511
50. Mackenbach JP, Kunst AE. Measuring the magnitude of socio-economic inequalities in health: an overview of available measures illustrated with two examples from Europe. *Soc Sci Med* 1997;44(6):757-71. doi: 10.1016/s0277-9536(96)00073-1 [published Online First: 1997/03/01]
51. Bardel A, Wallander MA, Wallman T, et al. Age and sex related self-reported symptoms in a general population across 30 years: Patterns of reporting and secular trend. *PLoS One* 2019;14(2):e0211532. doi: 10.1371/journal.pone.0211532 [published Online First: 2019/02/05]
52. Asada Y, Hurley J, Grignon M, et al. Health inequalities and inequities by age: Stability for the Health Utilities Index and divergence for the Frailty Index. *SSM - Population Health* 2018;5:17-32. doi: https://doi.org/10.1016/j.ssmph.2018.04.002
53. Granström F, Molarius A, Garvin P, et al. Exploring trends in and determinants of educational inequalities in self-rated health. *Scand J Public Health* 2015;43(7):677-86. doi: 10.1177/1403494815592271 [published Online First: 2015/07/04]
54. Aguilar-Palacio I, Carrera-Lasfuentes P, Sánchez-Recio R, et al. Recession, employment and self-rated health: a study on the gender gap. *Public Health* 2018;154:44-50. doi: 10.1016/j.puhe.2017.10.013 [published Online First: 2017/12/05]
55. Karasek R, Baker D, Marxer F, et al. Job decision latitude, job demands, and cardiovascular disease: a prospective study of Swedish men. *Am J Public Health* 1981;71(7):694-705. doi: 10.2105/ajph.71.7.694 [published Online First: 1981/07/01]
56. Caman OK, Calling S, Midlöv P, et al. Longitudinal age-and cohort trends in body mass index in Sweden--a 24-year follow-up study. *BMC Public Health* 2013;13:893-93. doi: 10.1186/1471-2458-13-893
57. Reither EN, Hauser RM, Yang Y. Do birth cohorts matter? Age-period-cohort analyses of the obesity epidemic in the United States. *Social science & medicine (1982)* 2009;69(10):1439-48. doi: 10.1016/j.socscimed.2009.08.040 [published Online First: 2009/09/19]
58. Diouf I, Charles MA, Ducimetière P, et al. Evolution of obesity prevalence in France: an age-period-cohort analysis. *Epidemiology* 2010;21(3):360-65. doi: 10.1097/EDE.0b013e3181d5bff5
59. Statistisches Jahrbuch 2019. Deutschland und Internationales www.destatis.de/jahrbuch: Statistisches Bundesamt (Destatis); 2019 [accessed 15. May 2019 2019.

60. Blanchard RD, Bunker JB, Wachs M. Distinguishing aging, period and cohort effects in longitudinal studies of elderly populations. *Socio-Economic Planning Sciences* 1977;11(3):137-46. doi: https://doi.org/10.1016/0038-0121(77)90032-5

Table 1: Weighted sample characteristics in % by time period, GSOEP 2002-2016, $n_{observations}$=170,317.

	2002-2006 (n=54,244)	2007-2011 (n=56,299)	2012-2016 (n=59,774)
Sex	%	%	%
Women	54.2	53.7	53.2
Men	45.8	46.3	46.8
Missings (n)	0	0	0
Age groups in years			
50-64	49.2	48.2	50.0
65-79	40.2	40.0	38.7
80+	10.6	11.8	11.3
missing (n)	0	0	0
School education			
primary / no education	58.5	51.3	43.9
secondary	19.5	23.4	26.2
tertiary	14.6	17.0	19.6
other qualification	7.4	8.3	10.3
missing (n)	1689	1262	1212
Income			
<60%	14.5	15.8	15.3
60% - < 150%	67.5	65.9	65.6
≥ 150 %	18.0	18.3	19.1
missing (n)	16	13	31
Living with partner			
yes	67.8	66.7	66.6
no	32.2	33.3	33.4
missing (n)	0	0	1
Nationality			
German	93.6	92.8	92.8
others	6.4	7.2	7.2
missing (n)	0	0	1

GSOEP: German Socio-Economic Panel; n= number of observations (maximum sample size of annually surveys 2002 to 2016), income: equivalized net income.

