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Social inequalities in health and labour participation during the late career of older employees in Germany

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Abstract

The 1990s constitute a paradigm shift from early to late retirement in Germany. This shift was marked by the implementation of policies that aim to extend the working life of older employees. Today, the German baby boomers find themselves in a late career phase and are approaching retirement, some birth cohorts have already retired. Demographic ageing and globalisation, challenge social welfare systems and demand competitiveness from national labour markets. During the past three decades the economic risks accompanied with these phenomena have increasingly been shifted from state- and firm-level stakeholders to individuals, for example by reducing options for early exit from employment, by delaying retirement, and by deregulation of employment contracts.

Not all socio-economic groups are equally affected. Researchers have raised concerns that the burden of the above-described trends are socially structured, e.g., by education, occupation, income, and sex. This is because some populations of older workers are more strongly affected by poor working and employment conditions than others and are lacking the prerequisites and motivators to extend the working life and will therefore be at higher risk of the negative consequences of a longer working life. Thus, to counteract existing and emerging social inequalities, more nuanced pension and labour market policies are required, which account for the excessive risks for health and labour participation that some groups of older workers experience. To provide sound advice for stakeholders and decision makers more research is needed in order to provide answers to the following questions, particularly for Germany:

- What is the contribution of work factors and the health-related lifestyle to educational inequalities in physical health among older workers in Germany?
- What is the contribution of work factors, health, and work ability to educational inequalities in early exits from employment in Germany?
- Are there social inequalities in the exposure to trajectories of precarious employment and their potential effect on mental health among older workers in Germany?

The aim of the present dissertation is to investigate these questions. The dissertation consists of three studies (I, II, III), each addressing one of the above questions. The studies were published in international peer-reviewed journals. All studies used data from the German lidA (leben in der Arbeit) study, a prospective cohort study representative of socially insured employees from the German baby boom birth cohorts 1959 and 1965 (Hasselhorn et al., 2014). Study I and II used data from the first three waves (2011, 2014, 2018), study III from all waves including wave four (2022). Only panel cases were investigated.

Study I investigated the quantitative contribution of work factors and health behaviours to educational inequalities in physical health. Causal mediation analyses were conducted, including n=2653 panel cases. The study finds that work factors contribute 21% to inequalities in physical health between low and high educated women and 5% between low and high educated men (Rohrbacher & Hasselhorn,

2023). Health behaviours contributed additional 26% to these inequalities among women and 24% among men (Rohrbacher & Hasselhorn, 2023). Possibilities for development at work and the Body Mass Index may constitute key variables to level physical health inequalities among older female employees (Rohrbacher & Hasselhorn, 2023). Smoking and leisure-time physical activity may be key variables to level physical health inequalities among older male employees (Rohrbacher & Hasselhorn, 2023).

Study II investigated the quantitative contribution of work factors, health, and work ability to educational inequalities in early exits from employment via disability pension, long-term unemployment, and unspecific early labour market exits. Causal mediation analyses were conducted, including n=2438 panel cases. The study finds that social inequalities in early exits through disability pension are mainly attributable to differences in work ability between educational groups and social inequalities in early exits through long-term unemployment mainly to differences in physical health (Rohrbacher & Hasselhorn, 2022).

Study III investigated social inequalities in the exposure to trajectories of precarious employment and their effect on mental health. Group-Based Trajectory Modelling was used to compute employment quality trajectories over a follow-up period of 11 years. Associations between trajectory membership and mental health were tested using weighted logistic regression. N=1636 panel cases were included. The study finds that 20.2% of older women versus 5.5% of older men experienced a trajectory of precarious employment over 11 years during the late career (Rohrbacher et al., 2024). Among women, the experience of a precarious employment trajectory (versus non-precarious employment), increased the risk of poor mental health at follow-up. This was not observed among men (Rohrbacher et al., 2024).

In synopsis, the studies highlight that the risk of experiencing poor health and reduced labour participation is structured by social positions. This dissertation focused mainly on social inequalities between educational groups and sexes. The use of high-quality quantitative survey data, partly in combination with employment-register data and the application of modern statistical methods are major strengths of the present dissertation. The results indicate that differences in work factors and health behaviours contribute to physical health inequalities to the disadvantage of low educated older employees (study I), that the exposure to a precarious employment trajectory increases the risk of poor mental health to the disadvantage of older female employees (study III), and that educational differences in health and work ability contribute to social inequalities in early exits from employment (study II). Improving working and employment conditions as well as supporting health-promotive behaviours and work ability are – when addressing disadvantaged groups – levers to counteract social inequalities in health and labour participation during the late career of older employees in Germany.

Keywords: social inequalities; health; labour participation; precarious employment; older worker

Abstract (German)

In den 1990er Jahren fand in Deutschland ein politischer Paradigmenwechsel statt, der durch die Initialisierung von Maßnahmen zur Verlängerung des Erwerbslebens gekennzeichnet war. Heute befinden sich die deutschen Babyboomer in einer späten Erwerbsphase, einige Geburtsjahrgänge haben bereits das Renteneintrittsalter erreicht. Aktuelle gesellschaftliche Herausforderungen, wie der demographische Wandel, gefährden die Nachhaltigkeit der sozialen Sicherungssysteme. Die zunehmende Globalisierung erfordert die Wettbewerbsfähigkeit von nationalen Arbeitsmärkten. Während der letzten drei Jahrzehnte wurden die ökonomischen Risiken, die mit diesen Phänomenen einhergehen, zunehmend auf Beschäftigte verlagert, z. B. durch restriktive Maßnahmen zur Verringerung früher Erwerbsaustritte, durch die Erhöhung des Regelrenteneintrittsalters und durch die Deregulierung von Beschäftigungsverhältnissen.

