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Sociodemographic and work-related determinants of self-rated health trajectories: a collaborative meta-analysis of cohort studies from Europe and the US

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Self-rated health is a major indicator of an individual's overall health status, but its development during midlife to old age, as well as influence of sociodemographic and work-related factors on it, are poorly understood. We used longitudinal individual-level data to examine trajectories of self-rated health and their determinants in 38,163 participants (median age 50 (range 36–66) years at baseline) of the English Longitudinal Study of Ageing, the Finnish Longitudinal Study on Aging Municipal Employees, and the French GAZ and ELectricité study from Europe and the Health and Retirement Study from the US. A group-based latent trajectory analysis showed that self-rated health was constantly good for over half of the participants, constantly suboptimal for about 11–21%, and it was changing, either improving or declining, for the rest. Pooled evidence suggests that being single (summary odds ratio 1.20, 95% confidence interval 1.07–1.35), medium educational attainment (1.26, 1.16–1.37), medium occupational class (1.22, 1.10–1.34), and exposure to high physical job demands (1.18, 1.08–1.29) were associated with declining self-rated health. Suboptimal self-rated health was more prevalent among those in low occupational class (1.81, 1.56–2.10), and those who experienced high physical job demands (1.52, 1.33–1.74). In these European and US populations, 23–40% of people experienced suboptimal or declining health trajectories. In conclusion, large variation in development of self-rated health from midlife to old age was observed and it was partly determined by sociodemographic and work-related factors.

Keywords Pathways of health, Multicohort study, Social and work-related determinants

Self-rated health (SRH) is an important indicator of an individual's overall health status and an important predictor of health outcomes[1,2]. For instance, poor SRH is a marker of increased morbidity and mortality risk and a correlate of abnormalities in biomarkers[3], irrespective of chronic diseases[2,4]. SRH encompasses a broad range of health dimensions, including physical, mental, and social well-being, as perceived by the individual, thereby comprehensively reflecting the individual's subjective assessment of their health.

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The stress Process Model[5] emphasizes the importance of resources in mitigating the impact of chronic stressors on health outcomes. This model suggests that limited coping resources among low socioeconomic groups may result in increased stress and poorer SRH. Similarly, the Social Determinants of Health Framework[6] highlights the integral role of socio-economic factors in shaping the health outcomes, emphasizing the social gradient as a global phenomenon. For example, individuals with low socioeconomic status are more likely to face adverse work exposures, such as high physical demands, and have fewer resources to buffer the stress associated with these exposures, which eventually leads to suboptimal health outcomes.

Furthermore, the life course approach suggests that cumulative exposure to risks and limited resources across life span influence health outcomes and contribute to variability in health in during later life[7,8]. For example, interrupted career trajectories due to caregiving roles or workplace inequalities may reduce socio-economic resources particularly among women making them more susceptible to poorer health. This perspective integrates the influence of socioeconomic, sociodemographic, and contextual work-related factors over time, acknowledging that the impact of these factors on health trajectories is shaped by socio-cultural and historical context[9]. The socioeconomic environment, therefore, is important in shaping the health over the life course[8,10–12].

Extensive evidence links socioeconomic and sociodemographic disadvantage to worse health outcomes[13–26]. Gender is an integral social characteristic, and previous studies have explored gender differences in SRH[27–32]. While it remains unclear, whether SRH differs between men and women, studies have suggested that the longitudinal patterns of SRH may be more heterogenous among women[31], and there may be little to no gender difference in SRH[27]. Family relationships, such as marital status, may also affect SRH[33,34] although longitudinal evidence remains limited precluding definite conclusions[35]. Additionally, low occupational grade[22,23,36] and low educational attainment[19–21,23,37] have been reported to be associated with poorer SRH. Investigating the role of work-related contextual factors is equally critical as there is evidence on the association of adverse physical1[4,36,38] and psychological[22,36,39] work exposures with suboptimal SRH.

While health generally declines with age, the trajectory of SRH during it exhibits wide variability influenced by sociodemographic factors[14]. However, there is limited longitudinal evidence on the interrelationships between sociodemographic factors and SRH, particularly regarding the changing patterns in SRH over the adult life course. Investigating these relationships using collaborative meta-analysis of cohort studies can offer insights into the mechanisms driving health inequalities from midlife to old age[31]. In this study, we aim to identify SRH trajectories from midlife to old age and examine their structural and work-related determinants. To ensure robust[23,26] and contextually inclusive findings, we used individual-level data from four different longitudinal cohort studies from Europe (Finland, France and the UK) and the US, representative of the Western countries with diverse welfare state regimes.

Methods

Data and study design

We derived the study population from four prospective cohort studies: the English Longitudinal Study on Aging (ELSA), the UK[40], the Finnish Longitudinal study on Aging Municipal Employees (FLAME), Finland[41], the French *GAZ* and *ELectricité cohort study* (GAZEL), France[42] and the Health and Retirement Study (HRS), the US[43]. ELSA constituted of a sample of men and women representative of the population aged 50 years or older. The study commenced in 2002 which involved the collection of socioeconomic and health related data. ELSA was designed and started as a sister study to the HRS study. For FLAME, the participants had been chosen at random from members of all municipal professions in Finland, and the first set of questions were sent in 1981 which explored lifestyle, health, and work-related factors. The GAZEL Cohort Study was launched in January 1989 to facilitate epidemiological research on various diseases and multiple health-related factors among employees of Électricité *de France-Gaz de France* (EDF-GDF), which is the only utility firm in France involved in production, transmission, and distribution of energy. The data are extracted regularly from the files of the personnel and medical departments of EDF-GDF and from the national registers and a postal questionnaire is sent to the participants each year to gather information on sociodemographic, lifestyle related, psychosocial, occupational exposures and health outcomes. HRS is a nationally representative longitudinal survey carried out every 2 years since 1992 which involved the collection of data on socioeconomic status, health, work and retirement as a national resource associated with ageing at both individual and population levels in the US.

In ELSA, SRH was measured 8 times over a 14-year follow-up. The corresponding figures were 5 times in 28-years in FLAME, 26 times in 26-years in GAZEL, and 13 times in 24-years in HRS.

Our study population was restricted to participants who responded to the self-rated health question at least three times: in the first (baseline), second, and at least one of the proceeding surveys. For ELSA and HRS, an additional selection criterion was applied i.e., respondents were restricted to maximum 66 years at baseline (average maximal working age). The detailed selection of study population from each cohort is described in Fig. 1. The final analytical sample did not differ substantially in terms of sociodemographic and lifestyle factors and morbidity, from the eligible sample in any of the included cohorts (Supplement Table T1). Ethical approval was obtained from London Multicentre Research Ethics Committee for ELSA (MREC/01/2/91), ethics committee of the Finnish Institute of Occupational Health for FLAME (42/410/08), France's national ethics committee (*Commission Nationale Informatique et Libertè*/CNIL) for GAZEL and University of Michigan Institutional Review Board for HRS. Informed consent was obtained from all study participants. The study was conducted in accordance with the Declaration of Helsinki and ethical guidelines for research involving human subjects.

