Effects of Changes in Living Environment on Physical Health

Aretz, Benjamin; Doblhammer, G.; Janssen, Fanny

The German Socio-Economic Panel study

997
2018

SOEPpapers
on Multidisciplinary Panel Data Research

SOEP — The German Socio-Economic Panel study at DIW Berlin 997-2018

Effects of Changes in Living Environment on Physical Health: A Prospective Cohort Study of Movers and Non-Movers in Germany

Benjamin Aretz, Gabriele Doblhammer, Fanny Janssen

DIW SOEP

ISSN: 1864-6689 (online)

German Socio-Economic Panel (SOEP)
DIW Berlin
Mohrenstrasse 58
10117 Berlin, Germany

Contact: soeppapers@diw.de

Effects of Changes in Living Environment on Physical Health: A Prospective Cohort Study of Movers and Non-Movers in Germany

Benjamin Aretz[*a], Gabriele Doblhammer[a,b,c], Fanny Janssen[d,e]

a Faculty of Economics and Social Sciences, University of Rostock

b German Center for Neurodegenerative Diseases

c Rostock Center for the Study of Demographic Change

d Faculty of Spatial Sciences, University of Groningen

e Netherlands Interdisciplinary Demographic Institute

[*] Corresponding author. Chair for Empirical Social Research and Demography, Institute for Sociology and Demography, University of Rostock, Ulmenstrasse 69, DE-18057 Rostock, Germany. E-mail: benjamin.aretz@uni-rostock.de, Tel.: +49 381 498 4060, Fax: +49 381 498 4395.

Abstract

Longitudinal studies on associations between changes in living environment and health are few and focus on movers. Next to causal effects, differences in health between living environments can, however, result due to residential mobility. The present study explored changes in living environment related to (changes in) physical health among movers and non-movers. Causality was reinforced by a novel study design. We obtained longitudinal data on both living environment and physical health covering 4,373 participants with 12,403 health observations aged 50+ from the Socio-Economic Panel (SOEP) between 1999 and 2014. Changing and stable perceived living environmental characteristics from four domains (infrastructure, environmental pollution, housing conditions, contacts to neighbours) were included at household level. Gender-specific linear regressions and generalised estimating equations were performed to predict the Physical Component Summary (PCS) at baseline and changes in PCS over time. We found that worsening of environmental pollution (men: -2.32, p = 0.001; women: -1.68, p = 0.013) and housing conditions were associated with lower PCS at baseline. Improved infrastructure was related to lower women's PCS at baseline (-1.94; p = 0.004) but a positive PCS development (0.62, p = 0.095) thereafter among female and especially among female non-movers (0.812, p = 0.042). Men who experienced stable worst (-0.57, p = 0.021) or worsened environmental pollution (-0.81, p = 0.036) indicated a negative developing PCS. These results were particularly strong among non-movers. We showed that changes in infrastructure and environmental pollution were associated with health developments. Due to our methodological approach – imposing a strict time order between cause and outcome while controlling for time-varying individual characteristics - it appears that these associations are indeed causal.

Keywords: changes in living environment, Physical Component Summary, changes in physical health, movers and non-movers, generalised estimating equations, causal inference

1 INTRODUCTION

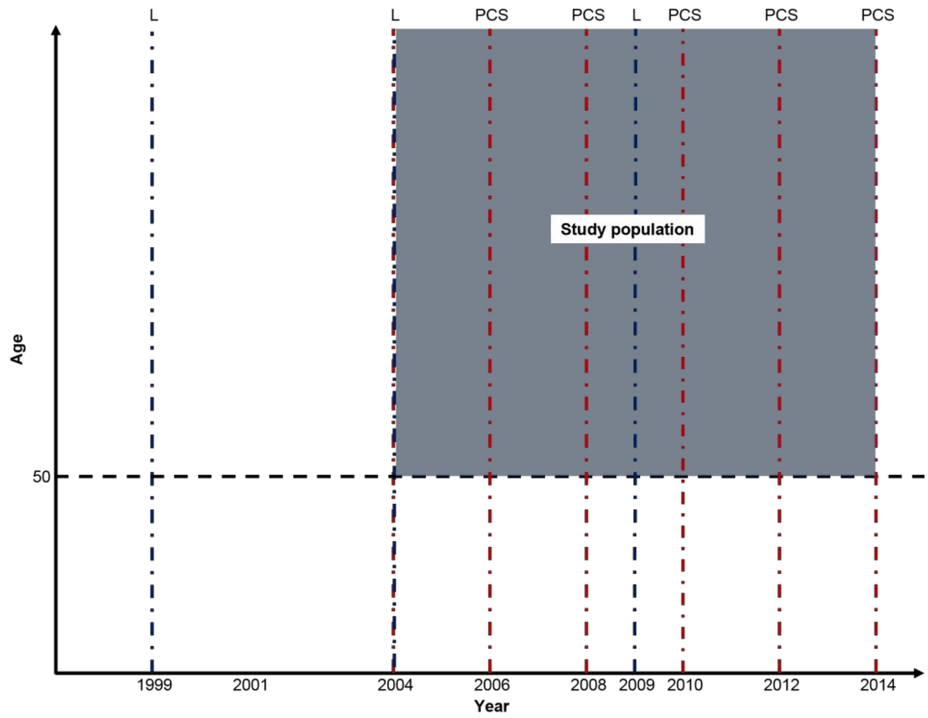
In the context of globalization, climate change and different places of residence over the life course, a holistic view on health inequalities covering living environmental characteristics and their changes becomes more relevant (Rao et al. 2007). Numerous epidemiological studies have found that advantaged living environment was associated with good health and disadvantaged with worse health. (Mair et al. 2008; Stafford et al. 2008; Jokela 2014; Jokela 2015; Stafford; Marmot 2003; Weimann et al. 2015) However, most previous studies have pursued cross-sectional designs (Schüle; Bolte 2015) or just used the baseline measurement of living environment characteristics in a longitudinal design (Diez Roux et al. 2001; Balfour; Kaplan 2002) and cannot control for social selection (Diez Roux 2004; Oakes 2004a; Oakes 2004b). Other studies concentrated only on the movers (Jokela 2014; Jokela 2015) but those approaches may lead to biased results due to specific individual characteristics that may affect the decision to move (e.g. health, socioeconomic determinants) and they neglect secular changes in living environments of the non-movers. Causal inference in investigating living environment health associations is a huge issue in view of selection bias (Ware 2007; Huber 1967; White 1980), and is why additional longitudinal approaches are necessary. The few previous longitudinal studies (Jokela 2014; Jokela 2015; Weimann et al. 2015) found less evidence supporting the hypothesis of causal environmental effects on people's health, or found only weak evidence for the beneficial effects of advantaged environmental conditions. One study identified lower mortality risks for people living in more green areas (Mitchell; Popham 2008), but another study detected hardly any positive health effect of moving to a neighbourhood with more green qualities (Weimann et al. 2015). We explored longitudinal associations of changing or stable living environment characteristics related to physical health and most important, subsequent health changes among movers and non-movers. For this purpose, we used longitudinal data from Germany on both living environment and health, and, applied some new methodological strategies to tackle the issue of social selection and strengthen the causal explanatory power of the results. We performed gender-specific analyses in accordance with previous cross-sectional studies (Stafford et al. 2005; Matheson et al. 2010). We hypothesised that disadvantaged or worsening living conditions are associated with a negative health and health development over time; whereby beneficial or improving living conditions may lead to good health and positive changes in physical health.