Table 2: Educational inequalities in HRQOL (MCS / PCS) and poor SRH in men and women, stratified by life stage, GSOEP 2002-2016

		Men							
		MCS			PCS		Poor SRH		
Life stage	**Education**	**n**	**Coef.**	**95% CI**	**Coef.**	**95% CI**	**OR**	**n**	**95% CI**
all ages	low	13902	**-0.85*****	-1.31- -0.40	**-4.07*****	-4.53 - -361	**1.66*****	30102	1.50 - 1.84
	medium	6857	**-0.48**◊	-0 98 - 0.02	**-2.40*****	-2.88 - -1.92	**1.21****	14604	1.08 - 1.37
	high	8578	1		1		1	17640	
Later working life (50-64 yr.)	low	6050	-0.40	-0.99 - 0.19	**-4.59*****	-5.17 - -4.00	**1.90*****	13042	1.65 - 2.17
	medium	4501	-0.42	-1.01 - 0.18	**-2.70*****	-3.26 - -2.15	**1.28****	9590	1.11 - 1.48
	high	5008	1		1		1	10411	
Young seniors (65-79 yr.)	low	6727	**-1.23*****	-1.89 - -0.57	**-3.49*****	-4.19 - -2.79	**1.51*****	14484	1.30 - 1.75
	medium	2031	-0.25	-1.05-0.55	**-1.89*****	-2.76 - -1.03	1.15	4278	0.96 - 1.39
	high	3140	1		1		1	6244	
Old age (80+ yr.)	low	1125	**-2.25***	-4.14 - -0.36	**-2.29****	-4.01 - -0.57	**1.42***	2576	1.05 - 1.11
	medium	325	-1.42	-3.40 - 0.55	-1.31	-3.42 - 0.79	1.20	736	0.83 - 1.74
	high	430	1		1		1	985	
		Women							
		MCS			PCS		Poor SRH		
Life stage	**Education**	**n**	**Coef.**	**95% CI**	**Coef.**	**95% CI**	**OR**	**n**	**95% CI**
all ages	low	16251	**-1.10*****	-1.64 - -0.57	**-3.31*****	-3.84 - -2.77	**1.56*****	35521	1.40-1.75
	medium	9544	-0.21	-0.74 – 0.33	**-1.76*****	-2.29 - -1.22	**1.19****	20149	1.06-1.34
	high	5970	1		1		1	12599	
Later working life (50-64 yr.)	low	6347	-0.50	-1.16 - 0.17	**-3.67*****	-4.32 - -3.02	**1.54*****	13665	1.34 - 1.76
	medium	6494	0.50	-0.57 - 0.67	**-1.91*****	-2.52 - -1.32	1.10	13609	0.96 - 1.26
	high	4103	1		1		1	8561	
Young seniors (65-79 yr.)	low	7880	**-2.64*****	-3.47 - -1.80	**-3.16*****	-4.08 - -2.24	**1.77*****	17176	1.48 - 2.12
	medium	2590	**-1.04***	-1.97 - -0.12	**-1.81****	-2.83 - -0.78	**1.39****	5519	1.14 - 1.70
	high	1615	1		1		1	3422	
Old age (80+ yr.)	low	2024	**-3.87*****	-5.99 - -1.74	-1.02	-3.00 - 0.96	**1.43***	4680	1.04 - 1.08
	medium	460	-1.65	-4.08 - -0.77	1.54	-0.74 - 3.82	1.08	1021	0.76 - 6.21
	high	252	1		1		1	616	

Adjusted for age, nationality, living with partner and equivalized net income; GSOEP: German Socio-Economic Panel; MCS: Mental Component Summary; PCS: Physical Component Summary; SRH: Self-Rated Health; Coef.: Coefficient; CI: Confidence Interval; ◊ p<0.10, *p<0.05, **p<0.01, ***p<0.001.

Table 3: Time trends in HRQOL (MCS / PCS) and poor SRH in men and women, stratified by life stage and level of education, GSOEP 2002-2016