Assessment of self-rated health

Self-rated health status was assessed with a five-point scale in FLAME, ELSA and HRS and on an eight-point scale in GAZEL. For the analyses, we used a binary self-rated health variable including categories "good" versus "sub-optimal". Categorization was similar in ELSA and HRS ("good": 1 = excellent, 2 = very good and 3 = good;

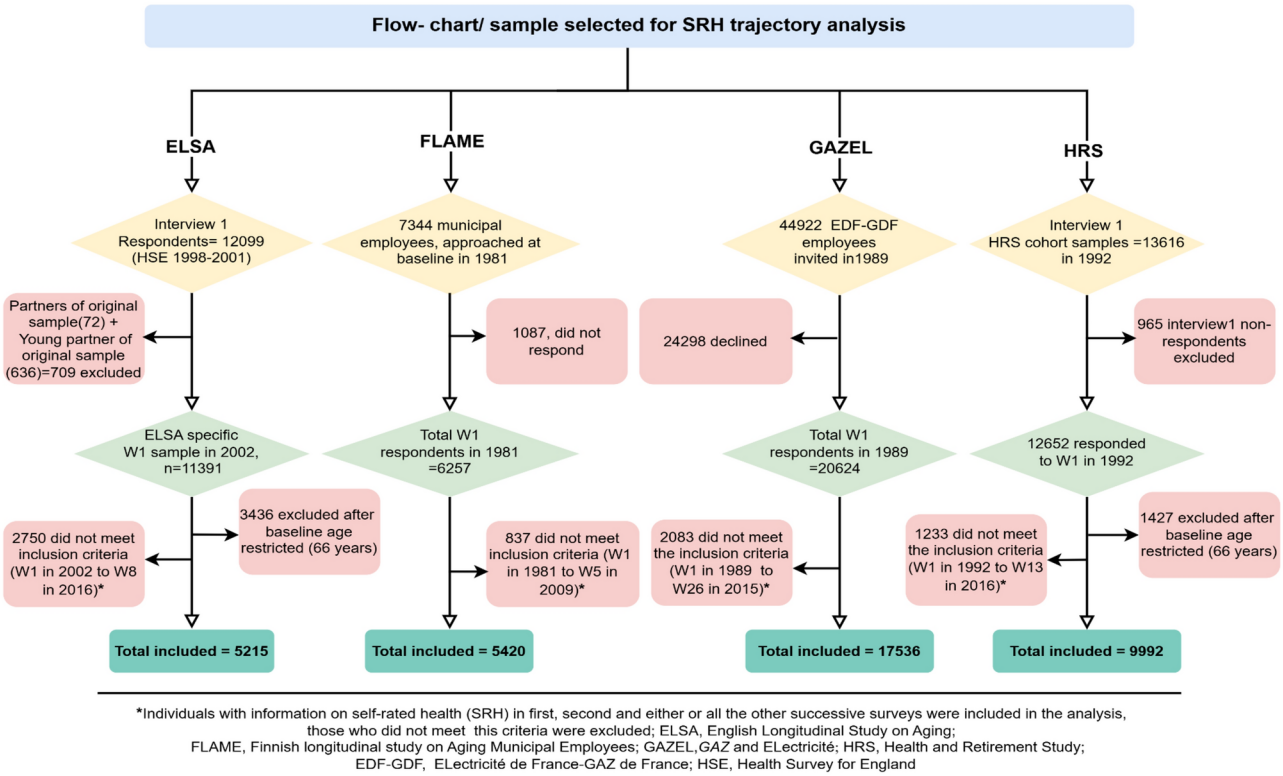

Fig. 1. Flow-chart of selection of study population.

"suboptimal": 4 = fair and 5 = poor), but slightly different in FLAME ("good": 1 = very good and 2 = good; "suboptimal": 3 = average, 4 = poor and 5 = very poor), and GAZEL ("good": 1–4; "suboptimal": 5–8)[36,44].

The decision to use binary SRH instead of scale was for brevity as it is the most common way to treat SRH variable while investigating long-term development of SRH[22,36,37]. Dichotomization of SRH simplifies the ordinal data making it easier and meaningful to interpret as most of the public health policies and interventions are based on thresholds of health such as identifying individuals having "poor health"[45]. Moreover, binary SRH may be helpful in assessing health disparities[46,47] as it has been shown to be a robust indicator of overall health status and health risk[2].

Assessment of socio-demographic factors

Socio-demographic factors were assessed at baseline. Gender was classified as men and women. The measurement of marital status varied between cohort studies, including alternatives such as unmarried, cohabiting, conjugal partnership, civil partnership, married, divorced, non-cohabiting or separated and widowed. For the analysis, marital status was dichotomized into "married" (currently married/ cohabiting/ conjugal partnership/ civil partnership) and "single" (unmarried/ separated/ non-cohabiting/ single/ divorced/ widowed). Occupational title was classified according to the broad skill level defined by International Standard Classification of Occupations (ISCO), including three categories for occupational class: "high" (skill level 3 and 4: e.g., managers, professionals), "medium" (skill level 2: e.g., service and sales workers) and "low" (skill level 1: e.g., elementary occupations)[48]. In ELSA and HRS, educational attainment was based on the number of years in education, which was categorized in to "low" (0–8 years), "medium" (9–12 years) and "high" (≥ 13 years). Educational attainment in FLAME was based on a question on basic education, which was categorized into "low" (no school or elementary school partly), "medium" (elementary school or middle school or high school partly) and "high" (high school graduate or above) educational attainment. The corresponding questionnaire item in GAZEL was categorized into "low" (basic or junior secondary), "medium" (vocational or professional competency certificate) and "high" (academic degree or other diploma) educational attainment.

Assessment of baseline work-related characteristics

In ELSA, psychological job demands were assessed using a single item about feeling of under pressure due to workload. Responses were given on a four-point Likert scale (strongly disagree-strongly agree). In FLAME, psychological job demands were assessed using two items: one addressing the involvement complex decision making in current tasks and the other on decision making under pressure, both with a five-point Likert scale response format (not at all – very often). In GAZEl, psychological job demands were assessed using a single item requesting on mentally tiring work with eight-point rating (low–high). In HRS, a single item about job stress was assessed on a five-point Likert scale (strongly agree-does not apply). For the analysis, responses were dichotomized into "low" and "high" psychological job demands for all four cohorts.

In ELSA, physical job demands were assessed with a single item on the requirements of physical effort in current job (response on a four-point rating from sedentary to heavy manual) and in FLAME, with three items, on similar repeated movements, carrying objects by hand, and sudden strainful efforts in work tasks (responses on a five-point Likert scale ranging from 'not at all' to 'quite a lot'). In GAZEL, the assessment was based on a single item on physically tiring work (an 8-point rating from low to high) and in HRS, based on three statements on physical effort, heavy load and sudden strainful efforts at work (response on a five-point Likert scale from 'almost all the time' to 'does not apply'). For the analysis, responses were dichotomized into "low" and "high" physical job demands in all four cohorts as applied in previous research[41,49]. Dichotomizing simplifies the interpretation by identifying critical thresholds where the health risk escalates[50]. While medium levels of physical job demands may contribute a little additional explanatory power, the upper threshold has significant relevance for understanding health-related outcomes. Additionally, dichotomizing is essential for conducting meta-analysis and large-scale comparisons[51].

Covariates

The decision to select the covariates was partly based on cultural-behavioral and psychosocial theories of health inequalities[10,11] and their significant consideration by earlier studies examining trajectories of SRH[22,36]. For example, health-related behaviors such as smoking, alcohol consumption, low level of physical activity and the possible outcomes associated with poor health-related behaviors such as obesity may be culturally prevalent among those in lower socioeconomic class[10,11], which may have long-lasting consequences for overall health of an individual[10]. Prospective life-course research also supports origin of unhealthy lifestyle behaviors and subsequent poor health is related to socioeconomic disadvantage[16].

Body mass index (BMI) was calculated based on self-reported height and weight and dichotomized into < 30 kg/m^2 and ≥ 30 kg/m^2 for the analysis. Smoking status was categorized into "non-smoker", "former smoker", and "current smoker". Alcohol intake was based on frequency or quantity of alcohol consumption, which was categorized into "abstinent", "medium drinker" and "heavy drinker". Leisure time physical activity (LTPA) was assessed with questions on participants' frequency of sports, light and vigorous intensity exercises, or other physically strenuous leisure-time activity and was categorized into "vigorous", "moderate" and "low". Chronic diseases were self-reported using a list of diagnoses by a physician and were categorized into "no disease", "single disease" and "≥ 2 disease". For the GAZEL cohort, sick leave during two consecutive baseline waves were used as a proxy for chronic disease. A detailed description of the assessments and operationalization of the covariates is presented in electronic supplementary material ESM_2.