2 METHODS

2.1 Data and sample

Longitudinal data from 1999 to 2014 were obtained from the publicly available Socio-Economic Panel (SOEP) (Schupp et al.), a representative prospective cohort study of German adults (Goebel et al. 2018). The yearly waves contain, among other information, data on socioeconomic and sociodemographic characteristics at the individual level. Information on the living environment at the household level is available on a five-year basis: 1999, 2004, 2009. Physical health in the form of the Physical Component Summary (PCS)(see Outcomes) is available on a two-year basis from 2002 onwards. The present study used all participants aged 50 and older at baseline (*Figure 1*). The baseline is defined as the first health measurement of people in the age 50 or older from wave 2004 onwards and took place in the waves 2004, 2006, 2008, 2010 or 2012 due to the two-year basis of the health data.

Figure 1. Data and study population used for analyses



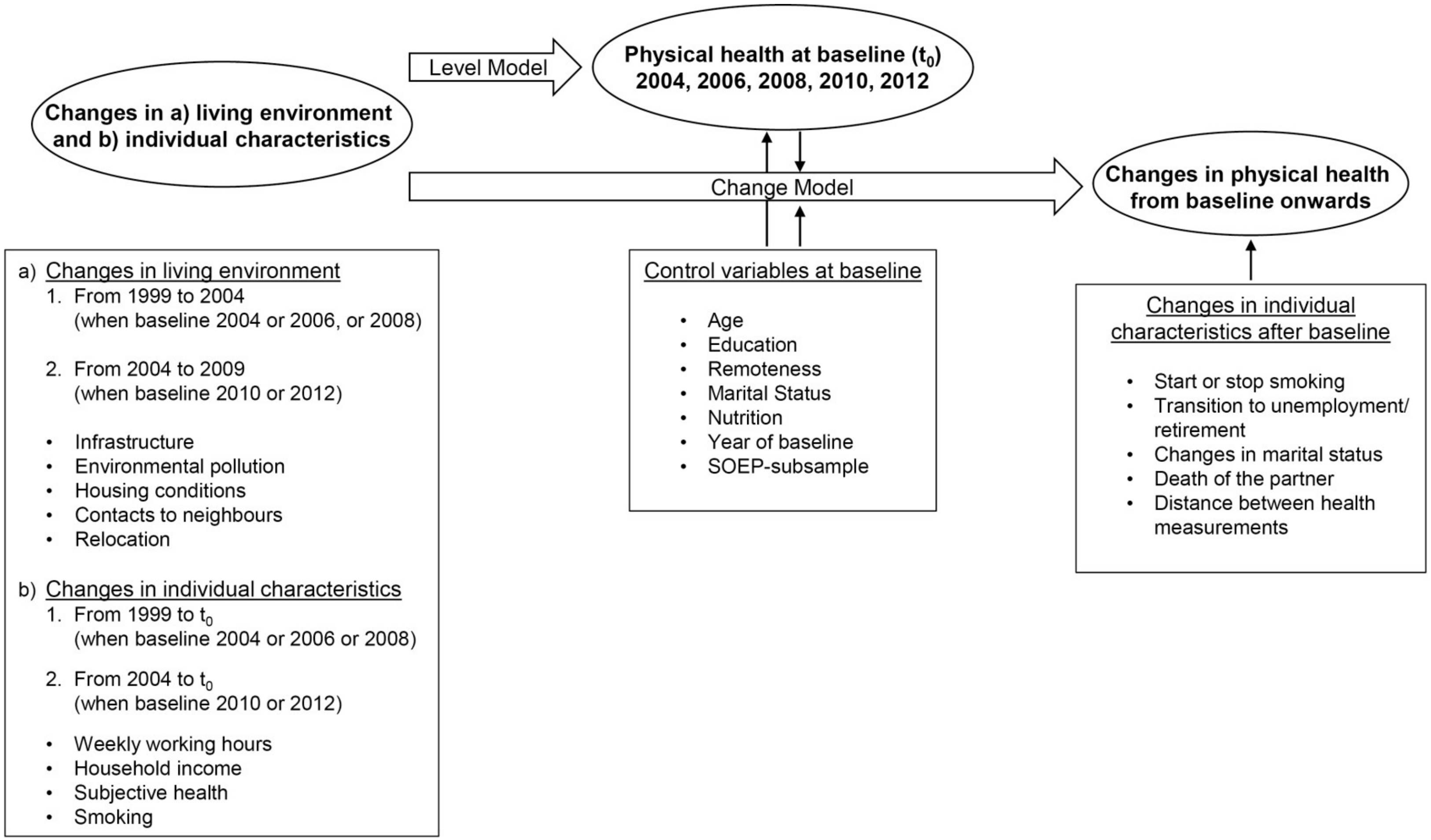
Notes: The lexis diagram is based on the SOEP data 1999-2014 (version 31.1). The red lines show waves with measurements of the outcome variable (PCS: Physical Component Summary) and blue lines measurements of living environmental characteristics (L).

A minimum of two health measurements and two observations of the living environmental characteristics were required to become part of the analysis population. Supplementary *Figure 4* (APPENDIX) shows a study flow chart illustrating the steps of arriving at the analysis. The final analysis population covered 4,373 persons residing in Germany and aged 50 and older at baseline (in 2004, 2006, 2008, 2010, 2012) with a total of 12,403 health observations and 8,030 health changes (from 2004 to 2014). This study was conducted in accordance with all principles embodied in the Declaration of Helsinki.

2.2 Study design

We employed a longitudinal study design characterised by four aimed methodological strategies: a) imposing a strict time order between living environment and physical health to exclude the possibility of reverse causation, b) predicting changes in health over time and do not only regard different health levels, c) estimating separate models for movers and non-movers as well as men and women, and, d) controlling for important time-invariant and time-varying individual characteristics. We defined two models: the Level Model and the Change Model. In the Level Model, we related the health status at baseline to changes in the environment and in individual characteristics before baseline. In the Change Model, we explored changes in health from baseline onwards, dependent on changes in the environment before baseline, as well as changes in individual characteristics before and after baseline, and health at baseline (*Figure 2*). To refine the results we estimated separate models for men and women as well as movers and non-movers to tackle the issue of health selection into relocation.

Figure 2. Novel study design to strengthen the causal explanatory power



2.3 Measures

2.3.1 Outcomes

Physical health was measured by the Physical Component Summary (PCS), which is one of the two main dimensions of the 12-Item Short Form Survey version 2, invented by the RAND Corporation (Ware 2007). PCS consists of six variables: two on physical functioning one on general health, one on bodily pain and two on the role of functioning. The SOEP reports the PCS as a metric variable (min = 0; max = 100) with higher scores indicating better health. The score was mean-centered to a value of 50, that means that scores lower or higher than 50 indicate worse or better health than the average in the whole SOEP sample. In the Level Model PCS is the main outcome measure. In the Change Model a change in physical health (Δy_i) from baseline onwards is the main outcome measure. $\Delta y_i = y_{it+1} - y_{it}$ is the difference between the PCS score from the next following valid wave $(t + 1)$ of a subject (i) minus the PCS score of the previous wave (t). In this way, negative scores of y indicate individual health deterioration, a score of zero unchanged health and positive scores individual health improvements. We used a maximum of three changes in PCS for one individual from baseline onward to ensure reasonable proximity between measures of living environment and health.