Forschende verschiedener Public Health Domänen haben Bedenken geäußert, dass die dadurch entstehende Belastung sozial strukturiert ist, z. B. nach Bildung, Beruf, Einkommen und Geschlecht. Dies liegt daran, dass einige ältere Beschäftigte stärker als andere von widrigen Arbeits- und Beschäftigungsbedingungen betroffen sind, dass ihnen die Voraussetzungen und Anreize für eine Verlängerung des Erwerbslebens fehlen und dass für sie damit ein höheres Risiko negativer Folgen für Gesundheit und Beschäftigung einhergeht. Es erfordert unter anderem eine differenziertere Renten- und Arbeitsmarktpolitik, um diesen sozialen Ungleichheiten entgegenzuwirken. Um hier fundierte Hinweise für mögliche Ansatzpunkte zu liefern, sind weitere Untersuchungen zu den folgenden Fragen erforderlich:

- Welche ist die Rolle der Arbeit und des gesundheitsrelevanten Lebensstils bei der Entwicklung gesundheitlicher Ungleichheit im höheren Erwerbsalter?
- Welchen Einfluss nehmen Arbeitsbedingungen, Gesundheit und die Arbeitsfähigkeit hinsichtlich der sozialen Ungleichheit beim frühzeitigen Austritt aus dem Erwerbsleben?
- Gibt es soziale Ungleichheiten in Bezug auf die Exposition gegenüber prekären Beschäftigungsbedingungen und deren möglichem Effekt auf die psychische Gesundheit?

Das Ziel der vorliegenden Dissertation ist es, diese Fragen zu untersuchen. Die Dissertation umfasst drei Studien (I, II, III), die in internationalen Fachzeitschriften mit Peer-Review-Verfahren veröffentlicht wurden. Sie verwenden Daten der deutschen lidA(leben in der Arbeit)-Studie, einer prospektiven Kohortenstudie. Sie ist repräsentativ für sozialversicherungspflichtig Beschäftigte der deutschen Babyboom-Jahrgänge 1959 und 1965 (Hasselhorn et al., 2014). In den Studien I und II wurden Daten der ersten drei Wellen verwendet (2011, 2014, 2018), in der Studie III Daten aus allen Wellen einschließlich der vierten Welle (2022). Es wurden ausschließlich Panel-Fälle untersucht.

Studie I untersuchte den quantitativen Beitrag von Arbeitsfaktoren und Gesundheitsverhalten zu Bildungsungleichheiten bei der körperlichen Gesundheit. Hierzu wurden kausale Mediationsanalysen durchgeführt. Es wurden n=2653 Panel-Fälle einbezogen. Die Studie kommt zu dem Ergebnis, dass

Arbeitsfaktoren zu 21 % zu gesundheitlichen Ungleichheiten zwischen Frauen mit niedrigem und hohem Bildungsniveau und zu 5 % zwischen Männern mit niedrigem und hohem Bildungsniveau beitragen (Rohrbacher & Hasselhorn, 2023). Das Gesundheitsverhalten trägt zu weiteren 26 % zu gesundheitlichen Ungleichheiten bei Frauen und 24 % bei Männern bei (Rohrbacher & Hasselhorn, 2023). Bei weiblichen Beschäftigten könnten der Body-Mass-Index sowie die Entwicklungsmöglichkeiten bei der Arbeit, bei männlichen Beschäftigten das Rauchen und die körperliche Aktivität in der Freizeit Schlüsselvariablen darstellen, um gesundheitlichen Ungleichheiten in der späten Erwerbsphase entgegenzuwirken (Rohrbacher & Hasselhorn, 2023).

Studie II untersuchte den quantitativen Beitrag von Arbeitsfaktoren, Gesundheit und Arbeitsfähigkeit zu Bildungsungleichheiten beim vorzeitigen Austritt aus dem Erwerbsleben via Erwerbsminderungsrente, Langzeitarbeitslosigkeit und unspezifischer früher Ausstiege. Es wurden kausale Mediationsanalysen durchgeführt. N=2438 Panel-Fälle wurden einbezogen. Die Studie kommt zum Ergebnis, dass soziale Ungleichheiten beim frühen Austritt via Erwerbsminderungsrente vor allem auf Unterschiede in der Arbeitsfähigkeit zurückzuführen sind, soziale Ungleichheiten beim frühen Austritt via Langzeitarbeitslosigkeit dagegen hauptsächlich auf Unterschiede hinsichtlich der körperlichen Gesundheit (Rohrbacher & Hasselhorn, 2022).

Studie III untersuchte soziale Ungleichheiten hinsichtlich der Exposition gegenüber prekären Beschäftigungsbedingungen und deren Auswirkungen auf die psychische Gesundheit. Mithilfe eines Group-Based Trajectory Modelling wurden die Verläufe der Beschäftigungsbedingungen über einen Zeitraum von elf Jahren modelliert. Die Assoziation zwischen den resultierenden Trajektorien und der psychischen Gesundheit wurde mithilfe einer gewichteten logistischen Regression getestet. N=1636 Panel-Fälle wurden einbezogen. Die Studie kommt zu dem Ergebnis, dass 20,2 % der Frauen und lediglich 5,5 % der Männer über einen Zeitraum von elf Jahren konstant in prekärer Beschäftigung waren (Rohrbacher et al., 2024). Nur bei Frauen erhöhte die Exposition gegenüber prekärer Beschäftigung im Verlauf von elf Jahren die Wahrscheinlichkeit einer Verschlechterung der psychischen Gesundheit (im Vergleich zu nicht prekärer Beschäftigung) (Rohrbacher et al., 2024).