Statistical analysis

We used a group-based latent trajectory analysis to study the changes and heterogeneity in SRH during the follow-up, separately for each cohort. The latent trajectory analysis enables the identification of distinct groups of individuals in the data that show a similar development over time[52,53]. We used the PROC TRAJ macro in the statistical software SAS 9.4 (SAS Institute Inc., Cary, NC, USA) to estimate the latent trajectories.

The latent class growth model was based on binary logit function as we used binary SRH as the dependent variable which is commonly used in earlier studies investigating trajectories of SRH[22,36,37]. The follow-up period indicative of the number of surveys was treated as an independent variable in the trajectory model. We fitted an increasing number of SRH trajectory models with linear, quadratic, cubic and curvilinear shapes until no further improvements in model fit was observed. The assessment of model fit was based on Bayesian information criterion values (BIC), Akaike information criterion values (AIC), posterior probabilities, prevalence of latent classes as well as Odds of Correct Classification (OCC). The chosen four trajectory (Stable good, Declining, Improving and Stable suboptimal) solution had comparatively higher posterior probability, and a lower BIC value than other solutions, indicating good class separation in the models, and in all trajectories, OCC values exceeded 5, which is considered good[53]. The detailed model fit statistics for SRH trajectories with 2 to 6 different trajectory solutions are presented in Supplementary Table T2.

After determining the optimal trajectory models in each cohort, the respondents were classified into the derived trajectories and the associations of sociodemographic and work-related characteristics with SRH trajectory were assessed using multinomial regression analysis with odds ratios (OR) and 95% confidence intervals (CIs). We present the results with Stable good trajectory of SRH as the reference group. The initial model included age and gender (Model I), and educational attainment, occupational class, BMI, smoking status, alcohol consumption, LTPA and chronic diseases were added in Model II. The sets of variables included in Model II varied based on the determinants. All cohort specific estimates for the association of sociodemographic and work-related characteristics and trajectories of SRH from Model II were pooled (Summary OR and 95% CI) using random effect meta-analysis in the R-meta package (R version 4.3.2). I^2 statistics with corresponding p-values were reported to quantify between-study heterogeneity. All the tests of statistical significance were two-sided, and the level of significance was set at 0.05.

There was a relatively higher proportion of missing data on psychological or physical job demands in some of the included cohorts (Supplement Table T3) therefore missing data were imputed using multiple imputation method aiming to increase power. The fully conditional specification (imputation by chained equations) was used to impute the missing values for physical and psychological job demands as it does not assume a joint distribution but uses a separate conditional distribution for each imputed variable[54,55]. A set of predictor variables (age, gender, educational status, and occupational status) were used to impute the missing values to avoid unnecessary variation into the imputed values, as both job demands variable were missing at random[56,57]. The algorithm models each missing values for each variable with missing data using observed data from all other variables. The imputation was done for those with information on occupational status at baseline as there was a significant association between occupational class and job demands ($p < 0.001$) across all cohorts (Supplement

Table T4). To reach a good relative efficiency for effect estimates we generated 20 imputed datasets. There was no indication of non-convergence with imputation process converged after 10 iterations and Rubin's rule was used to report the estimates from the pooled results to account for the variability between imputations[58]. Multiple imputation and pooled analysis were done in IBM SPSS Statistics for Windows V 29.0.1.0 (IBM Corp, Armonk, NY). The distribution of analytical sample for job demands across cohorts before and after the imputation are presented in Supplement Table T3.

Results

As shown in Fig. 1, exclusion of those not meeting the selection criterion from the eligible population resulted in an analytical sample of 38,163 participants (5125 from ELSA, 5420 from FLAME, 17,536 from GAZEL, and 9992 from HRS) including 15,698 women and 22,465 men with median age of 50.0 years at baseline (age range: 36–66 years). The mean number of repeated SRH measurements was 12.6 times (SD 9.2), the cohort-specific numbers ranging from 3.7 (SD 1.3) to 19.4 (SD 8.9), depending on the length and number of follow-up points. The basic characteristics of the cohorts are provided in Table 1.

The gender distribution was almost similar in ELSA (54% women), FLAME (57% women) and HRS (52% women), but there was a lower proportion of women in GAZEL (26%). Median age at baseline was nearly similar in ELSA (57 years, inter quartile range 8), FLAME (50, 6) and HRS (56, 6), but the participants of GAZEL (44, 5) were slightly younger. Around one fifth of the total study sample were single or not cohabiting (17%). More than two-thirds of the participants belonged to either high (38%) or the medium (36%) occupational class. Half of the participants had a medium level of educational attainment (50%) and slightly less than one-third had a higher level of educational attainment (29%). Similar proportion (49%) of the total sample were exposed to high psychological and high physical job demands.

Characteristics	Total (N = 38,163)		ELSA (N = 5215)		FLAME (N = 5420)		GAZEL (N = 17,536)		HRS (N = 9992)	
	n	%	n	%	n	%	n	%	n	%
Country			UK		Finland		France		US	
Follow-up, period			2002–2016		1981–2009		1989–2015		1992–2016	
Number of study waves			8		5		26		13	
Follow-up length, year			14		28		26		24	
SRH response rate, mean (SD)[a]	12.6 (9.2)		4.7 (2.7)		3.7 (1.3)		19.4 (8.9)		9.5 (3.7)	
Baseline SRH (suboptimal %)	7194	19	1311	25	1493	28	2231	13	2159	22
Gender										
Women	15,698	41	2820	54	3073	57	4633	26	5172	52
Men	22,465	59	2395	46	2347	43	12,903	74	4820	48
Age, year										
Mean (SD)	50.1 (6.9)		57.7 (4.7)		50.4 (3.6)		44.3 (3.5)		56.3 (3.9)	
Median (IQR)	50(8)		57(8)		50(6)		44(5)		56(6)	
Marital status										
Married	31,322	83	3856	74	4069	75	15,499	90	7898	79
Single	6606	17	1358	26	1345	25	1809	10	2094	21
Occupational class										
High	12,999	38	1717	33	1531	28	7696	28	2055	31
Medium	12,367	36	1783	35	1678	31	6191	31	2715	40
Low	9086	26	1671	32	2211	41	3282	41	1922	29
Educational attainment										
High	10,763	29	1988	40	536	10	4652	27	3587	36
Medium	18,970	50	1168	23	3740	70	8914	52	5148	51
Low	7867	21	1869	37	1100	20	3641	21	1257	13
Psychological job demands										
Low	17,367	51	3304	64	2840	52	8662	51	2561	38
High	17,085	49	1867	36	2580	48	8507	49	4131	62
Physical job demands										
Low	17,423	51	1919	37	1997	37	9933	58	3574	53
High	17,029	49	3252	63	3423	63	7236	42	3118	47

Table 1. Baseline cohort specific sociodemographic and work-related characteristics of the study population. *ELSA* English Longitudinal Study on Aging, *FLAME* Finnish longitudinal study on Aging Municipal Employees, *GAZEL* French *GAZ* and *ELectricité study*, *HRS* Health and Retirement Study, *SD* Standard Deviation, *IQR* Inter quartile range. [a]SRH, Self-rated health response rate in terms of number of survey point.