2.3.2 Predictors

We included predictors from two main domains, namely the living environment which is our domain of interest and individual characteristics which may confound our results. We captured four dimensions of the living environment, namely infrastructure, environmental pollution, housing conditions, and contacts to neighbours, and, distinguished between stable, improved and worsened conditions. Additionally, we added relocation to identify whether changed or stable living environment resulted from a move or not, and most important, to perform separate models for movers and non-movers. Remoteness, which measured the distance of the people's residence to the next city center at baseline, served as a control variable. As for the individual characteristics, we identified relevant demographic, socio-economic and lifestyle determinants from the literature covering age, sex, education, weekly working hours, nutrition, unemployment/ retirement, household income, smoking, marital status, death of the partner and subjective health. Supplementary *Table 3* (APPENDIX) provides the list of all abovementioned predictors, their full descriptions, the reclassifications, and the final categories. In addition, we accounted for some design variables: the year of baseline (at baseline), the SOEP-subsample (at baseline) and the distance between the single health measurements (from baseline onwards) that were used to calculate the changes in health serving as outcomes in the Change Model. From both domains, living environment and individual characteristics, the predictors were included either as time-invariant variables (at baseline) or as time-varying ones (up to baseline/ from baseline onwards). All time-varying living environmental characteristics were calculated by forming the difference of the two available assessments. They were assessed by the key-person of the household (household head) and were then linked to all individuals in the same household. All time- varying individual characteristics up to baseline were calculated by forming the difference between the measurement of each covariate at the time of first wave of living environment examination (1999 or 2004) and the assessment at baseline of this variable. In both cases, we defined a change equal or greater than one standard deviation across all waves as improved or worsened conditions and distinguished between stable, improved and worsened characteristics. In the Change Model, we added some event variables controlling for changes in individual characteristics after baseline. They were represented through several dichotomous variables, with the value one if an event occurred and zero otherwise.

2.4 Statistical analysis

In the Level Model, we examined associations between changes in the living environment and in individual characteristics before or up to baseline and PCS at baseline using linear regressions. Due to heteroscedastic residuals (Breusch-Pagan test: $p < 0.001$), we applied robust standard errors by Huber/White (Huber 1967; White 1980). In the Change Model, we performed generalised estimating equations (Liang; Zeger 1986; Zeger et al. 1988) using the identity link function and a normally distributed outcome variable (= changes in PCS score). By doing this, we controlled for multiple observations per person taking the autocorrelation of repeated measurements of the same persons into account. The within-person residual covariance matrix was specified by an independent correlation structure based on the quasi-likelihood information criterion (Pan 2001). We performed separate models for men and women as well as movers and non-movers. All calculations were performed using Stata/IC 12.1, and procedures reg and xtgee.

3 RESULTS

The analysis sample consisted of 2,063 (47.18%) men and 2,310

(52.82%) women (*Table 1*).

Table 1. Selected descriptive statistics (n = 4,373)

Variable	Men			Women		
	%	No. of Obs.	Mean[a] (SD)	%	No. of Obs.	Mean [a] (SD)
PCS at baseline	47.18	2,063	45.04 (9.90)	52.82	2,310	44.03 (10.04)
PCS from baseline onwards	47.09	5,840	44.27 (9.96)	52.91	6,563	43.17 (10.11)
Relocation before baseline						
Yes (movers)	13.09	270		13.25	306	
No (non-movers)	86.91	1,793		86.75	2,004	
Infrastructure						
Stable best	30.54	630		28.40	656	
Stable moderate	25.21	520		26.88	621	
Stable worst	28.02	578		27.23	629	
Improved	7.17	148		7.32	169	
Worsened	9.06	187		10.17	235	
Environmental pollution						
Stable best	38.15	787		38.53	890	
Stable moderate	25.74	531		23.98	554	
Stable worst	19.97	412		21.21	490	
Improved	9.11	188		9.78	226	
Worsened	7.03	145		6.49	150	
Housing conditions						
Stable good	62.72	1,294		62.55	1,445	
Stable in need of renov.	16.24	335		15.71	363	
Improved	11.97	247		12.03	278	
Worsened	9.06	187		9.70	224	
Contacts to neighbours						
Stable best	11.63	240		12.25	283	
Stable moderate	33.69	695		33.85	782	
Stable worst	7.95	164		7.01	162	
Improved	23.12	477		23.59	545	
Worsened	23.61	487		23.29	538	

Notes: Abbreviations: No., number; Obs., observations; SD, standard deviation; PCS, Physical Component Summary.
Mean PCS at baseline was calculated by using the measurement of PCS at baseline and mean PCS from baseline onwards was calculated by using the multiple PCS measurements from baseline onwards.

739 (16.9%) experienced changing infrastructure, 709 (16.2%) differences in environmental pollution, 936 (21.4%) changes in housing conditions and 2047 (46.81%) changing contact to neighbors; 270 men (13.09%) and 306 women (13.25%) relocated at least once before

baseline (*Table 2*). At baseline, men's mean PCS was 45.04 and ranged between 11.34 and 69.38 with a standard deviation (SD) of 9.90. For women, the mean PCS was 44.03 ranging between 13.76 and 66.90 (SD, 10.04). From baseline onwards, we included 5,840 PCS observations for men and 6,563 for women that resulted in 3,777 (men) or 4,253 (women) changes in PCS. Among men, 1,689 positive health changes, 2,027 negative changes occurred, whereas 61 ones indicated no differences. Women contributed 1,967 positive changes, 2,242 negative ones and 44 observations without any changes. *Table 4* lists frequencies of the other covariates.

3.1 Level Model

Changes in living environmental characteristics influenced health at baseline, albeit with some differences between the two sexes (*Table 2*). Women living in environments with stable worst infrastructure experienced worst health (-1.78, $p < 0.001$), while there was no association for men (-0.30, $p = 0.511$). For both sexes, worsening environmental pollution was associated with worse health (compared to stable best pollution: men -2.32, $p = 0.001$; women -1.68, $p = 0.013$). This was also true for women from areas with stable moderate environmental pollution (-1.25, $p = 0.003$).

Table 2. Changes in living environment and PCS at baseline (Level Model) and changes in PCS (Change Model)

Variable	Level Model				Change Model			
	Men		Women		Men		Women	
	Coeff.	95% CI	Coeff.	95% CI	Coeff.	95% CI	Coeff.	95% CI
Infrastructure								
Stable best	Ref.		Ref.		Ref.		Ref.	
Stable moderate	0.43	-0.41, 1.27	-1.54[a]	-2.35, -0.72	0.27	-0.18, 0.72	-0.01	-0.44, 0.43
Stable worst	-0.30	-1.18, 0.59	-1.78[a]	-2.63, -0.93	-0.08	-0.56, 0.40	0.13	-0.34, 0.59
Improved	-0.48	-1.87, 0.90	-1.94[a]	-3.27, -0.61	0.52	-0.30, 1.34	0.62[c]	-0.11, 1.34
Worsened	-0.77	-1.98, 0.44	-1.42[b]	-2.61, -0.23	0.06	-0.60, 0.71	0.14	-0.44, 0.71
Environmental pollution								
Stable best	Ref.		Ref.		Ref.		Ref.	
Stable moderate	-0.42	-1.23, 0.38	-1.25[a]	-2.06, -0.44	-0.29	-0.74, 0.16	-0.33	-0.75, 0.09
Stable worst	-0.68	-1.55, 0.19	-0.67	-1.52, 0.18	-0.57[b]	-1.05, -0.09	-0.08	-0.54, 0.39
Improved	-0.16	-1.36, 1.05	0.19	-0.93, 1.32	0.18	-0.49, 0.85	-0.17	-0.76, 0.42
Worsened	-2.32[a]	-3.74, -0.90	-1.68[b]	-3.02, -0.37	-0.81[b]	-1.56, -0.05	-0.43	-1.14, 0.28
Housing conditions								
Stable good	Ref.		Ref.		Ref.		Ref.	
Stable in need of renovation	-0.96[b]	-1.85, -0.07	-1.33[a]	-2.17, -0.48	-0.40	-0.90, 0.10	-0.05	-0.55, 0.45
Improved	-0.38	-1.42, 0.67	-0.62	-1.64, 0.40	-0.15	-0.73, 0.42	-0.45	-1.00, 0.10
Worsened	-1.47[a]	-2.55, -0,40	0.22	-0.86, 1.29	0.01	-0.63, 0.62	-0.32	-0.87, 0.23
Contacts to neighbours								
Stable best	Ref.		Ref.		Ref.		Ref.	
Stable moderate	-0.59	-1.66, 0.48	-0.31	-1.37, 0.74	-0.36	-0.93, 0.22	-0.17	-0.74, 0.39
Stable worst	-0.99	-2.47, 0.49	-0.98	-2.51, 0.55	0.30	-0.57, 1.16	0.05	-0.79, 0.89
Improved	-1.09[c]	-2.22, 0.05	-0.77	-1.90, 0.36	-0.45	-1.22, 0.31	-0.48	-1.25, 0.29
Worsened	-0.38	-1.49, 0.72	0.01	-1.11, 1.12	-0.02	-0.81, 0.76	-0.07	-0.79, 0.65