Zusammenfassend zeigen die drei Studien, dass das Risiko, einen schlechten Gesundheitszustand und eine geringere Erwerbsbeteiligung zu erfahren, durch die soziale Position strukturiert wird. Diese Dissertation konzentrierte sich hauptsächlich auf soziale Ungleichheiten zwischen Bildungsgruppen und den Geschlechtern. Die Analyse hochwertiger quantitativer Befragungsdaten, teilweise in Kombination mit erwerbsbiographischen Prozessdaten sowie die Anwendung moderner statistischer Methoden sind wesentliche Stärken der vorliegenden Dissertation. Die Ergebnisse deuten darauf hin, dass Unterschiede bei den Arbeitsfaktoren und dem Gesundheitsverhalten zu Ungleichheiten bei der körperlichen Gesundheit zum Nachteil von älteren Beschäftigten mit niedrigem Bildungsniveau beitragen (Studie I), dass die Exposition gegenüber prekären Beschäftigungsverhältnissen das Risiko einer schlechten psychischen Gesundheit zum Nachteil älterer weiblicher Beschäftigter erhöht (Studie III) und dass Unterschiede bei der Gesundheit und der Arbeitsfähigkeit zu sozialen Ungleichheiten beim

frühen Austritt aus dem Erwerbsleben beitragen (Studie II). Die Verbesserung der Arbeits- und Beschäftigungsbedingungen sowie die Förderung von gesundheitsförderndem Verhalten und der Arbeitsfähigkeit sind – wenn sie sich besonders an benachteiligte Gruppen richten – vielversprechende Ansatzpunkte, um sozialen Ungleichheiten in Bezug auf Gesundheit und Erwerbsbeteiligung während der späten Erwerbsphase älterer Beschäftigter in Deutschland entgegenzuwirken.

Keywords: Soziale Ungleichheit; gesundheitliche Ungleichheit; Erwerbsbeteiligung; prekäre Beschäftigung; ältere Beschäftigte

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List of abbreviations

ALMP	Active labour market policies
BMI	Body Mass Index
BZgA	German Federal Centre for Health Education
CI	Confidence Interval
COPSOQ	Copenhagen Psychosocial Questionnaire
ELSA	English Longitudinal Study of Ageing
ERI	Effort-Reward-Imbalance
EWL	Extended Working Life
GBTM	Group-Based Trajectory Modelling
HILDA	The Household, Income and Labour Dynamics in Australia (Survey)
HMH	Hans Martin Hasselhorn
HR	Hazard Ratio
IAB	German Institute of Employment Research
IAQ	Institute for Work, Skills and Training
ILO	International Labour Organisation/Office
lidA	leben in der Arbeit (study)
MR	Max Rohrbacher
NMS	Nuria Matilla-Santander
OECD	The Organization for Economic Cooperation and Development
PLMP	Passive labour market policies
RR	Relative Risk
S-MGA	German Study on Mental Health at Work
SES	Socioeconomic status
SF-12 MCS	Short Form Health Survey Mental Component
SF-12 PCS	Short Form Health Survey Physical Component

Preface

This thesis consists of a general introduction and discussion and three studies published in international peer-reviewed scientific journals:

I.   Rohrbacher, M., & Hasselhorn, H. M. (2023). The contribution of work and health-related lifestyle to educational inequalities in physical health among older workers in Germany. A causal mediation analysis with data from the lidA cohort study. *PLOS ONE*, *18*(8), e0285319. https://doi.org/10.1371/journal.pone.0285319

II. Rohrbacher, M., & Hasselhorn, H. M. (2022). Social inequalities in early exit from employment in Germany: a causal mediation analysis on the role of work, health, and work ability. *Scandinavian Journal of Work, Environment & Health*, *48*(7), 569–578. https://doi.org/10.5271/sjweh.4043

III. Rohrbacher, M., Hasselhorn, H. M., & Matilla-Santander, N. (2024). Associations between precarious employment trajectories and mental health among older workers in Germany: Vertical and horizontal inequalities. *Scandinavian Journal of Work, Environment & Health*, *50*(4), 290–299. https://doi.org/10.5271/sjweh.4160

1 General introduction

"Longer work lives come at the expense of people with the effects of cumulative disadvantage across the life course" (Lain & Phillipson, 2019, p. 71).

The present dissertation investigates social inequalities in health and labour participation during the late career of older employees in Germany. In view of the findings of this dissertation, the above quote, which is based on findings from England and the USA, appears to apply similarly to Germany.

To understand the findings of this thesis, it is essential to comprehend the cohort of older workers in Germany and the socio-political context, to elaborate on the existing evidence, to review theories and to discuss the plausibility of the findings. The first aim of this dissertation is to uncover social inequalities during the late career of older employees in Germany with respect to health and labour participation. The second aim is – based on the new evidence – describe and discuss a counterfactual world, in which social inequalities would be levelled. Closely linked to the latter is the third and last aim, namely, to conclude the thesis with evidence-based recommendations for meta-, meso- and micro-level stakeholders on key target variables to reduce social inequalities in the late working life.

Consequently, this dissertation consists of three chapters: In **chapter 1**, I will delineate the context and cohort under investigation and present empirical as well as theoretical knowledge on social inequalities in health and labour participation. The first chapter ends with a short description of the research gaps and study objectives. In **chapter 2**, the three studies of this dissertation will be summarised. In *study I,* the contribution of work factors and the health-related lifestyle to educational inequalities in physical health among older workers in Germany is investigated. *Study II* examines the contribution of work factors, health, and work ability to educational inequalities in early exits from employment in Germany. Lastly, *study III* explores social inequalities in the exposure to trajectories of precarious employment and their potential effect on mental health among older workers in Germany.

In **chapter 3**, the main findings and their implications for society, politics, and research will be discussed.

1.1 Work-related social inequalities from a European perspective

To date, Germany is one of the wealthiest countries in the world. The inequalities described and evaluated in the following lines and chapters are described and evaluated from a relatively narrow European perspective. Clearly, there are many continents and countries in the world, where social inequalities are much more pronounced. It is also obvious that over the past decades and centuries our society has developed, living and working conditions have improved and many social inequalities have regressed. However, new inequalities have also emerged, some are persisting, and some socio-political changes give reason to study potentially aggravating inequalities.