In all four cohorts studied, four distinct developmental pathways of SRH were identified (Fig. 2A–D). Two of the trajectories represented stable levels (Stable good and Stable suboptimal), while the other two trajectories representing an Improving (Suboptimal to good) and Declining SRH ratings (Good to suboptimal) respectively. The proportion of participants in each trajectory did not substantially vary between cohorts: Stable good (ELSA: 62%, n = 3226; FLAME:54%, n = 2935; GAZEL:61%, n = 10,740; and HRS:52%, n = 5191), Stable suboptimal (20%, n = 1076; 15%, n = 823; 11%, n = 1875; and 21%, n = 2149), Improving (6%, n = 296; 16%, n = 858; 16%, n = 2796; and 8%, n = 782) and Declining (12%, n = 617; 15%, n = 804; 12%, n = 2125; and 19%, n = 2149).

The membership of SRH trajectories by baseline characteristics of the study population are presented in Supplementary Table T5.

Cohort specific estimates of the association (Model I) of sociodemographic and work-related characteristics with Declining, Stable Suboptimal, and Improving trajectories of SRH, compared to the Stable good trajectory, are presented in Fig. 3.

Both genders showed a little to no difference in likelihood of Declining, Stable suboptimal, or Improving SRH compared to Stable good SRH across most cohorts. However, being single was significantly associated with higher odds of having Declining, Stable suboptimal, and Improving SRH compared to good SRH. Individuals in lower occupational class were more likely than those in higher occupational class to experience Declining, Stable Suboptimal, and Improving SRH. The patterns were similar for educational attainment. However, the results were mixed for work-related characteristics. For instance, individual exposed to high psychological job demands had a lower likelihood of having Stable suboptimal SRH compared to Stable good SRH in the FLAME and ELSA cohorts, while the opposite was true in the GAZEL cohort. For physical job demands, those with high exposure were more likely to have Declining, Stable suboptimal, and Improving SRH compared to Stable good SRH across all four cohorts. (Fig. 3).

The pooled estimates from Model II suggest that the likelihood of having Declining SRH (vs. Stable good SRH) tend to be higher among men, but the estimates were imprecisely estimated, showed significant between study heterogeneity (e.g. an opposite finding was observed in the GAZEL with underrepresentation of women) (Summary OR 1.05, 95% CI 0.88–1.26, I2 = 84%, $p < 0.01$) (Fig. 4). Being single (1.20, 1.07–1.35, $I^2 = 25\%$, $p = 0.26$), having medium educational attainment (1.26, 1.16–1.37, $I^2 = 0\%$, $p = 0.89$), medium occupational class (1.50, 1.28–1.75, $I^2 = 0\%$), $p = 0.73$), and being exposed to high physical job demands (1.18, 1.08–1.29, $I^2 = 0\%$, $p = 0.46$) were associated with a higher likelihood of having Declining SRH, with little heterogeneity between studies. Likewise, low educational attainment (1.98, 1.36–2.87, $I^2 = 94\%$, $p < 0.01$), low occupational class (1.49, 1.26–1.76, $I^2 = 57\%$), $p = 0.07$), and high psychological job demands (1.17, 1.02–1.34, $I^2 = 76\%$, $p < 0.01$) were associated with a higher likelihood of having Declining SRH, but there was high heterogeneity in effect sizes between studies.

The pooled estimates for Stable suboptimal (vs. Stable good) SRH are presented in Fig. 5. Having low occupational class (1.81, 1.56–2.10, $I^2 = 34\%$, $p = 0.21$) and experiencing high physical job demands (1.35, 1.03–

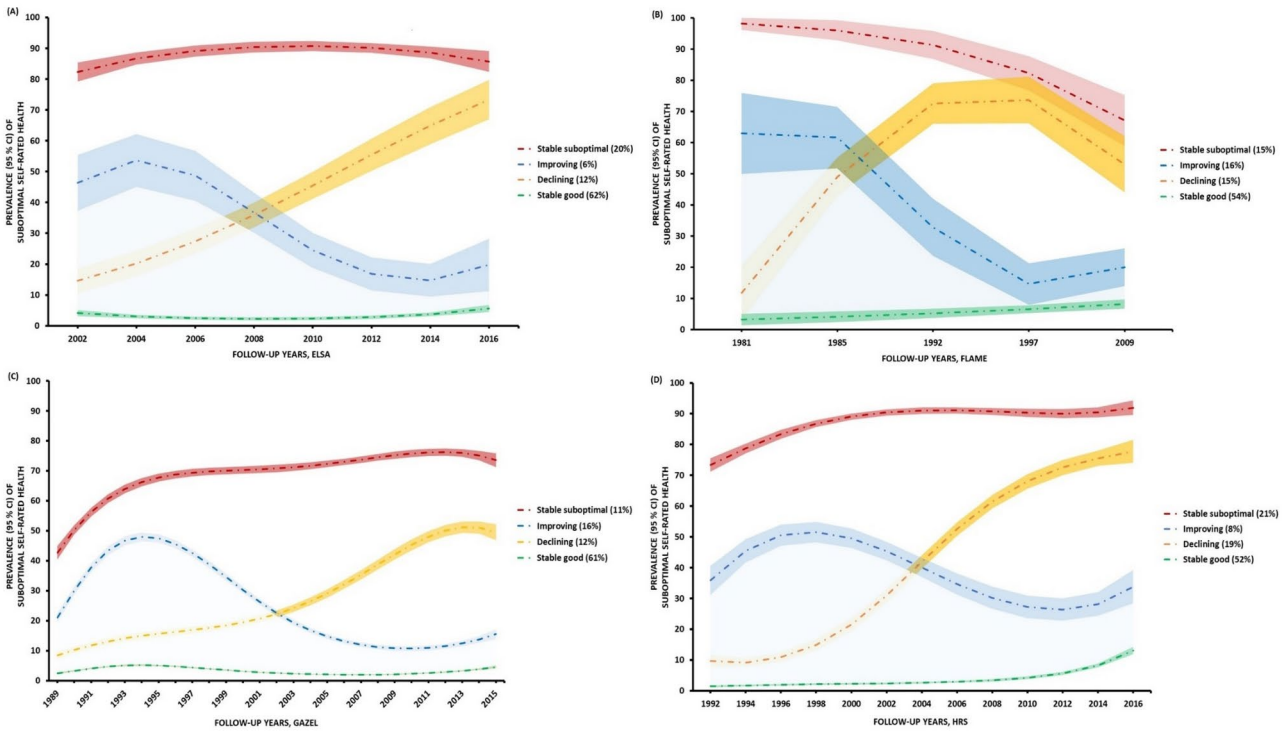

Fig. 2. (**A**–**D**) Trajectories of self-rated health (SRH) among four different cohorts; *ELSA* English Longitudinal Study on Aging, *FLAME* Finnish longitudinal study on Aging Municipal Employees, *GAZEL* French *GAZ* and *ELectricité study*, *HRS* Health and Retirement Study, *CI* Confidence Interval.