	Men							
	MCS			PCS		Poor SRH		
Time trend	**n**	**Coeff.**	**95% CI**	**Coeff.**	**95% CI**	**n**	**OR**	**95% CI**
Later working life (50 - 64 yr.)								
Education low	6050	0.79	- 0.16 - 1.74	- 0.68	- 1.63 - 0.27	13042	1.06	0.89 - 1.26
medium	4501	0.21	- 0.90 - 1.33	- 0.75	- 1.79 - 0.30	9590	1.12	0.89 - 1.44
high	5008	**1.01***	0.04 - 1.98	- 0.32	- 1.20 - 0.56	10411	1.00	0.77 - 1.30
Young seniors (65 - 79 yr.)								
Education low	6727	**1.82*****	0.80 - 2.85	**1.56****	0.56 - 2.56	14484	**0.69*****	0.57 - 0.83
medium	2031	**1.85***	0.19 - 3.50	0.33	- 1.33 - 2.00	4278	1.16	0.77 - 1.62
high	3140	0.47	- 0.89 - 1.83	0.53	- 0.87 - 1.93	6244	**0.74**◊	0.53 - 1.08
Old age (80+ yr.)								
Education low	1125	0.63	- 2.31 - 3.57	0.05	- 2.42 - 2.53	2576	0.91	0.61 - 1.35
medium	325	-2.63	- 7.05 - 1.80	2.07	- 2.97 - 7.10	736	1.22	0.56 - 2.65
high	430	2.59	- 1.57 - 6.75	0.89	- 2.79 - 4.57	985	0.56	0.26 - 1.21
	Women							
Time trend	**MCS**			**PCS**		**Poor SRH**		
	n	**Coeff.**	**95% CI**	**Coeff.**	**95% CI**	**n**	**OR**	**95% CI**
Later working life (50 - 64 yr.)								
Education low	6347	0.90	- 0.10 - 1.89	**-1.65****	- 2.65 - 0.66	13665	**1.33***	1.12 - 1.59
medium	6494	0.36	- 0.60 - 1.32	- 0.34	- 1.25 - 0.57	13609	1.04	0.84 - 1.28
high	4103	0.78	- 0.39 - 1.95	0.36	- 0.78 - 1.49	8561	0.97	0.75 - 1.27
Young seniors (65 - 79 yr.)								
Education low	7880	**2.75*****	1.74 - 3.76	**1.30****	0.39 - 2.21	17176	**0.73*****	0.62 - 0.89
medium	2590	0.78	- 0.78 - 2.34	- 0.13	- 1.83 - 1.57	5519	0.83	0.61 - 1.13
high	1615	1.44	- 0.58 - 3.45	**1.97**◊	- 0.01 - 3.94	3422	**0.67**◊	0.43 - 1.03
Old age (80+ yr.)								
Education low	2024	0.77	- 1.33 - 2.87	0.61	- 1.01 - 2.22	4680	0.70	0.53 - 0.94
medium	460	0.04	- 4.62 - 4.71	**3.35**◊	- 0.04 - 6.74	1021	0.75	0.41 - 1.36
high	252	1.57	- 2.80 - 5.95	1.59	- 3.97 - 7.15	616	0.88	0.41 - 1.90

Adjusted for age, nationality, living with partner and equivalized net income; MCS: Mental Component Summary; PCS: Physical Component Summary; SRH: Self-Rated Health; n: number of observations; GSOEP: German Socio-Economic Panel; ◊ p<0.10, *p<0.05, **p<0.01, ***p<0.001

Table 4: Trends in relative (RII) and absolute (SII) educational inequalities in HRQOL (MCS / PCS) and poor SRH, stratified by gender and life stage, GSEOP 2002-2016

		n	RII	95% CI	SII	95% CI
Men						
all ages	MCS	35208	1.01	0.98-1.04	0.52	-0.84-1.87
	PCS	35208	1.02	0.99-1.05	0.91	-0.38-2.20
	Poor SRH	69095	0.88	0.69-1.12	-0.03	-0.08-0.03
Later working life (50 - 64 yr.)	MCS	18947	1.00	0.96-1.03	-0.20	-2.04-1.64
	PCS	18947	0.99	0.95-1.03	-0.56	-2.39-1.23
	Poor SRH	37316	1.16	0.80-1.67	0.03	-0.04-0.10
Young Seniors (65-79 yr.)	MCS	13840	**1.05***	1.01-1.10	**2.76***	0.41-5.11
	PCS	13840	**1.05**◊	1.00-1.11	**2.12**◊	-0.27-4.51
	Poor SRH	27028	0.73	0.48-1.13	**-0.10***	-0.19-0.01
Old age (80+yr.)	MCS	2421	1.03	0.91-1.17	1.44	-5.20-5.09
	PCS	2421	0.89	0.77-1.04	-4.71	-10.58-1.16
	Poor SRH	4751	1.08	0.52-2.26	0.06	-0.23-0.34
Women						
		n	RII	95% CI	SII	95% CI
all ages	MCS	38229	**1.03***	1.00-1.06	**1.41**◊	-0.03-2.86
	PCS	38229	0.98	0.95-1.01	-0.59	-1.95-0.76
	Poor SRH	75142	0.99	0.80-1.23	0.01	-0.04-0.06
Later working life (50 - 64 yr.)	MCS	20412	1.00	0.97-1.04	0.27	-1.61-2.15
	PCS	20412	**0.94****	0.90-0.98	**-2.98****	-4.86- -1.11
	Poor SRH	40074	1.29	0.94-1.78	**0.07***	0.00-0.14
Young Seniors (65-79 yr.)	MCS	14371	**1.06***	1.01-1.12	**2.82***	0.16-5.50
	PCS	14371	1.02	0.96-1.09	0.85	-1.82-3.52
	Poor SRH	28179	1.10	0.74-1.63	-0.04	-0.14-0.07
Old age (80+yr.)	MCS	3446	1.03	0.91-1.17	1.19	-5.25-7.63
	PCS	3446	0.97	0.84-1.13	-0.96	-6.63-4.72
	Poor SRH	6889	1.02	0.57-1.22	-0.02	-0.28-0.23