A multitude of research domains are interested in investigating work-related social inequalities. Each domain has their own theoretical and methodological approach. Therefore, it is important to highlight that this dissertation is written from an occupational health science and social epidemiological perspective. Consequently, certain aspects of social inequalities are in focus. In this dissertation, the focus is on social inequalities relating to working conditions and employment conditions, their interaction with a health-related lifestyle and their effects on health and labour participation.

Social inequalities exist when valuable assets or goods are not absolutely equally distributed in society (Hradil, 2001). The word absolute – in contrast to relative – thereby means that the slightest difference in possession could be described as unequal (c.f., Hradil, 2001). Relative inequality on the other hand measures the access or distribution of assets and goods relative to certain allocation criteria, such as performance, age, and education (Hradil, 2001). From a sociological perspective neither case is automatically unjust (Hradil, 2001). Hence, the question is, why do we not simply use the word 'social differences' in exchange? In this respect Hradil (2001) notes that the term social inequality is appropriate when the distribution of (dis)advantages is consistently socially structured.

Social structures are characteristics, such as age, occupation, sex etc. that per se do not indicate an advantage or disadvantage, but increase or decrease the probability of experiencing (dis)advantages (Hradil, 2001). Various social positions can be clustered as determinants of vertical inequalities and horizontal inequalities (Mielck, 2005). The term 'vertical' indicates social positions that structure societies vertically, meaning higher and lower. Examples are education, occupational status, and income (Mielck, 2005). 'Horizontal' indicates social positions that do not allow an ordering but describe nominal categories of humans, for example, male or female (sex), young or old (age) (c.f., Mielck, 2005).

Over the past decades, various theories have tried to capture the genesis and nature of social inequalities, often by using one or more of these social positions as explanatory variables. In the transition from industrial to (late-) modern post-industrial societies, prevailing social class theories have been adapted to the growing complexity of societies and co-existence and increasingly emphasise the pluralisation of lifestyles, growing individualisation and the loss of traditional class identity (Burzan, 2005; Hradil, 2001; Reckwitz, 2019). Nonetheless, the term 'social class' might still be appropriate, even topical, as the German sociologist Andreas Reckwitz (2019) points out. According to Reckwitz (2019), the downturn of the industrial sector and the rise of the service sector, along with educational expansion, have mainly led to the emergence of three new classes: the new middle class, the old middle class and the precarious class. The precarious class is described as 'losers' of post-industrialisation and is characterised by low educational attainment and structurally insecure living conditions and poor quality jobs (Reckwitz, 2019). The descriptions by Reckwitz (2019), highlight the growing importance of education in post-industrial societies and give reason to assume that some societal groups are (dis)advantaged by this development. His descriptions further suggest that socio-political changes may lead to a socially patterned accumulation of health and employment risks.

In European societies, the past decades have been characterized by several socio-political macro-trends. Related to this, two main terms dominate the literature: demographic change and globalisation. Germany is one of the fastest ageing countries and currently has the oldest population in Europe (Hinrichs, 2021), and second oldest, following Japan, of all The Organization for Economic Cooperation and Development (OECD) countries (OECD, 2023b). This can be inferred from the old-age-dependency ratio, an indicator that describes the ratio between persons aged 65 and over per 100 people of working age (i.e., 20-64 in OECD statistics) (OECD, 2023b). In Germany this ratio has risen steadily from 23.5% in 1990 to 41.4% in 2023 and is projected to rise to 58.1% in 2050 (OECD, 2023b). An increasing life expectancy, the baby boom, and a subsequent steep (so-called 'Pillenknick') and then continued decrease in birth rates are the three predominant causes attributed to this demographic trend (Börsch-Supan et al., 2020).

Demographic ageing puts the sustainability of pension systems under pressure, as a decreasing share of people of working age will have to contribute to pensions of a continuously increasing share of retired persons (Hofäcker et al., 2016). This prospect has urged policy makers to initialise a paradigm shift from early to late retirement starting around the 1990s (Hofäcker et al., 2016). Pension reforms can be broadly categorised into parametric and structural reforms (Hinrichs, 2021). Table 1 provides an overview of pension and labour market reforms in Germany, since the 1950s. Additionally, the age of the two birth cohorts which were investigated in this dissertation, based on data from the German lidA ('leben in der Arbeit') study (Hasselhorn et al., 2014), are displayed in table 1. Noticeably, both parametric and structural reforms have since been introduced. Parametric reforms constitute adjustments to existing system parameters and structures, while the latter type introduces structural changes to established systems (Hinrichs, 2021). Potential levers for parametric reforms are changes to the pensioner-worker ratio (e.g., by raising the official retirement age, as seen in Germany since the 1990s; see Table 1), the benefit ratio (e.g., lowering the pension level) and the tax funded share of pension schemes (Hinrichs, 2021). Structural reforms comprise, for example, shifts from defined-benefit to defined-contribution schemes (as seen in Germany since 1957; see Table 1), or transitions from single-pillar (public pensions only) to multi-pillar pension arrangements (e.g., by partial privatisation of pension provisions through supplementary private funded schemes as seen in Germany since 2001, see Table 1) (Hinrichs, 2021).

Another socio-political macro-trend is globalisation. The last decades were characterized by increasing international collaboration and competition, which demand increased labour market flexibility (Blossfeld et al., 2011). It has been observed that on both company and state levels, globalisation-related market risks have increasingly been shifted to employees (Buchholz et al., 2011; Krekula & Vickerstaff, 2020). On the company level, employment conditions have been made more flexible to the advantage of employers (Buchholz et al., 2011). Concurrently, welfare states have reduced their generosity in areas such as (disability) pension eligibility and unemployment benefits in order to make their national markets more attractive to businesses (Buchholz et al., 2011; Krekula & Vickerstaff, 2020).