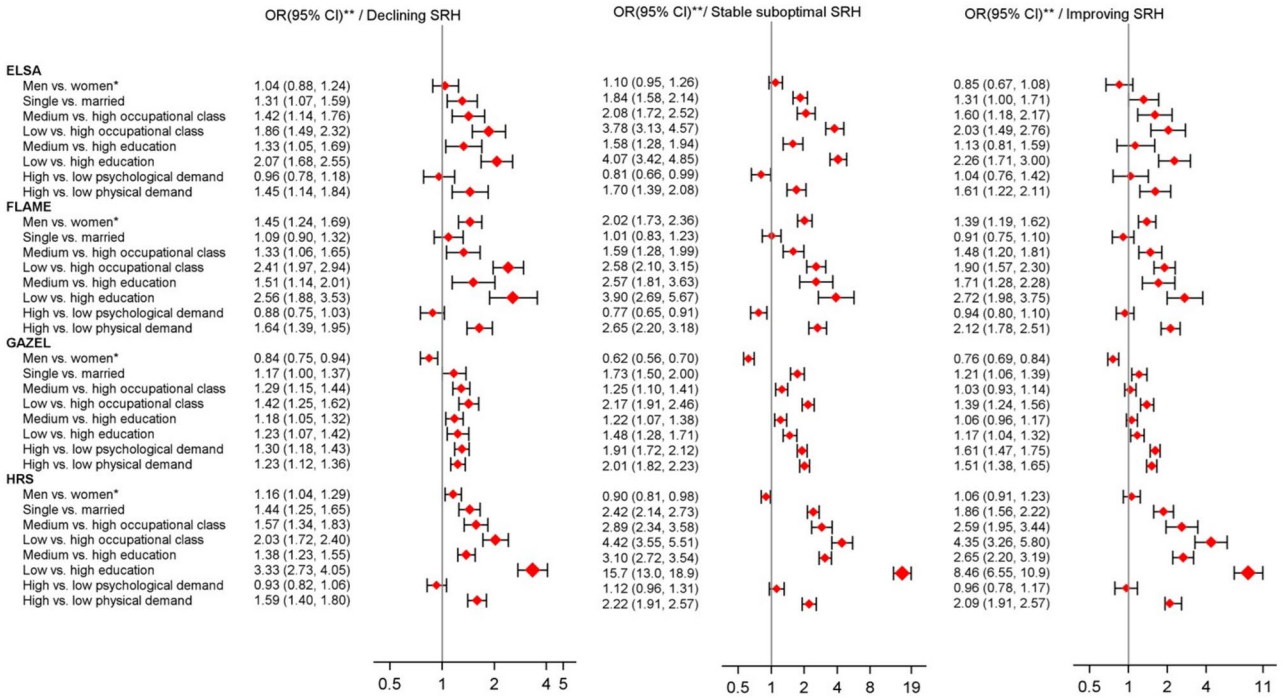

Fig. 3. Association of sociodemographic and work-related characteristics with trajectories of self-rated health (Model I: *model includes age; **model includes age and gender). *ELSA* English Longitudinal Study on Aging, *FLAME* Finnish longitudinal study on Aging Municipal Employees, *GAZEL* French *GAZ* and *ELectricité study*, *HRS* Health and Retirement Study, *OR* Odds Ratio, *CI* Confidence Interval, *SRH* Self-rated health.

1.78, $I^2 = 12\%$, $p = 0.33$) were associated with a higher likelihood of having Stable suboptimal SRH. Being single (1.51, 1.10–2.08), having medium (1.65, 1.06–2.58) or low educational attainment (3.50, 1.26–9.74), and medium occupational class (1.36, 1.10–1.67) were also associated with a higher likelihood of having Stable suboptimal SRH. However, there was high between-study heterogeneity in these estimates ($I^2 \geq 78\%$, $p < 0.01$). We were also interested in examining the contrast between Stable suboptimal and Improving trajectory of SRH. Therefore, we have presented the pooled estimates for Stable suboptimal (vs. Improving) SRH in Supplementary Figure S1. Being single and having low educational attainment were associated with a higher likelihood of having Stable suboptimal SRH compared to Improving SRH.

As shown in Fig. 6**,** low educational attainment (2.41, 1.01–5.73, $I^2 = 98\%$, $p < 0.01$), low occupational class (1.51, 1.12–2.05, $I^2 = 79\%$, $p < 0.01$) and high psychological job demands (1.29, 1.06–1.57, $I^2 = 85\%$, p < 0.01) were associated with having Improving (vs. Stable good) SRH, the between-cohort heterogeneity in effect estimates being substantial. In contrast, experiencing high physical job demands (1.46, 1.30–1.65, $I^2 = 20\%$, $p = 0.29$) was associated with a higher likelihood of having Improving SRH with little between-cohort heterogeneity.

The magnitude of the estimates was attenuated in Model II, but the direction of the associations did not change in all cohort specific results. For cohort specific estimates (Model II) of Declining, Stable suboptimal, and Improving trajectory of SRH compared to Stable good, see *Supplementary Figure S2*. The results (Model I and II) for Declining (vs. Improving) and Stable suboptimal (vs. Improving) SRH trajectory are presented in *Supplementary Figures S3-S4,* respectively**.**

Discussion

To our knowledge, this is one of the few prospective multicohort studies examining the development of self-rated health across midlife and old age and how sociodemographic and work-related factors associate with these trajectories. We identified four distinct developmental pathways of SRH using individual participant data from more than 38,163 participants and showed that they were dependent on marital status, occupational status, educational attainment, and physical job demands.

Our findings on the development of SRH in adulthood partly align with previous studies that have investigated trajectories of SRH. In a study of Dutch community dwelling older adults, Feenstra and colleagues identified four stable trajectories of SRH[19] but no Declining and Improving developments. The difference in the developmental trajectories could be partly explained by the length of follow-up, which was five years in their study by Feenstra and colleagues, compared to a minimum of 16 years in the cohorts included in the present multicohort study. Letelier and Colleagues, using a Mexican cohort of older adults, found four SRH trajectories among men but eight different trajectories among women[31]. A comparative study on SRH trajectories in the US and UK by Sacker and colleagues showed relatively stable good and poor health trajectories, combined with more decline in health than improvement. These developmental pathways are broadly consistent with those in our analyses[59]. Stenholm