Adjusted for age, nationality, living with partner and equivalised net income; MCS: Mental Component Summary; PCS: Physical Component Summary, SRH: Self-Rated Health; n: number of observations; GSOEP: German Socio-Economic Panel; RII: Relative Index of Inequality, SII: Slope Index of inequality; ◊ p<0.10, *p<0.05, **p<0.01, ***p<0.001

Figure captions

Figure 1: Trends in HRQOL (MCS / PCS) and poor SRH (predicted means and probabilities) by life stages among **men**.

Figure 2: Trends in HRQOL (MCS / PCS) and poor SRH (predicted means and probabilities) by life stages among **women**.

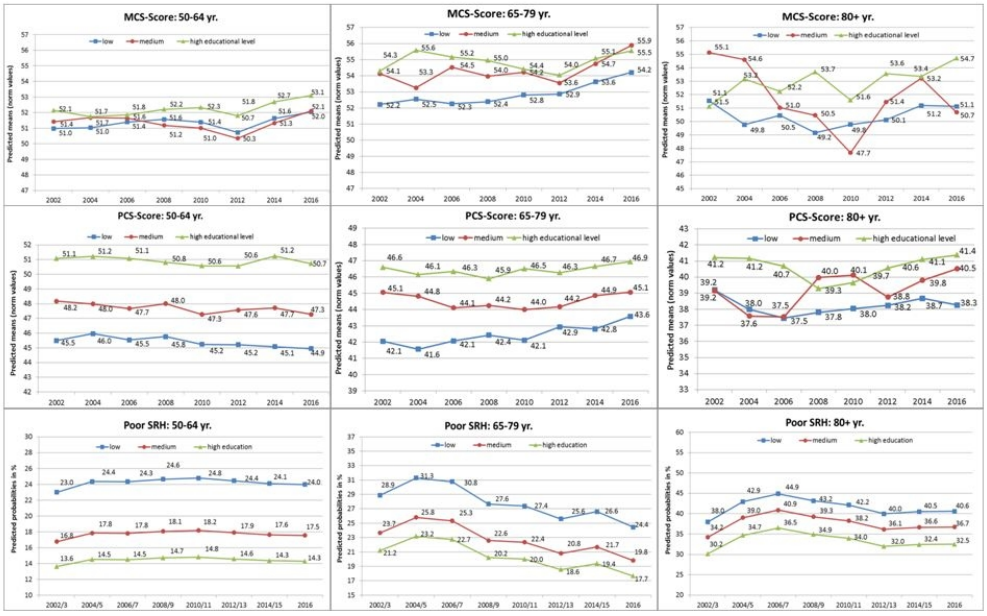

Figure 1: Trends in HRQOL (MCS / PCS) and poor SRH (predicted means and probabilities) by life stages among men.