In this context, two hypotheses originated on whether the disadvantages for employees inherent with the globalisation process are driving social inequalities or not. The first hypothesis suggests a levelling effect, whereby new labour market risks are supposed to affect all individuals alike, thus lifting conventional class patterns and levelling inequalities (Buchholz et al., 2011). In contrast, the second hypothesis suggests a rise of inequalities through a process of placing the burden of the globalisation on the already disadvantaged workers (Buchholz et al., 2011). Both hypotheses might, in fact, hold true to some extent, and this is dependent of national institutional settings (Hofäcker et al., 2011).

Welfare states act as so-called 'institutional filters' for the risks induced by globalisation and thereby structure social inequalities differently (Buchholz et al., 2011). For example, social-democratic welfare regimes feature redistributive welfare elements, focus on active and re-integrative labour market policies and life-long training programmes; they are supposed to filter globalisation risks and are generally associated with a low degree of social inequality (Hofäcker et al., 2011). Germany follows the Conservative welfare model (Buchholz & Kolb, 2011). Conservative welfare regimes are very work-centred and consequently protect some social groups better than others against market risks, which is believed to reinforce social inequalities (Hofäcker et al., 2011). Those who are already employed and established in the labour market are typically called 'insiders', while labour market entrants and those with interrupted, non-continuous careers may be regarded as 'outsiders' (Hofäcker et al., 2011). In Conservative welfare regimes, inequality patterns are predominantly structured by age, sex and education (Hofäcker et al., 2011).

Table 1

Major pension and related labour market reforms in Germany from 1957 to 2023

Year	Labour market and/or pension reform	Age of investigated cohorts and lidA[a] survey waves	
		Birth cohort 1959	Birth cohort 1965
1957	Change to Pay-As-You-Go (PAYG) system initialised; pension benefits will be inferred from contribution; normal retirement age is 65; early retirement/exit (from age 60) options for women and unemployed[1]	-	-
1968	PAYG system fully established[1]	9	3
1972	Early retirement/exit options for those with long service life (from age 63) and persons with disability (from age 60); public retirement insurance becomes accessible for self-employed and housewives[1]	13	7
1977	Divorced couples have the possibility to split pensions[1]	18	12
1986	Introduction of childcare benefits to account for gendered working lives; both sexes are granted equal treatment with respect to survivor's pensions[1,2]; regulation (originating in 1985) that unemployed aged 58 or older are not obliged to register with the unemployment agencies extended until 2000[3]	27	21
1992	Reversal of early retirement options for unemployed, disabled and women initialised; introduction of actuarial adjustments for early retirement (0,3% benefit reduction for each month of advanced retirement entry, 0,5% benefit increase for each month of postponed retirement entry)[2]; years of education counting towards service life were reduced[1]; Extension of child education benefits[1]	33	27
1994	Stepwise (from 2000 - 2001) increase of retirement age for unemployed and partially retired from 63 to 65 years[3]	35	29
1997	Stepwise (from 2000 - 2004) increase of retirement age for women from 60 to 65 years[3]; stepwise (from 2000 - 2001) increase of retirement age for long-term insured from 63 to 65 years[3]	38	32

Year	Labour market and/or pension reform	Age of investigated cohorts and lidA[a] survey waves	
		Birth cohort 1959	Birth cohort 1965
1998	Introduction of the value added tax to stabilise contributions to the pension insurance; introduction of the demographic factor for pension calculation[1]	39	33
1999	Demographic factor for pension calculation revoked; restriction of early exit paths for women and unemployed – exceptions still exist for persons with disabilities[1]; retirement age for disabled persons was raised[3]	40	34
2000	Regulation (originating in 1985) that unemployed aged 58 or older are not obliged to register with the unemployment agencies extended until 2005[3]	41	35
2001	Paradigm shift to a multi-pillar pension system by introducing the "Riester reforms"[1,2]; previous single pillar system changed by reducing pensions through modified gross indexation and providing supplementary second (capital funded) and third pillars (tax relief)[1]; redefinition of "disability": 'inability to work pension' (German: Erwerbsunfähigkeitsrente) and 'occupational disability pension' (German: Berufsunfähigkeitsrente) merge into a single 'disability pension' (German: Erwerbsminderungsrente)[1,2,3]; allowance for child education were further increased; a child bonus and pension splitting for married couples was introduced; the survivor's pension benefits were reduced[1]	42	36
2003	The means-tested minimum pension was introduced[1]; gradual introduction of Hartz reforms, enacted between 2003 and 2005 and marked by reduction of generosity of unemployment assistance and sanction measures[4]	44	38
2004	The sustainability factor was introduced[1]; reduction of the maximum duration of unemployment benefits for older workers from 32 to 18 months[3]	45/46	39/40
2004/2005	Old Age Income Act (German: Alterseinkünftegesetz)[1]; 2005 Hartz reforms: merge of social welfare and unemployment benefits (Hartz IV)[4]		
2006	Introduction of the General Equal Treatment Act (German: Allgemeines Gleichbehandlungsgesetz [AGG]) including sanctions to counteract labour market discrimination on grounds of, for example, ethnic origin, religion, gender, disability, and age; introduction of measures to support training for low-skilled and older workers in companies, such as the 'Weiterbildung Geringqualifizierter und beschäftigter älterer Arbeitnehmer im Unternehmen (WeGebAU)'[2]	47	41
2007	The 'RV-Altersgrenzenanpassungsgesetz' raised the pensionable age from 65 to 67[1,2] (stepwise from 2012 until 2029). Birth cohorts subject to changes are those born 1947 or later. This leads to an official retirement age of 66 years and two months for those born in 1959 and an official retirement age of 67 of all cohorts born after 1963, including the 1965 birth cohort. A sanction free option to retire at 65 was introduced.	48	42
2008	The Home Care Leave Act (German: Gesetz über die Pflegezeit) was introduced[2]; partial reversal of 2004 reform by extension of the maximum duration of unemployment benefits for older workers from 18 months to 24 months[4]	49	43
2009	Effective from 2009, public subsidies for partial retirement schemes were removed[3]	50	44
2011	-	52	46
		Completion of lidA[a] wave 1	
2014	Extension of care credits[2,5]; Effective from July 2014, employees with 45 contributory years have the option to retire at age 63 (plus two months for every year born after 1952, until age 65 is reached).[5]	55	49
		Completion of lidA[a] wave 2	
2015	Introduction of statutory minimum wage per hour; 'Gesetz zur besseren Vereinbarkeit von Familie, Pflege und Beruf' was introduced aiming for better reconciliation of family care and work; the introduction of the 'Pflegeunterstützungsgeld' provides options to claim caring benefits to take extra leave of up to one year[2]	56	50
2016	Introduction of the 'Arbeitslosenversicherungsschutz- und Weiterbildungsstärkungsgesetz' to promote basic skill- and further training for employed persons without vocational qualification within the unemployment insurance system[2]	57	51
2017	Optional continuation of pension contributions for individuals working past official retirement age will contribute to the level of pension benefits; workers are allowed to pre-pay pension contributions starting from age 50 (as compared to 55) to later access earlier retirement without benefit reduction[6]; abolition of old earnings test for those aged 63 to 67 with earnings up to EUR 6,300 who continue working while receiving a pension. Pensions are reduced by 40% of additional earning for annual earnings above EUR 6,300 (German: Hinzuverdienstgrenze)[6]; voluntary health check-ups from the age of 45 financed by the statutory pension insurance[2]	58	52
2018	Effective from July 2019, reduced social insurance contributions also acquire full pension entitlements; 'Doppelte Haltelinie': from 2019-2025 the replacement rate for old-age pensions is fixed at min. 48% and the bipartite pension contribution rate is set to max. 20% of covered earnings.[7]	59	53
		Completion of lidA[a] wave 3	
2020	Temporary increase of the annual supplementary income limit (German: Hinzuverdienstgrenze) to EUR 44.590 as a reaction to increased demand for medical personal during the COVID-19 pandemic; Starting 2020 the supplementary income limit has been lifted until abolished in 2023[8]	61	55
2021	Introduction of income-related pension supplement ('Grundrente') for those with at least 33 years of pension insurance contributions and low earnings throughout working life[9]	62	56