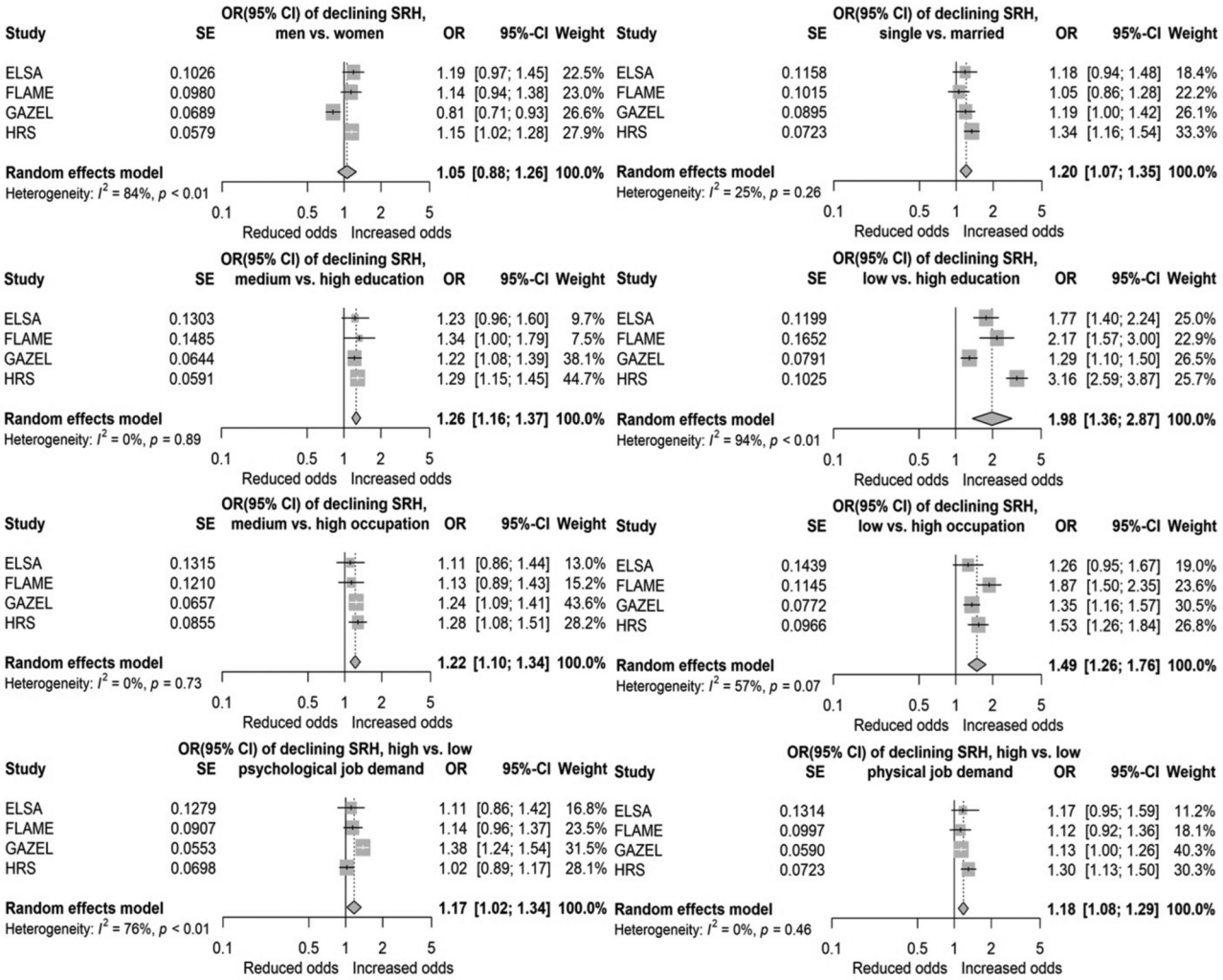

Fig. 4. Pooled estimates for association of sociodemographic and work-related characteristics with Declining (vs. Stable good) trajectory of self-rated health (based on Model II: *men vs. women* includes age, educational attainment, behavioral and health-related factors (body mass index, smoking status, alcohol consumption, leisure time physical activity, and chronic disease); *single vs. married* & *occupation* includes age, gender, educational attainment, behavioral and health-related factors; *education* includes age, gender, and behavioral and health-related factors; *job demands* include age, gender, educational attainment, occupational status, behavioral and health-related factors). *ELSA* English Longitudinal Study on Aging, *FLAME* Finnish longitudinal study on Aging Municipal Employees, *GAZEL* French *GAZ* and *ELectricité study*, *HRS* Health and Retirement Study, *OR* Odds Ratio, *CI* Confidence Interval, *SRH* Self-rated health.

and colleagues, using two cohorts of Finnish public sector employees, found that the majority maintained their SRH before and after retirement and only a minority had Declining or Improving pathways[36]. We found similar results using the FLAME cohort, which also includes Finnish public sector employees. Additionally, Sargent-Cox and colleagues reported that SRH tends to decline across the adult life course, but positive health behaviors may protect health from declining[32]. In our study, we observed an overall improvement in SRH for a subgroup of participants across all four cohorts, although in GAZEL and HRS cohort this pattern included an initial decline in the first few years, followed by a gradual improvement. Since retirement can improve SRH[60,61] and reduce the prevalence of suboptimal SRH[22], the gradual improvement observed may be partly attributed to the positive effects of retirement.

We found no systematic gender differences in SRH trajectories. This finding is in agreement with some (27, 29), but not all previous studies[30,31]. We also observed a higher likelihood of Declining trajectories for men than for women in some cohorts, but this gender difference was masked in synthesized evidence. It is still possible that sex difference plays a role in SRH, although the trajectories of SRH do not differ significantly based on gender[27,29]. One possible explanation is women may report poorer health due to their tendency to express symptoms or seek medical advice whereas due to social expectation of stoicism men may under report poorer health[27]. We found a higher prevalence of declining SRH among unmarried/single individuals compared to married individuals, independent of other background characteristics, confirming findings from previous

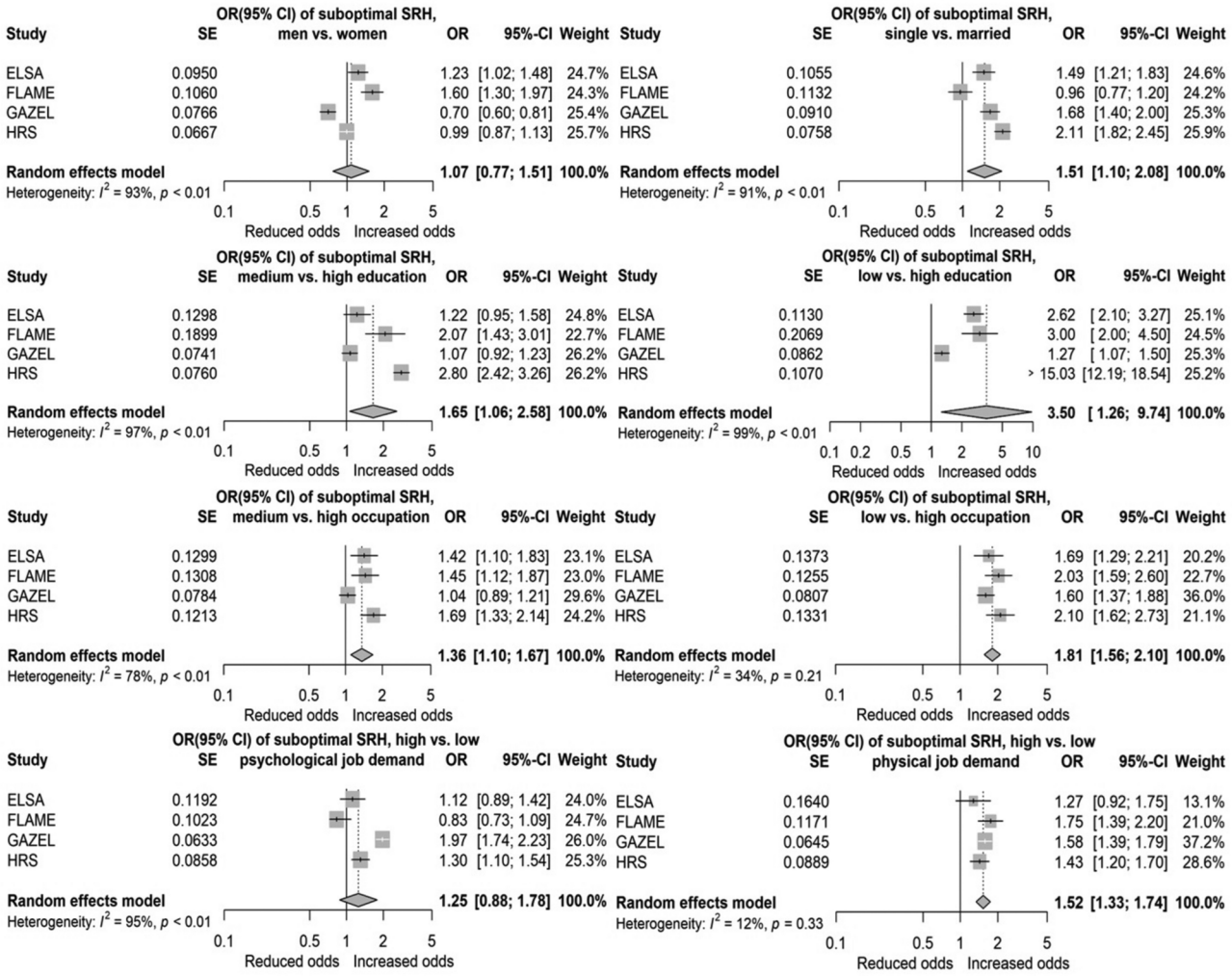

Fig. 5. Pooled estimates for association of sociodemographic and work-related characteristics with Stable suboptimal (vs. Stable good) trajectory of self-rated health (based on Model II: *men vs. women* includes age, educational attainment, behavioral and health-related factors (body mass index, smoking status, alcohol consumption, leisure time physical activity, and chronic disease); *single vs. married* & *occupation* includes age, gender, educational attainment, behavioral and health-related factors; *education* includes age, gender, and behavioral and health-related factors; *job demands* include age, gender, educational attainment, occupational status, behavioral and health-related factors). *ELSA* English Longitudinal Study on Aging, *FLAME* Finnish longitudinal study on Aging Municipal Employees, *GAZEL* French *GAZ* and *ELectricité study*, *HRS* Health and Retirement Study, *OR* Odds Ratio, *CI* Confidence Interval, *SRH* Self-rated health.

studies that reported a decline in health for those no longer in a cohabiting relationship[34] and a significant role of marital status in long term SRH[35]. These relationships can partly be attributed to social causation in which marriage has protective health effects that are not present for those who are unmarried.