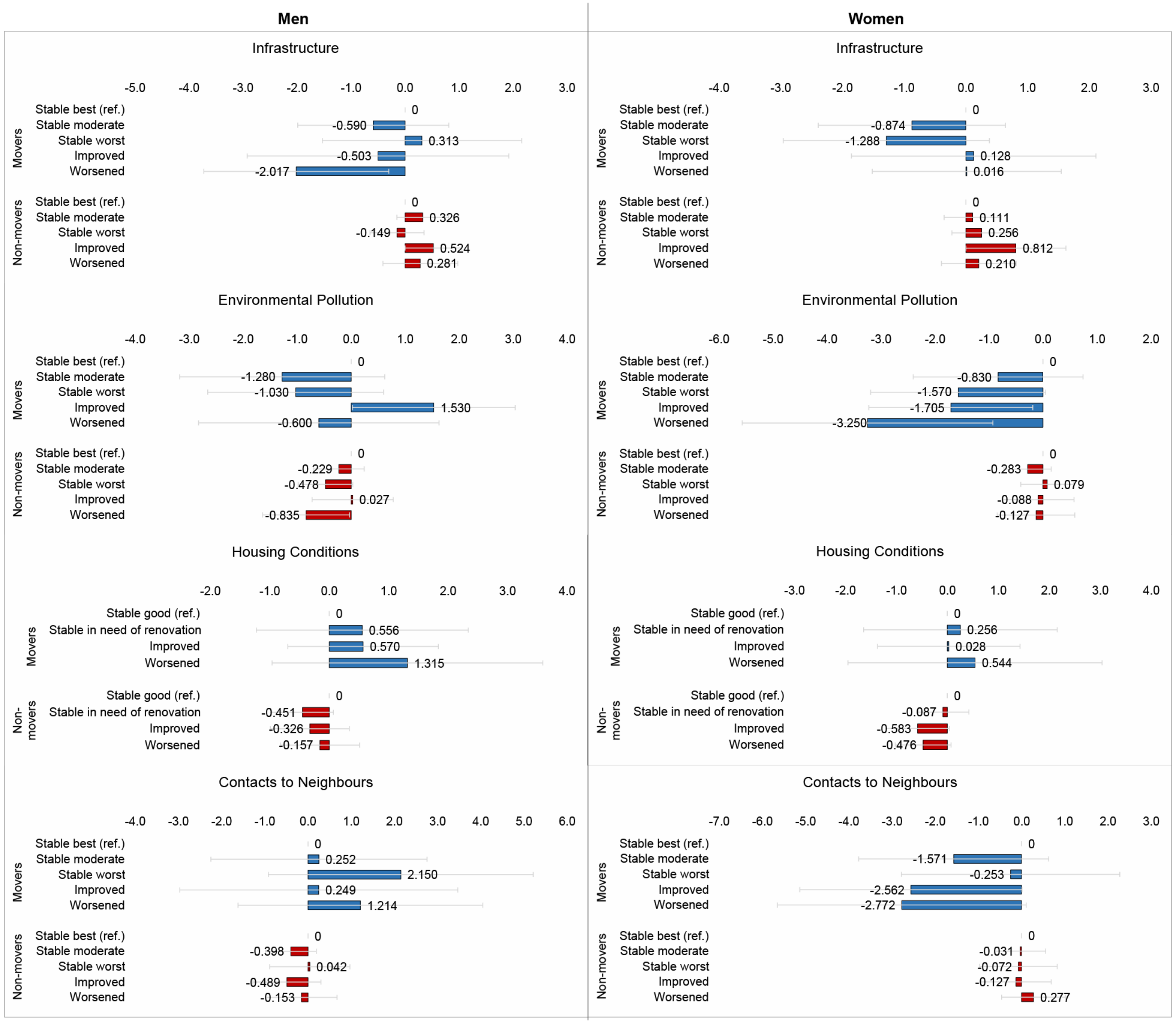
Notes: Abbreviations: Coeff., Coefficient; CI, confidence interval; Ref., reference.
[a] $p < 0.01$; [b] $p < 0.05$; [c] $p < 0.10$.

Concerning housing conditions, living in need-of-renovation-buildings was associated with worse health independent of sex (men -0.96, p = 0.035; women -1.33, p = 0.002). In addition, for men worsening housing conditions were connected to worse health (-1.47, p = 0.007).

3.2 Change Model

Stable worst (-0.57, p = 0.021) and worsened environmental pollution (-0.81, p = 0.036) were associated with negative changes in PCS from baseline onwards among men. A similar tendency was observed among women, although it was not statistically significant. Improved infrastructure was related to a positive health development among women only (0.62, p = 0.095) The results become more informative when we distinguished between movers and non-movers (*Figure 2*) to tackle the issue of health selection into relocation. Among the non-movers, improved infrastructure was related to positive developing health for women (0.812, p = 0.042). Furthermore, stable worst (-0.478, p = 0.064) and worsened (-0.835, p = 0.042) environmental pollution were associated with declining health in men. Living in need-of-renovation-housing was associated with health declines among men (-0.451, p = 0.091). Women experiencing improved (-0.583, p = 0.067) or worsened (-0.476, p = 0.088) housing conditions indicated larger declines in PCS (ref. stable good conditions). Turning to the movers, who may be prone to positive health selection, we found that worsened infrastructure was related to larger health declines (-2.017, p = 0.021) only among men. Among women stable worst (-1.566, p = 0.058), improved (-1.705, p = 0.028) and worsened (-3.250, p = 0.006) environmental pollution were associated with a negative health development.

Figure 3. Gender-specific Change Models separated by movers and non-movers



For men, however, improved environmental pollution was interrelated with health improvements (1.531, p = 0.047). Contacts to neighbors were only associated with women's health developments insofar that changing conditions were related to negative health changes, independent of whether they had improved (-2.562, p = 0.051) or worsened (-2.772, p = 0.059).

4 DISCUSSION

4.1 Summary of principal findings

Our study has shown that, in line with our hypotheses, worsened and stable worst perceived environmental pollution and poor housing conditions were associated with worse physical health at baseline among German individuals aged 50 or above in 2004-2014. For men, this was also true for worsened and stable worst environmental pollution and changes in physical health from baseline onwards. Women in living environments with best infrastructure had the best health at baseline, and we found that improved infrastructure was related to a positive health development from baseline onwards. These results were particularly strong among non-movers.