Year	Labour market and/or pension reform	Age of investigated cohorts and lidA[a] survey waves	
		Birth cohort 1959	Birth cohort 1965
2022	Increase in disability pensions through consideration of previous contribution years and the so-called 'Zurechnungszeit', simulating counterfactual contributions based on previous average income[10]	63	57
2023	Abolition of supplementary income limits (German; Hinzuverdienstgrenze). Full pensions will be granted regardless of additional earnings.[10]; persons with partial disability pension are allowed additional earnings of EUR 35,647.50, those with full disability pensions EUR 17,823.75.[10]	64	58
		Completion of lidA[a] wave 4	

[a]lidA (leben in der Arbeit) cohort study
[1]Wilke, C. B. (2008). *German Pension Reform. On Road Towards a Sustainable Multi-Pillar System*. Peter Lang Internationaler Verlag der Wissenschaften.
[2]Romeu-Gordo, L., & Sarter, E. K. (2020). Germany. In *Extended Working Life Policies* (pp. 271–281). Springer International Publishing. https://doi.org/10.1007/978-3-030-40985-2_20
[3]Dietz, M., & Walwei, U. (2011). Germany—No Country for Old Workers? *Zeitschrift Fur Arbeitsmarktforschung*, *44*(4), 363–376. https://doi.org/10.1007/s12651-011-0092-4
[4]Jacobi, L., & Kluve, J. (2007). Before and After the Hartz Reforms: The Performance of Active Labour Market Policy in Germany*. *Zaf*, *40*(October 2006), 45–64. https://econpapers.repec.org/RePEc:iab:iabzaf:v:40:i:1:p:45-64
[5]OECD. (2015). *Pensions at a Glance 2015: OECD and G20 Indicators*. OECD Publishing. https://doi.org/10.1787/pension_glance-2015-en
[6]OECD. (2017). *Pensions at a Glance 2017: OECD and G20 Indicators*. OECD Publishing. https://doi.org/10.1787/pension_glance-2017-en
[7]OECD (2019). *Pensions at a Glance 2019: OECD and G20 Indicators*. OECD Publishing. https://www.oecd-ilibrary.org/social-issues-migration-health/pensions-at-a-glance-2019_b6d3dcfc-en
[8]Deutsche Rentenversicherung [DRV]. (2021). Änderungen in der Rentenversicherung zum 1. Januar 2022.
[9]OECD (2021). *Pensions at a Glance 2021: OECD and G20 Indicators Glance*. OECD Publishing. https://doi.org/10.1787/ca401ebd-en
[10]Deutsche Rentenversicherung [DRV]. (2022). *Änderungen in der Rentenversicherung ab 1. Januar 2023*. https://www.deutsche-rentenversicherung.de/DRV/DE/Ueber-uns-und-Presse/Presse/Meldungen/2022/221221_aenderungen_rv_ab_januar_2023.html#:~:text=Ab Januar 2023 steigt der,der festgesetzte steuerfreie Rentenbetrag bestehen.