Our study has successfully established an association between socioeconomic characteristics and trajectories of SRH using pooled estimates from three different cohorts from Europe and one from the US. These results support previous evidence from single-cohort and multiple-cohort analyses[31,34,36]. Sacker and colleagues, utilizing multiple datasets from Europe and the USA presented different profile of long-term health and reported that the socioeconomically disadvantaged mostly experience poorer SRH trajectories compared to other groups[34]. In prospective follow up study of Mexican workers, Letelier and colleagues reported that adverse socioeconomic circumstances, such as low education and occupation, predicted the suboptimal developmental pathways of SRH[31]. Similarly, Stenholm and colleagues, using two different cohorts of Finnish public sector employees reported that the prevalence of suboptimal SRH was higher among those with low occupational status, which remained highly prevalent even after retirement[36]. This agrees with our study in which the association persisted even after adjusting for both physical and psychological job demands[36]. Moreover, our findings confirm those of previous longitudinal studies suggesting associations of low educational attainment[14,19,21] and low occupational class[22,23] with poor SRH, although most of these studies did not examine the long-term change in SRH. According to socioeconomic inequalities perspective, individuals with lower socioeconomic status, such as low education

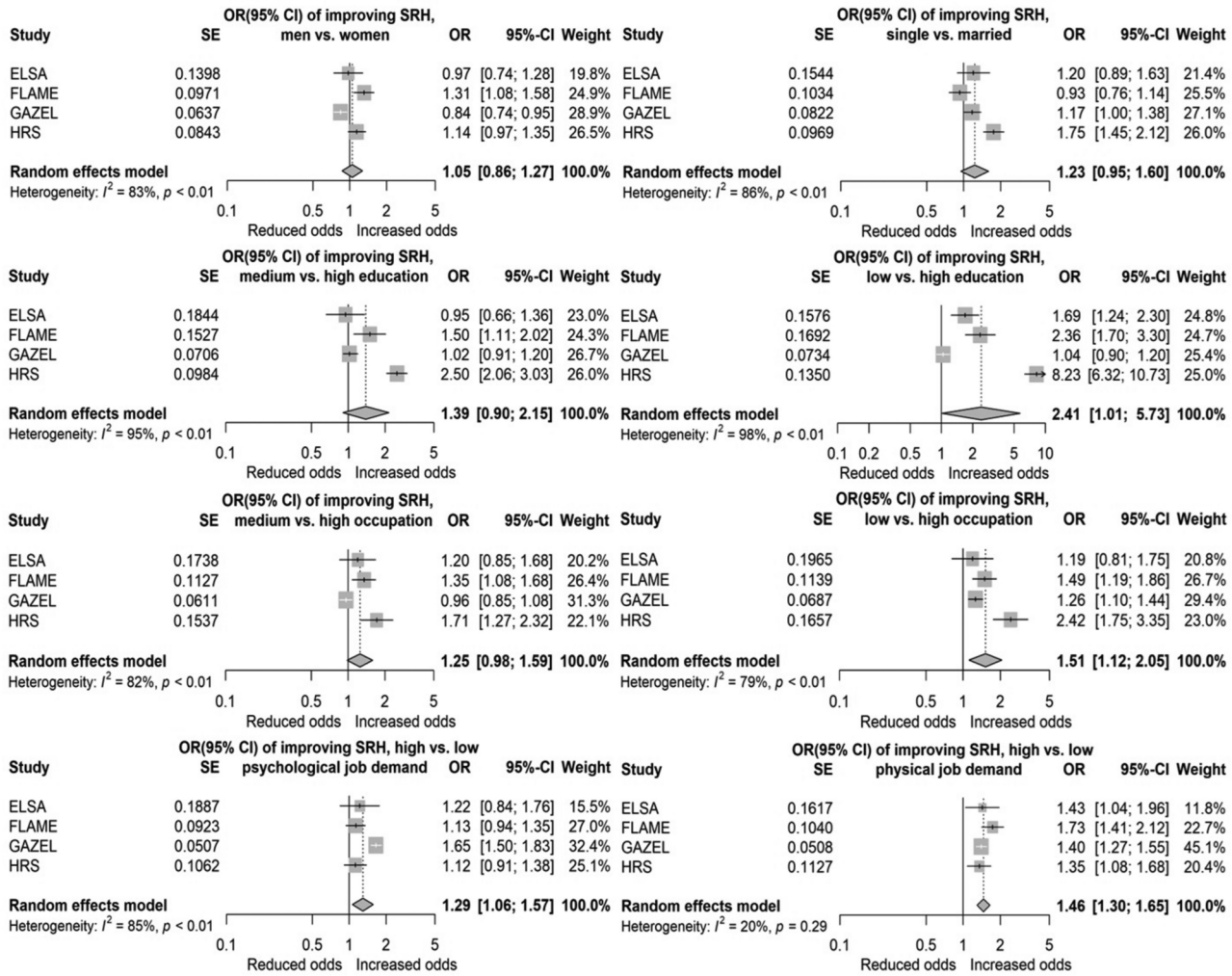

Fig. 6. Pooled estimates for association of sociodemographic and work-related characteristics with Improving (vs. Stable good) trajectory of self-rated health (based on Model II: *men vs. women* includes age, educational attainment, behavioral and health-related factors (body mass index, smoking status, alcohol consumption, leisure time physical activity, and chronic disease); *single vs. married* & *occupation* includes age, gender, educational attainment, behavioral and health-related factors; *education* includes age, gender, and behavioral and health-related factors; *job demands* include age, gender, educational attainment, occupational status, behavioral and health-related factors). *ELSA* English Longitudinal Study on Aging, *FLAME* Finnish longitudinal study on Aging Municipal Employees, *GAZEL* French *GAZ* and *ELectricité study*, *HRS* Health and Retirement Study, *OR* Odds Ratio, *CI* Confidence Interval, *SRH* Self-rated health.

and lower occupational grades, tend to rate their health worse than their counterparts with high socioeconomic status[18] and this socio-economic gradient may persist to old age[6,14,17].

The importance of relationship of work-related characteristics and SRH has been highlighted in a previous systematic review and meta-analysis[23,26], and we have further explored this relationship using long-term changes in SRH. Consistent with results from previous longitudinal studies[22,36,39,44], we found physical job demands as a strong predictor of developmental pathways of SRH. Individuals exposed to high physical demands had a higher likelihood of belonging to both Stable suboptimal and Declining SRH compared to Stable good SRH. The exposure to physical demands at work was reported to be associated with deterioration in SRH[62], and we replicated these findings using a more sophisticated approach by incorporating multiple cohorts from Europe and the US. The decline in SRH before and after retirement was reported to be more likely among individuals with physically strenuous work than those in less physically strenuous work[36] and suboptimal health while at work and after leaving the labor market was found strongly associated with high physical work demands during midlife[22] in the previous studies. We found increased odds of belonging to Stable suboptimal and Declining SRH for those exposed to high psychological demands at work than among those with low level of exposure, but there was substantial heterogeneity between-studies. These results for cohort-specific estimates are in line with the findings of previous studies[22,36,62].