4.2 Evaluation of data and methods

Our study has two strengths compared to previous studies in the field. First, we considered both repeated health and neighbourhood assessments, which had only been done by a few previous studies in the field (Schüle; Bolte 2015). To the best of our knowledge, this is the first study in the field that has explored changes in health over time, and not only health levels, while additionally controlling for time-varying individual characteristics.

We controlled for baseline health to make sure that the results were not confounded by poor or good health at baseline. Second, our results stem from a study design which imposes a strict time dimension between exposure and outcome to avoid reverse causation, and, we distinguished between movers and non-movers. The causal explanations of our findings for improved infrastructure among women and stable worst as well as worsened environmental pollution among men in the Change Model are strengthened by the fact that they are visible among non-movers, in whom positive health selection does not play a role (see *Figure 2*). Associations, which were only found among the movers, may indicate some evidence for selection, due either to unobserved individual characteristics of the movers or to the health status as a reason for an individual's decision to move (Jokela 2014; Jokela 2015). Nevertheless, our study does have some limitations. First, our study design covers short-term changes in living environment, i.e. changes within five years. Contextual effects may, however, affect over the entire life course in the form of cumulated exposures or in critical periods. (Kuh et al. 2003; Kuh; Ben-Shlomo 2004) However, for air pollution it has been shown that even short-term deprivations influence people's health. (Mustafic et al. 2012) Due to their proximity to physical health it is especially the changes in physical environment, represented in our study by environmental pollution and infrastructure, which might become health-relevant rather rapidly. Second, perceived living environment in the SOEP was assessed at the household level. Even if there is a certain degree of autocorrelation between the household members within a household, perceptions can differ among the individual household members. However, it is unlikely that our gender-specific findings are the result of a gender bias in asking household heads only, as the distribution is 59.93% male and 40.07% female. Moreover, our study did not cover any objective characteristics of the living environment in addition to subjective ones. (Weden et al. 2008) Additional (sensitivity) analyses suggest that our estimates are on the conservative side; there are two reasons for this. First, to verify the robustness of our findings we performed some sensitivity analyses. Including the after-baseline-movers, our models displayed similar results with even stronger associations, particularly in the Change Model (results not shown). Including all participants with at least one measurement of PCS in the Level Model indicated even stronger associations of environmental pollution (results not shown). Second, we dealt with same-source bias by performing separate models for householders, who were asked for their perceptions of the living environment in the SOEP, and non-householders (*Table 4*). The model for the non-householders might be less influenced by same source bias. Indeed, the Change Model for non-householders indicated even stronger associations for infrastructure (women) and environmental pollution (men) than the model for both, householders and non-householders (Supplementary *Table 5,* APPENDIX).

4.3 Interpretation of findings

We found that changes in infrastructure and environmental pollution are associated with people's physical health and health changes over time. Due to our methodological approach, which considered a strict time order between living environment and health, these associations seem to be causal. The causal mechanism behind this might be that the beneficial or deprived physical characteristics of living environments influence people's bodily conditions and may delay or accelerate ageing processes in addition to individual age- related factors. (Andrews; Phillips 2005) A previous longitudinal study (Hirsch et al. 2014), which focused on changes in the built environment and changes in amount of walking, found that an in-creasing density of infrastructure promotes more walking. Walking provides better health (Haskell et al. 2007) due to positive effects on physical and cognitive functioning (Christensen et al. 1996). There is also empirical evidence that higher levels of environmental pollution, e.g. air and noise pollution, are associated with worse physical and mental health. Exposures to fine particles impair the lung function and cause further physical and cognitive decline thereafter. (Kramer et al. 1999) It has also been shown that relocating from high to low polluted areas (or vice versa) is associated with subsequent changes in lung function growth. (Lichtenfels et al. 2018) A high level of noise pollution, especially nocturnal noise exposure, influences people's sleeping behaviour and can thus affect health negatively. (Jarup et al. 2008) We found interesting differences by gender in the observed associations. That is, infrastructure proved to be more relevant among women and environmental pollution more relevant among men. Infrastructure appeared to be associated with PCS at baseline and changes in PCS thereafter among women only. A previous study found that the access to banks, building societies and health services in the neighbourhood was only associated with women's self-rated health. (Kavanagh et al. 2006) Turning to environmental pollution, a previous cross-sectional study found associations between perceived physical problems (air quality, waste disposal) and self-rated health only for men. (Sundström; McCright 2014) There are three possible explanations for gender differences in the association between (changes in) the living environment and health discussed in the literature (Kavanagh et al. 2006): First, men and women perceive or experience their living environments in different ways. (Ellaway; Macintyre 2001) In our study, this hypothesis is less applicable, because the questions on the living environment were answered by the key-person of the households. Second, the dose of exposure to the different living environmental characteristics differ between men and women, which may also be influenced by different social roles. (Xiao; McCright 2015) Results from the German Time Use Survey in 2012/13 (Destatis 2015) seem to support this explanation. That is, women spend more daily time shopping and using public services in Germany, whereas men spend more time with outside physical activities. Third, sex differences in the vulnerability for specific environmental characteristics, in terms of sensibility of bodies and biological systems, (Snow 2008) can lead to different health consequences for men than for women.

5 CONCLUSION

The present findings can truly provide support for the hypothesis that effects of changes in infrastructure and environmental pollution on people's perceived physical health are causal. This is something that has not been shown in a series of previous studies. In addition, the results suggest that even short-term changes in infrastructure and environmental pollution are sufficient to influence people's life quality in the age of 50 or higher. The observed support for causal effects of changes in living environment on people's physical health point towards the importance of public health policies and spatial planning projects which address the issue of adverse living conditions. We recommend paying particular attention to gender differences in the relevance of particular living environmental conditions.

REFERENCES

Andrews, Gavin J.; Phillips, David R. (2005): Ageing and place. Perspectives, policy, practice. London: Routledge (Routledge studies in human geography, 9).

Balfour, Jennifer L.; Kaplan, George A. (2002): Neighborhood environment and loss of physical function in older adults: evidence from the Alameda County Study. In: *American journal of epidemiology* 155 (6), S. 507–515.

Christensen, H.; Korten, A.; Jorm, A. F.; Henderson, A. S.; Scott, R.; Mackinnon, A. J. (1996): Activity levels and cognitive functioning in an elderly community sample. In: *Age and ageing* 25 (1), S. 72–80.

Destatis (2015): Zeitverwendungserhebung. Aktivitäten in Stunden und Minuten für ausgewählte Personengruppen 2012/2013. Wiesbaden. Online verfügbar unter https://www.destatis.de/DE/Publikationen/Thematisch/EinkommenKonsumLebensbedingungen/Zeitbudgeterhebung/Zeitverwendung5639102139004.pdf?__blob=publicationFile.

Diez Roux, A. V.; Merkin, S. S.; Arnett, D.; Chambless, L.; Massing, M.; Nieto, F. J. et al. (2001): Neighborhood of residence and incidence of coronary heart disease. In: *The New England journal of medicine* 345 (2), S. 99–106. DOI: 10.1056/NEJM200107123450205.

Diez Roux, Ana V. (2004): Estimating neighborhood health effects: the challenges of causal inference in a complex world. In: *Social science & medicine* 58 (10), S. 1953–1960. DOI: 10.1016/S0277-9536(03)00414-3.

Ellaway, A.; Macintyre, S. (2001): Women in their place. Gender and perceptions of neighbourhoods and health in the West of Scotland. In: Isabel Dyck, Nancy Lewis und Sara McLafferty (Hg.): Geographies of women's health. London, New York: Routledge (Routledge international studies of women and place), S. 265–281.