1.2 Older employees in Germany

The generation of baby boomers grew up and was socialised in the context of the socio-political macro-trends described in the previous chapter. The baby boom in Germany started around the mid-1950s (Oertel, 2022). In this dissertation, social inequalities in health and labour participation were investigated among German baby boomers. Representative samples of workers from the birth cohorts 1959 and 1965 were investigated using data from the German lidA ('leben in der Arbeit') study (Hasselhorn et al., 2014). The lidA study is a prospective cohort study, representative of socially insured employees of the birth cohorts 1959, 1965 (Hasselhorn et al., 2014) and, since 2022/2023 of the birth cohort 1971. The focus of lidA lies on the topics, work, age, health, and labour force participation (Hasselhorn et al., 2014) and it currently comprises four survey waves. In addition to the policy reforms, Table 1 shows the age of investigated cohorts for each reform year and the year when the lidA survey waves were concluded. This information may support the discussion of the findings of this dissertation in view of the socio-political context in the following chapters.

Many descriptions that follow will similarly apply to both of the investigated birth cohorts, because socio-political macro-trends and the change in societal norms are procedural phenomena and extend over generations, rather than just specific birth years. Nonetheless, specific circumstances, such as the counterculture in the 1960s and 1970s, as described by Tunney et al. (2022), may have influenced the older cohort but not the younger cohort. This section draws a rough picture of the investigated cohorts

and shows the importance of (contextual) experiences early in the life course in forming identity. Furthermore, it highlights that experiences of work and employment within a cohort may be stratified by sex, place of residence, education and (sub)cultures.

Events during baby boomers' early life may affect later life. While the early 1960s were still characterised by an authoritarian family environment, developments during the 1960s and 1970s counterculture characterised childhood and young adulthood of baby boomers (Oertel, 2022; Tunney et al., 2022). This period was marked by increasing individualism, pluralisation of life courses, growing subcultures and anti-war, anti-establishment and environmental protests (Oertel, 2022; Tunney et al., 2022). A quantitative study among older Dutch workers suggests that stronger identification with counterculture is prospectively associated with more active retirement views, which sees retirement as a new beginning or a continuation of work in a self-directed way (Tunney et al., 2022). Since the 1970s, a growing leisure orientation and a change in work morale towards 'working for life' instead of 'living for work' has been observed (Oertel, 2022). On the other hand, many traditional norms still persist to some degree among baby boomers, such as the importance of job security, the role of men as 'breadwinners' or the role of women taking care of household duties – also because established institutional structures reinforce them (Dudel et al., 2021; Lain et al., 2022; Oertel, 2022). This may be an indication that baby boomers' early life experiences and norms impact later life (e.g., views, decisions, behaviour).

Since the East-West divide, both parts of Germany were marked by different developments and different experiences: during the 70s, especially in East Germany, the energy crisis had a large impact on individuals due to the scarcity of resources (Oertel, 2022). The differences in attitudes toward female employment, influenced by differentiated public policies in the former East and West Germany, are still visible today, even after more than 30 years of unification (Dudel et al., 2021; Romeu-Gordo & Sarter, 2020). The 1970s were also marked by a high prevalence of youth unemployment (Oertel, 2022), thus, the older cohort of baby boomers under investigation might have been disadvantaged during the sensitive period of labour market entry. International evidence shows that experiences of unemployment during early career, negatively affect health (Brydsten et al., 2015; Strandh et al., 2014; Thern et al., 2017), and labour participation (Brandt & Hank, 2014) many years later.

In summary, the studies on the effects of experiences of cultural and socio-political influences, as well as economic downturns during the early career, stress the importance of sensitive periods for the life course. Sensitive periods refer to sequences during the life course in which certain exposures exert stronger effects on subsequent (e.g., health- or labour market-related) outcomes (c.f., Kuh et al., 2003). Furthermore, the studies highlight the heterogeneous experiences of individuals within cohorts. Today, crises, such as the financial crisis in 2008, terror, wars and most recently the COVID-19 pandemic with its economic consequences are thought to impact the security needs of baby boomers (Oertel, 2022). Most likely such exogenous shocks affect some socioeconomic status (SES) groups more severely than others (Bambra et al., 2021; Karanikolos et al., 2013).

While older workers are generally well established in the labour market, certain SES groups are disadvantaged in this respect. Many of today's 'young old' are on average very well established in the labour market and this can partly be explained by a high occupational position achieved during their early career due to early retirement practices for their predecessor generations (Oertel, 2022). Many live in materially secure circumstances and have access to a wide range of health-related resources (Amrhein et al., 2018). However, for certain SES groups disadvantages in education, income and assets, accumulate and increase the risk of impaired societal participation and poor health (Amrhein et al., 2018). Gender inequalities in education still persist: Both scholarly education and occupational qualifications are on average lower among women (Amrhein et al., 2018). Furthermore, income is unequally distributed along educational levels and between persons from the former West and East German states (Amrhein et al., 2018). Older employees with low education have on average half the income of those with high education (Amrhein et al., 2018). Similarly wealth is highly socially structured and this is perpetuated by inheritances (Amrhein et al., 2018). Moreover, poverty and its consequences on living conditions and health behaviours are much more prevalent among lower educated (Amrhein et al., 2018). Although the rate of women's employment participation has risen steeply during the past decades, women still take over the majority of house and care work (Amrhein et al., 2018). Every eighth woman between 55 and 65 regularly cares for a relative, while this applies to only one in 16 men (Amrhein et al., 2018). Moreover, intensive domestic care activities are more prevalent among lower educated and lower paid persons and increase the risk of negative health and labour market outcomes for carers (Amrhein et al., 2018).

This is only to name a few socio-political trends, but also persistent patterns of social inequality among German baby boomers. It was highlighted that certain experiences during youth and the early career may significantly impact health and labour market outcomes at later stages of the life course. Both socioeconomic variables, education and sex play an important role in the following parts of the dissertation. To which extent some of the described phenomena may have influenced the study findings will be elaborated more extensively in the discussion section of this dissertation.

1.3   Late careers and retirement

"Retirement is the outcome of life chances" (Ekerdt, 2010, pp. 72–73).

In this chapter, I will elaborate on the extending working life policies and their potential effects on those who are in the late stage of their career. This is followed by a short discussion on whether the framing of these policy reforms as 'extending the working life' is appropriate. Lastly, I will elaborate on the policies' potential to widen existing social inequalities during the late career.