Moreover, stress, mostly related to work in the form of physical or psychological demands, has already been acknowledged by some clinical guidelines as being related to the incidence of chronic diseases, such as cardiovascular disease. In individuals with pre-existing high atherosclerotic plaque burden, exposure to adulthood stress may trigger a cardiovascular event[63] associated with increased risk of metabolic disorders[64] and the same could be true for its relationship with SRH. Another possible explanation behind these associations is the higher level of exposure to work-related physical and psychological demands, which are often stressful and may lead to increase in allostatic load. Higher allostatic load may then lead to reduced SRH and physical health[65]. In a previous study, different lifestyle factors, such as alcohol intake, smoking and LTPA were reported as critical determinant of SRH with abstainers, nonsmokers, and those with improved LTPA levels being less likely to belong to declining SRH[32]. We used these covariates in our study, and the adjustment partly explained the relationship of sociodemographic and work-related factors with trajectories of SRH in every cohort specific result in our study. The role of social gradient in health inequality has been emphasized by various theories. The cultural-behavioral theory suggests that differences in health-related behaviors among socioeconomic classes may lead to health inequalities in adulthood. In contrast, the psychosocial theory emphasize that health status may be influenced by chronic stress responses resulting from the psychological impact of social inequality[10,11]. Additionally, the life course theory has underlined several mechanisms behind health inequalities, such as accumulation of positive and negative experiences over time[8]. Nonetheless, the integrated life-course perspective to work and health suggests that studying individuals from distinct socio-cultural, socioeconomic, and historical context may better capture these integrated concepts[9]. It is equally important to note that these theories may provide narrow insight in health inequalities if considered separately, but a combination of these theories could comprehensively explain the health inequalities across different welfare-state regimes[12]. The pooled evidence presented in this study has partly reflected a summarized representation of inequalities in health in different welfare regime based on different socio-cultural and historical contexts.

The strength of this study lies in its use of repeated measurements over a long follow-up period and the inclusion of four independent yet comparable cohorts from Europe and the US, providing a robust empirical platform to examine long-term changes in SRH. The use of binary self-ratings of health enables population level trajectory comparisons across different study populations and has been commonly used in previous research[36]. This study employes latent trajectory analysis to identify homogenous subgroups within the study population based on different health profiles[36,66]. By pooling individual level data from multiple cohort studies, our study reduces the risk of chance findings when examining the association of sociodemographic and work-related factors with developmental pathways of SRH from midlife to later life.

One potential limitation of this study is self-assessment of work demands, which may be susceptible to reporting and misclassification biases, potentially affecting the associations with self-rated health. Similarly, the assessment of psychological job demands relied on a limited number of items, which may not capture the full spectrum of psychosocial exposures at work. The between-cohort-heterogeneity in effect sizes for job demands may also be explained by the differences in how job demands were assessed across the cohorts included in our study. There was no substantial difference in overall and analytical samples for most of the cohorts with a few exceptions with difference in marital status, educational attainment and morbidity for ELSA that may indicate a possibility of health-related selection bias. However, there was no little to no difference in prevalence of suboptimal SRH at baseline between ELSA and other cohorts, which was the major selection criteria used in this study. From a life course perspective, there is a need for more knowledge on the duration, timing, intensity, and detailed history of exposures, particularly in studies involving working life and health research[9]. We were also interested in studying the association of changes in work exposures and changes in demographic characteristics, such as marital status, with development of SRH. Unfortunately, we lacked sufficient information on these changes for most of the included cohorts.

The observed results are most likely to be generalizable to high income countries, but not necessarily to middle- and low-income countries. Furthermore, some results should be cautiously interpreted as there was high between-study heterogeneity in the estimates. The heterogeneity observed in the cohort-specific estimates likely result from the differences in the included cohort studies in terms of background characteristics, period of study, length of follow up, and the nature of the included cohorts. The gender distribution was nearly similar in all the other cohorts except for GAZEL, which is a male dominant cohort. Likewise, there was significant heterogeneity in baseline age. An additional issue related to heterogeneity was the nature of the study population in the included cohorts. ELSA and HRS was conducted among general population with an objective to study health and retirement[40,43] whereas FLAME and GAZEL are occupational cohorts initiated to study the effect of work exposures on health[41,42]. However, all these studies were motivated with a common goal of active and healthy ageing and there are lots of similarities in survey instruments. Furthermore, we examined the development of SRH separately for each of the included cohorts and obtained the cohort specific estimates for predictors of membership of trajectories of SRH, which were then used in the meta-analysis to get the pooled estimates, which made the comparison more feasible. The two-step process also reduces the bias due to variation in cohort. We recommend further research on the topic using the alternative sources of data such as the Survey of Health, Ageing and Retirement in Europe (SHARE) as it may be useful to capture more heterogeneous institutional and societal contexts.

Our finding suggests that the policies and strategies to reduce health inequalities should address both absolute health differences and the specific needs of those with socioeconomic disadvantage, as well as the explicit needs of the labor force[12]. Additionally, it is crucial to recognize that health strategies evolve over time, exerting various impacts on individuals at different stages of the working life course[9].

In these European and US populations, 23–39% experienced suboptimal or declining health trajectories, which were linked to socioeconomic disadvantage and, to a lesser extent, unfavourable working conditions. Our findings on linkage of SRH trajectories with socioeconomic disadvantage and unfavourable working conditions

may have implications for policy, suggesting that reducing socioeconomic differences and improving working conditions may contribute to extending working life via improved health perceptions[22,67]. The self-rated health of individuals may be influenced by welfare policies, as social circumstances play a predictive role, and these circumstances are connected to country-specific policies[12]. For example, Social Democratic, conservative/ corporatist, and liberal welfare states may reflect their own ideals regarding the role of family, market and state in securing social welfare[68]. The social democratic welfare states (for example Finland) aim at reducing social stratification and state play major role in achieving equality through ensuring broad access to benefits. The welfare benefits are mostly aimed at the disadvantaged with a minimal state intervention in liberal welfare states (for example the UK and the US). The provision of benefits is often linked to social status and work history in conservative/ corporatist welfare states (for example France)[68].

Data availability

ELSA (https://www.elsa-project.ac.uk/) and HRS (https://hrs.isr.umich.edu/) are publicly available for research. FLAME and GAZEL data are not publicly available due to legislative and ethical restrictions but can be obtained upon reasonable request for research (to *subas.neupane@tuni.fi* for FLAME, and *marcel.goldberg@inserm.fr* for GAZEL). All authors had full access to all the data in the study and had final responsibility for the decision to submit for publication.

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Author contributions

PKC and SN contributed to the conception and design of the study. SN obtained project funding and contributed to the acquisition of data. PKC conducted the analysis, interpreted the results, and drafted the manuscript. Critical revision of the manuscript for important intellectual content: CHN, JK, KT, LN, MG, MK, PLA, SK, SN, and SS. Agreed to be accountable for all aspects of work and given final approval of the submission: CHN, JK, KT, LN, MG, MK, PLA, SK, SN, and SS.

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Declarations

Competing interests
The authors declare no competing interests.

Ethics approval
Ethical approval was obtained from London Multicentre Research Ethics Committee for ELSA, ethics committee of the Finnish Institute of Occupational Health for FLAME, France's national ethics committee (*Commission Nationale Informatique et Liberté*/CNIL) for GAZEL and University of Michigan Institutional Review Board for HRS.

Consent to participate
Informed consent was obtained from all individual participants included in ELSA, FLAME, GAZEL, and HRS.

Additional information
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