Goebel, Jan; Grabka, Markus M.; Liebig, Stefan; Kroh, Martin; Richter, David; Schröder, Carsten; Schupp, Jürgen (2018): The German Socio-Economic Panel (SOEP). In: *Jahrbücher für Nationalökonomie und Statistik* 0 (0), S. 423. DOI: 10.1515/jbnst-2018-0022.

Haskell, William L.; Lee, I-Min; Pate, Russell R.; Powell, Kenneth E.; Blair, Steven N.; Franklin, Barry A. et al. (2007): Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. In: *Circulation* 116 (9), S. 1081–1093. DOI: 10.1161/CIRCULATIONAHA.107.185649.

Hirsch, Jana A.; Moore, Kari A.; Clarke, Philippa J.; Rodriguez, Daniel A.; Evenson, Kelly R.; Brines, Shannon J. et al. (2014): Changes in the built environment and changes in the amount of walking over time. Longitudinal results from the multi-ethnic study of atherosclerosis. In: *American journal of epidemiology* 180 (8), S. 799–809. DOI: 10.1093/aje/kwu218.

Huber, P. J. (1967): The Behavior of Maximum Likelihood Estimates under Nonstandard Conditions. In: *Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability* (1), S. 221–233.

Jarup, Lars; Babisch, Wolfgang; Houthuijs, Danny; Pershagen, Göran; Katsouyanni, Klea; Cadum, Ennio et al. (2008): Hypertension and exposure to noise near airports: the HYENA study. In: *Environmental health perspectives* 116 (3), S. 329–333. DOI: 10.1289/ehp.10775.

Jokela, Markus (2014): Are neighborhood health associations causal? A 10-year prospective cohort study with repeated measurements. In: *American journal of epidemiology* 180 (8), S. 776–784. DOI: 10.1093/aje/kwu233.

Jokela, Markus (2015): Does neighbourhood deprivation cause poor health? Within-individual analysis of movers in a prospective cohort study. In: *Journal of epidemiology and community health* 69 (9), S. 899–904. DOI: 10.1136/jech-2014-204513.

Kavanagh, Anne M.; Bentley, Rebecca; Turrell, Gavin; Broom, Dorothy H.; Subramanian, S. V. (2006): Does gender modify associations between self rated health and the social and economic characteristics of local environments? In: *Journal of epidemiology and community health* 60 (6), S. 490–495. DOI: 10.1136/jech.2005.043562.

Kramer, A. F.; Hahn, S.; Cohen, N. J.; Banich, M. T.; McAuley, E.; Harrison, C. R. et al. (1999): Ageing, fitness and neurocognitive function. In: *Nature* 400 (6743), S. 418–419. DOI: 10.1038/22682.

Kuh, D.; Ben-Shlomo, Y.; Lynch, J.; Hallqvist, J.; Power, C. (2003): Life course epidemiology. In: *Journal of epidemiology and community health* 57 (10), S. 778–783.

Kuh, Diana; Ben-Shlomo, Yoav (Hg.) (2004): A life course approach to chronic disease epidemiology. 2nd ed. Oxford: Oxford University Press (Oxford medical publications). Online verfügbar unter http://dx.doi.org/10.1093/acprof:oso/9780198578154.001.0001.

Liang, Kung-Yee; Zeger, Scott L. (1986): Longitudinal Data Analysis Using Generalized Linear Models. In: *Biometrika* 73 (1), S. 13. DOI: 10.2307/2336267.

Lichtenfels, Ana Julia de; van der Plaat, Diana A.; Jong, Kim de; van Diemen, Cleo C.; Postma, Dirkje S.; Nedeljkovic, Ivana et al. (2018): Long-term Air Pollution Exposure, Genome-wide DNA Methylation and Lung Function in the LifeLines Cohort Study. In: *Environmental health perspectives* 126 (2), S. 27004. DOI: 10.1289/EHP2045.

Mair, C.; Diez Roux, A. V.; Galea, S. (2008): Are neighbourhood characteristics associated with depressive symptoms? A review of evidence. In: *Journal of epidemiology and community health* 62 (11), 940-6, 8 p following 946. DOI: 10.1136/jech.2007.066605.

Matheson, Flora I.; White, Heather L.; Moineddin, Rahim; Dunn, James R.; Glazier, Richard H. (2010): Neighbourhood chronic stress and gender inequalities in hypertension among Canadian adults. A multilevel analysis. In: *Journal of epidemiology and community health* 64 (8), S. 705–713. DOI: 10.1136/jech.2008.083303.

Mitchell, Richard; Popham, Frank (2008): Effect of exposure to natural environment on health inequalities. An observational population study. In: *Lancet* 372 (9650), S. 1655–1660. DOI: 10.1016/S0140-6736(08)61689-X.

Mustafic, Hazrije; Jabre, Patricia; Caussin, Christophe; Murad, Mohammad H.; Escolano, Sylvie; Tafflet, Muriel et al. (2012): Main air pollutants and myocardial infarction. A systematic review and meta-analysis. In: *JAMA* 307 (7), S. 713–721. DOI: 10.1001/jama.2012.126.

Oakes, J. Michael (2004a): Causal inference and the relevance of social epidemiology. In: *Social science & medicine* 58 (10), S. 1969–1971. DOI: 10.1016/j.socscimed.2003.05.001.

Oakes, J. Michael (2004b): The (mis)estimation of neighborhood effects: causal inference for a practicable social epidemiology. In: *Social science & medicine* 58 (10), S. 1929–1952. DOI: 10.1016/j.socscimed.2003.08.004.

Pan, Wei (2001): Akaike's Information Criterion in Generalized Estimating Equations. In: *Biometrics* 57 (1), S. 120–125. DOI: 10.1111/j.0006-341X.2001.00120.x.

Rao, Mala; Prasad, Sunand; Adshead, Fiona; Tissera, Hasitha (2007): The built environment and health. In: *Lancet* 370 (9593), S. 1111–1113. DOI: 10.1016/S0140-6736(07)61260-4.

Schüle, Steffen Andreas; Bolte, Gabriele (2015): Interactive and independent associations between the socioeconomic and objective built environment on the neighbourhood level and individual health. A systematic review of multilevel studies. In: *PloS one* 10 (4), e0123456. DOI: 10.1371/journal.pone.0123456.

Snow, R. C. (2008): Sex, gender, and vulnerability. In: *Global public health* 3 Suppl 1, S. 58–74. DOI: 10.1080/17441690801902619.

Socio-Economic Panel (SOEP), data for years 1984-2014, version 31.1, SOEP, 2016, doi: 10.5684/soep.v31.1

Stafford, M.; Cummins, S.; Macintyre, S.; Ellaway, A.; Marmot, M. (2005): Gender differences in the associations between health and neighbourhood environment. In: *Social science & medicine* 60 (8), S. 1681–1692. DOI: 10.1016/j.socscimed.2004.08.028.

Stafford, Mai; Gimeno, David; Marmot, Michael G. (2008): Neighbourhood characteristics and trajectories of health functioning: a multilevel prospective analysis. In: *European journal of public health* 18 (6), S. 604–610. DOI: 10.1093/eurpub/ckn091.

Stafford, Mai; Marmot, Michael (2003): Neighbourhood deprivation and health. Does it affect us all equally? In: *International Journal of Epidemiology* 32 (3), S. 357–366. DOI: 10.1093/ije/dyg084.

Sundström, Aksel; McCright, Aaron M. (2014): Gender differences in environmental concern among Swedish citizens and politicians. In: *Environmental Politics* 23 (6), S. 1082–1095.