81x60mm (300 x 300 DPI)

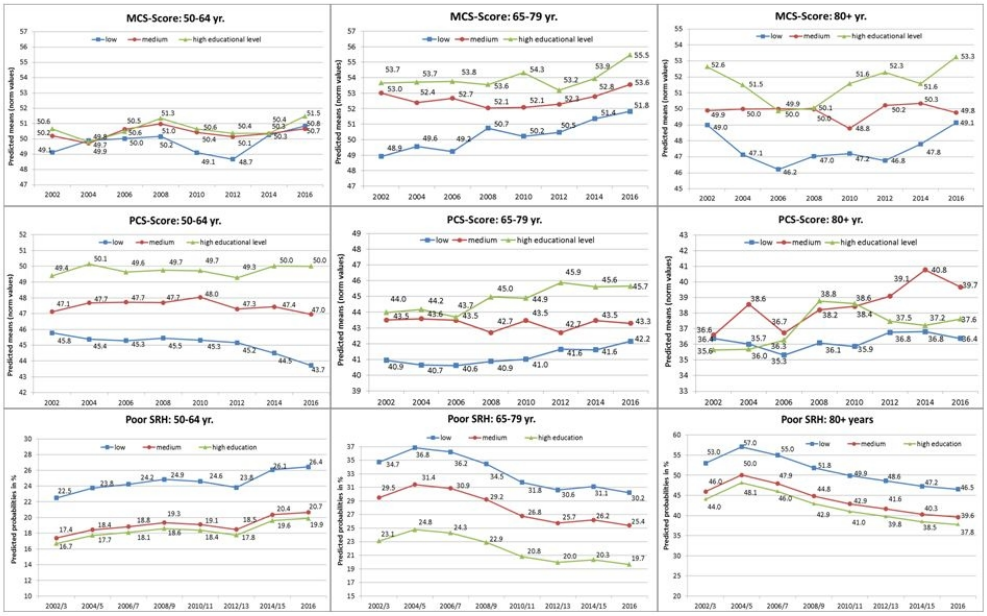

Figure 2: Trends in HRQOL (MCS / PCS) and poor SRH (predicted means and probabilities) by life stages among women.

81x60mm (300 x 300 DPI)

Reporting checklist for cross sectional study.

Based on the STROBE cross sectional guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

Upload your completed checklist as an extra file when you submit to a journal.

In your methods section, say that you used the STROBE cross sectionalreporting guidelines, and cite them as:

von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies.

		Reporting Item	Page Number
Title and abstract			
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	1
Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	#3	State specific objectives, including any prespecified hypotheses	5
Methods			

Study design	#4	Present key elements of study design early in the paper	5
Setting	#5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Eligibility criteria	#6a	Give the eligibility criteria, and the sources and methods of selection of participants.	5
	#7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources / measurement	#8	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. Give information separately for for exposed and unexposed groups if applicable.	6-7
Bias	#9	Describe any efforts to address potential sources of bias	7
Study size	#10	Explain how the study size was arrived at	5
Quantitative variables	#11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	7-8
Statistical methods	#12a	Describe all statistical methods, including those used to control for confounding	7-8
Statistical methods	#12b	Describe any methods used to examine subgroups and interactions	7-8
Statistical methods	#12c	Explain how missing data were addressed	6
Statistical methods	#12d	If applicable, describe analytical methods taking account of sampling strategy	6-7
Statistical methods	#12e	Describe any sensitivity analyses	14

Results			
Participants	#13a	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed. Give information separately for for exposed and unexposed groups if applicable.	"n/a. We did no select participants but used data from the German Socio-Economic Panel Study
Participants	#13b	Give reasons for non-participation at each stage	"n/a, see above"
Participants	#13c	Consider use of a flow diagram	"n/a, see above"
Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable.	8
Descriptive data	#14b	Indicate number of participants with missing data for each variable of interest	Table 1, p.21
Outcome data	#15	Report numbers of outcome events or summary measures. Give information separately for exposed and unexposed groups if applicable.	Figure 1 and 2
Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	p. 7; Tables 2-4; p.14
Main results	#16b	Report category boundaries when continuous variables were categorized	6
Main results	#16c	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	"n/a, see above"
Other analyses	#17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	14
Discussion			

Key results	#18	Summarise key results with reference to study objectives	10
Limitations	#19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	13
Interpretation	#20	Give a cautious overall interpretation considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence.	11-13
Generalisability	#21	Discuss the generalisability (external validity) of the study results	14
Other Information			
Funding	#22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15

Notes:

- 13a: "n/a. We did no select participants but used data from the German Socio-Economic Panel Study
- 13b: "n/a, see above"
- 13c: "n/a, see above"
- 16c: "n/a, see above"
- The STROBE checklist is distributed under the terms of the Creative Commons Attribution License CC-BY. This checklist was completed on 18. June 2020 using https://www.goodreports.org/, a tool made by the EQUATOR Network in collaboration with Penelope.ai