Ware, John E. (2007): User's manual for the SF-36v2 health survey. 2nd ed. London: Quality Metric.

Weden, Margaret M.; Carpiano, Richard M.; Robert, Stephanie A. (2008): Subjective and objective neighborhood characteristics and adult health. In: *Social science & medicine* 66 (6), S. 1256–1270. DOI: 10.1016/j.socscimed.2007.11.041.

Weimann, Hanna; Rylander, Lars; Albin, Maria; Skärbäck, Erik; Grahn, Patrik; Östergren, Per-Olof; Björk, Jonas (2015): Effects of changing exposure to neighbourhood greenness on general and mental health. A longitudinal study. In: *Health & place* 33, S. 48–56. DOI: 10.1016/j.healthplace.2015.02.003.

White, Halbert (1980): A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity. In: *Econometrica* 48 (4), S. 817. DOI: 10.2307/1912934.

Xiao, Chenyang; McCright, Aaron M. (2015): Gender Differences in Environmental Concern. In: *Environment and Behavior* 47 (1), S. 17–37. DOI: 10.1177/0013916513491571.

Zeger, Scott L.; Liang, Kung-Yee; Albert, Paul S. (1988): Models for Longitudinal Data. A Generalized Estimating Equation Approach. In: *Biometrics* 44 (4), S. 1049. DOI: 10.2307/2531734.

APPENDIX

Figure 4. Study flow chart based on the SOEP data from 1999 to 2014 (version 31.1).

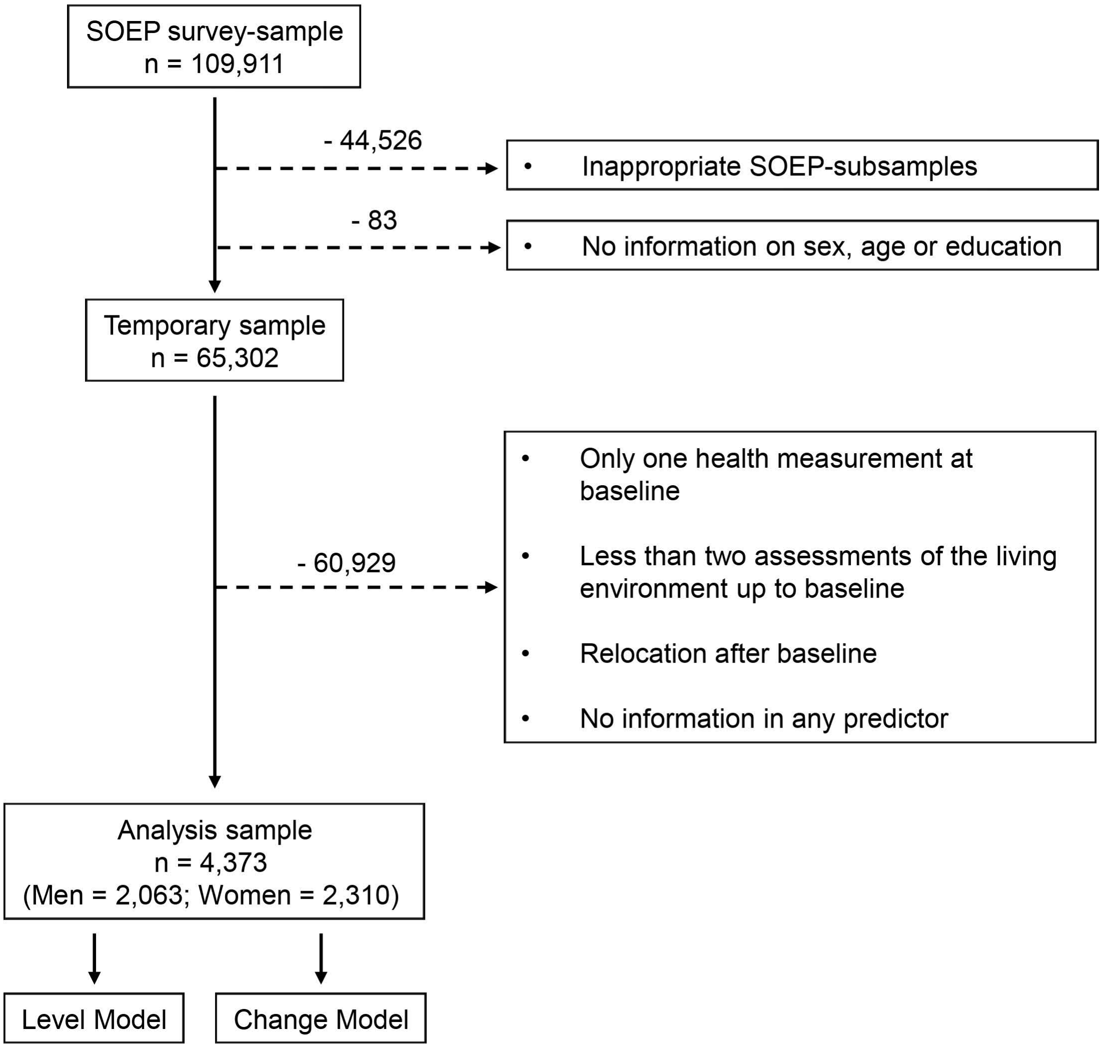


Table 3. Measures of time-invariant and time-varying living environment and individual characteristics

Time period[a]	Time dimension[b]	Domain	Measure	Description	Reclassification/ Calculation	Final categories
Up to baseline	Time-varying	Living environment	Infrastructure	Accessibility to retail, (social) services and public transport (11 items, 5-point Likert scale)	Aggregation into an average Likert scale with a minimum of 5 valid items to be included	Stable best, stable moderate, stable worst, improved, worsened
			Environmental pollution	Disturbances on air pollution, noise pollution and lack of green spaces (5-point Likert scale)	Aggregation into one summary scale [range, 5- 15]	Stable best, stable moderate, stable worst, improved, worsened
			Housing conditions	An item asking for inside conditions of the residential building	Aggregation of the two highest and the two lowest categories	Stable good, stable in need of renovation, improved, worsened
			Relocation	A question since which year people live in actual residential building	Changes in the year of living in actual residential building	Yes (movers), no (non-movers)
		Individual characteristics	Weekly working hours	An item asking for weekly working hours	Aggregation of persons that were not employed, in vocational training, in military service, community service or worked in a sheltered workshop	Stable full-time employment, stable part-time employment, stable not employed/ retired, increased working hours, decreased working hours
			Household income	An item asking for the yearly post-government household income	Dividing into income quintiles	Stable 1. quintile, stable 2. quintile, stable 3. quintile, stable 4. quintile, stable 5. quintile, more income, less income
			Subjective health	A question on how the person rated the own health in general	No reclassification applied	Stable very good, stable good, stable satisfactory, stable poor, stable bad, improved, worsened

			Smoking	A question about whether persons smoke	Aggregation of non-smokers and former smokers	Yes, no, started smoking, stopped smoking
			Remoteness	An item asking for the distance in kilometers to the next city center	No reclassification applied	< 10, 10-24, 25-39, 40-59, > 59
At baseline	Time-invariant	Living environment	Age	A question on when the person was born	Difference between wave year and birth year	Metric variable ranged between 18 and 96
		Individual characteristics	Sex	An item asking for the sex	No reclassification applied	Male, female
			Education	An item asking for highest school degree	Aggregation of the ISCED-97 scale into three educational groups	Low, middle, high
			Marital status	An items asking for the person's marital status	No reclassification applied	Married, single, widowed, divorced, separated
			Nutrition	A question about to what extent do persons follow a health-conscious diet	No reclassification applied	Very much, much, not so much, not at all
After baseline	Time-varying	Individual characteristics	Unemployment/ retirement	Event/ transition variable (dummy) that measures when persons became unemployed/ retired	Comparison of the previous state at baseline and the state at waves afterwards	Unemployment/ retirement (yes)
			Marital status	Event/ transition variables (dummies) that measures when persons experienced changes in marital status	Comparison of the previous state at baseline and the state at waves afterwards	Married, single, widowed, divorced, separated (yes)
			Death of the partner	Event/ transition variable (dummy) that measures when persons experienced a death of the partner	Comparison of the previous state at baseline and the state at waves afterwards	Death of the partner (yes)

	Start/ stop Smoking	Event/ transition variables (dummies) that measures when persons started or stopped smoking	Comparison of the previous state at baseline and the state at waves afterwards	Start smoking (yes) Stop smoking (yes)

Notes: Abbreviations: ISCED-1997, International Standard Classification of Education 1997.
[a] *Three different time periods were distinguished, namely the period up to baseline, the period at baseline and the period after baseline.*
[b] *Time dimension indicates whether the measures have time-invariant or time-varying values.*

Table 4. Descriptive statistics of the analysis sample for all variables used

Variable	Men			Women		
	%	No. of obs.	Mean[a] (SD)	%	No. of obs.	Mean[a] (SD)
PCS at baseline	47.04	2,063	45.04 (9.90)	52.96	2,310	44.03 (10.04)
PCS from baseline onwards	47.09	5,840	44.27 (9.96)	52.91	6,563	43.17 (10.11)
Relocation before baseline						
Yes (movers)	13.09	270		13.25	306	
No (non-movers)	86.91	1,793		86.75	2,004	
Age						
50-54	30.05	620		28.10	649	
55-59	13.72	283		13.46	311	
60-64	14.54	300		14.03	324	
65-69	14.20	293		13.68	316	
70-74	14.30	295		12.77	295	
75+	13.18	272		17.97	415	
Infrastructure						
Stable best	30.54	630		28.40	656	
Stable moderate	25.21	520		26.88	621	
Stable worst	28.02	578		27.23	629	
Improved	7.17	148		7.32	169	
Worsened	9.06	187		10.17	235	
Environmental pollution						
Stable best	38.15	787		38.53	890	
Stable moderate	25.74	531		23.98	554	
Stable worst	19.97	412		21.21	490	
Improved	9.11	188		9.78	226	
Worsened	7.03	145		6.49	150	
Housing conditions						
Stable good	62.72	1,294		62.55	1,445	
Stable in need of renovation	16.24	335		15.71	363	
Improved	11.97	247		12.03	278	
Worsened	9.06	187		9.70	224	
Contacts to neighbours						
Stable best	11.63	240		12.25	283	
Stable moderate	33.69	695		33.85	782	
Stable worst	7.95	164		7.01	162	
Improved	23.12	477		23.59	545	
Worsened	23.61	487		23.29	538	
Remoteness						
Residence in the city center	8.00	165		9.48	219	
Distance < 10 kilometers	23.75	490		24.50	566	
Distance 10-24 kilometers	26.81	553		26.10	603	

Distance 25-39 kilometers	15.80	326	14.50	335
Distance 40-59 kilometers	13.67	282	14.55	336
Distance > 59 kilometers	11.97	247	10.87	251
Education				
Low	11.97	247	24.63	569
Middle	52.21	1,077	51.52	1,190
High	35.82	739	23.85	551
Weekly working hours				
Stable full-time employment	39.55	816	14.20	328
Stable part-time employment	0.78	16	11.04	255
Stable not employed/retired	40.14	828	51.69	1,194
Increased working hours	2.96	61	7.71	178
Decreased working hours	16.58	342	15.37	355
Household income				
Stable 1. quintile	9.36	193	17.88	413
Stable 2. quintile	10.28	212	10.48	242
Stable 3. quintile	9.26	191	8.01	185
Stable 4. quintile	9.21	190	7.45	172
Stable 5. quintile	14.30	295	11.08	256
Increased income	26.81	553	22.68	524
Decreased income	20.79	429	22.42	518
Subjective health				
Stable very good	0.82	17	1.13	26
Stable good	18.27	377	16.10	372
Stable satisfactory	24.24	500	24.72	571
Stable poor	6.88	142	9.00	208
Stable bad	1.65	34	1.99	46
Improved	17.11	353	17.66	408
Worsened	31.02	640	29.39	679
Smoking status				
Yes	21.86	451	16.67	385
No	68.01	1,403	76.84	1,775
Started	7.71	159	4.37	101
Stopped	2.42	50	2.12	49
Marital status				
Married	78.53	1,620	65.24	1,507
Single	5.19	107	4.07	94
Widowed	6.54	135	19.48	450
Divorced	8.00	165	9.61	222
Separated	1.75	36	1.60	37
Nutrition behaviour				
Very much	6.35	131	12.64	292
Much	41.01	846	51.30	1,185
Not so much	46.73	964	33.64	777
Not at all	5.91	122	2.42	56

Events after baseline				
Start smoking	2.96	61	2.86	66
Stop smoking	6.11	126	4.85	112
Unemployment/retirement	12.02	248	11.34	262
Separated	0.82	17	1.00	23
Divorced	0.97	20	1.34	31
Married	3.15	65	2.25	52
Death of the partner	1.79	37	3.85	89

No., number; Obs., observations; SD, standard deviation; PCS, Physical Component Summary.

[a] Mean PCS at baseline was calculated by using the measurement of PCS at baseline and mean PCS from baseline onwards was calculated by using the multiple PCS measurements from baseline onwards.

Table 5. Change Models for householders and non-householders

Variable	Householders				Non-householders			
	Men		Women		Men		Women	
	Coeff.	**95% CI**	**Coeff.**	**95% CI**	**Coeff.**	**95% CI**	**Coeff.**	**95% CI**
Infrastructure								
Stable best	Ref.		Ref.		Ref.		Ref.	
Stable moderate	0.29	-0.20, 0.78	0.01	-0.63, 0.64	0.26	-0.86, 1.38	0.06	-0.44, 0.43
Stable worst	0.11	-0.41, 0.62	-0.08	-0.77, 0.61	-0.48	-1.71, 0.75	0.38	-0.34, 0.59
Improved	0.78	-0.18, 1.74	0.04	-0.90, 0.98	0.07	-1.68, 1.82	1.54[a]	-0.11, 1.34
Worsened	0.12	-0.60, 0.83	-0.11	-0.93, 0.71	-0.40	-2.08, 1.27	0.48	-0.41, 1.38
Environmental pollution								
Stable best	Ref.		Ref.		Ref.		Ref.	
Stable moderate	-0.24	-0.73, 0.26	-0.41	-1.03, 0.20	-0.63	-1.81, 0.55	-0.25	-0.86, 0.36
Stable worst	-0.35	-0.88, 0.18	-0.49	-1.16, 0.19	-1.55[a]	-2.67, -0.43	0.30	-0.39, 0.98
Improved	0.26	-0.44, 0.96	-0.25	-1.09, 0.60	-0.35	-2.07, 1.38	-0.25	-1.12, 0.62
Worsened	-0.34	-1.06, 0.38	-1.30[b]	-2.32, -0.28	-3.54[a]	-6.20, -0.89	-0.42	-0.64, 1.48

Notes: Abbreviations: Coeff., Coefficient; CI, confidence interval; Ref., reference.
[a] $p < 0.01$; [b] $p < 0.05$.