1.3.1 Extension of working life or delay of retirement?

In chapter 1.1, an overview of policy reforms introduced since 1957 was provided. Noticeably, the 1990s constitute a turning point in the orientation of policies. Previous, more generous policies allowing some groups to exit employment earlier were gradually reversed.

There was a necessity for reforms. In view of demographic change the norm of an early retirement was reversed mainly by three levers: increasing labour market participation of women, increasing the statutory retirement age and restricting early exit paths to retirement in terms of access and generosity (Hofäcker et al., 2016; Walwei & Deller, 2021). Earlier policies from the 1970s and 1980s originated in a context of economic downturn in many European countries due to the oil price shocks and arising competition from Asian countries (König et al., 2016). Older employees were incentivised to make room for labour market entrants, options for earlier exits from the labour market were generous (Hofäcker et al., 2016). This trend took a turn when the sustainability of the pension system was questioned in prospect of the potential consequences of demographic ageing. Earlier labour market and pension policies were reversed. Measures with the goal to extend the working life were introduced, targeting the driving forces of retirement timing.

According to Hofäcker and Radl (2016) these driving forces can be classified into 'pull', 'push', 'need', and 'maintain' factors. Pull factors incentivise earlier exits from the labour market (Hofäcker & Radl, 2016) and increase the choice about one's retirement timing. Many of the 1970s and 1980s policies followed the idea of pulling older workers from the labour force by making earlier exit paths to retirement financially attractive (Hofäcker & Radl, 2016), and widely accessible for certain groups, such as unemployed and workers with health issues. Especially blue collar-workers were attracted by these incentives (Hofäcker et al., 2016). Push factors are also associated with earlier exits but through a mechanism that hampers older workers ability and opportunity to continue employment (Hofäcker & Radl, 2016). In contrast to push factors, maintain factors enable older workers to extend their working life (Hofäcker & Radl, 2016). Lastly, need factors increase the need to extend the working life and reduce the choice about the retirement timing (Hofäcker & Radl, 2016). Since the 1990s, maintain factors and need factors have gained relevance due to the nature of the policy reforms introduced (Hofäcker & Radl, 2016). Policies that address maintain factors, follow the goal of 'active ageing' and comprise training opportunities, measures to enhance older workers' employability and measures to mitigate age discrimination at the workplace (Hofäcker & Radl, 2016). In contrast, policies that restrict early exit paths and raise the retirement age have the potential to increase the older workers' 'need' to extend the working life (Hofäcker & Radl, 2016).

As can be seen from Table 1, the members of the two cohorts studied, based on lidA data were 33 (born 1959) and 27 (born 1965) years old, when the reversal of early retirement was initialised in 1992.

Hence, employees had to adapt their expectations about retirement timing early in their career. Importantly, those with shorter education may have already worked for more than a decade, while those with longer education could have just entered the labour market a few months or years previously.

The policy reforms have contributed to changes in labour participation. In Germany, between 1990 and 2014 the labour force participation among older men and women increased continuously. Especially among the age group of 60-64, the trend reversal was clearly visible with the 1990s marking a turning point in labour force participation. Among men in this age group, labour force participation rose from around 30% in 1990 to around 65% in 2014 (35% points increase), among women from around 10% to around 50% (40% points increase) (Rausch et al., 2018). Also, in the 55-59 age group, labour force participation rose steadily with few local downturns from approx. 75% to approx. 85% (10% points increase) among men and approx. 40% to approx. 75% (30% points increase) among women (Rausch et al., 2018). More recent OECD data shows that this trend continued until 2022 (OECD, 2023a).

Female employment increased noticeably over the past decades and this happened largely in the form of part-time employment (Duell & Vetter, 2020). Female employment growth can – to some extent – be attributed to policy measures, which have improved the availability of (full-day) childcare (Duell & Vetter, 2020).

However, early exits from employment are still common in Germany. Despite the observed trend of increasing labour force participation among older workers, the average effective age of labour market exit in Germany in the period of 2015-2020 (men: 63.1; women: 63.2), was still below normal retirement age (65-57) (OECD, 2021). Moreover, less than half (46.1% of men and 45.3% of women in 2021) of newly acquired old age pensions are accessed after a transition from socially insured employment (IAQ, 2022). Disability pension, unemployment, and exits from social insurance are still common early exit pathways.

While the fraction of disability pensions in total pension receipt (i.e., ratio between disability pension and old age pension) has decreased from 19.7% in 2001 (redefinition of disability) to 15.8% in 2022, this decrease has been attributed to numerically greater birth cohorts entering old age pensions during the recent years, rather than to policy reforms (Institute for Work, Skills and Training [IAQ], 2023). Furthermore, a noticeable share of workers (12.2% of men and 9.1% of women in 2021) are still transitioning to retirement through unemployment (i.e., unemployed according to SGB III and unemployment beneficiaries according to SGB II) (IAQ, 2022). Lastly, the most important status (with 21.6% of men and 27.9% of women in 2021) before acquiring old age pension apart from socially insured employment has been passive insurance, which applies to those who stopped paying contributions, for example, due to economic inactivity or marginal employment (IAQ, 2022).

Do the policy reforms stimulate an extension of working life or a delay of retirement? Many of the policy reforms shown in Table 1 were introduced under the term, 'extension of working life', in short 'EWL'. Inspired by the 'active ageing' agenda by the World Health Organisation (Ogg & Rašticová, 2020), EWL policies were introduced in many European countries starting around the 1990s. One key element of extending working lives are increased efforts to provide continued training for (older) workers and to support the employability of the labour force (Ogg & Rašticová, 2020). However, today effective policies to support workers' employability are still lacking (Romeu-Gordo & Sarter, 2020; Street & Ní Léime, 2020) and seem to have been given lower priority compared to other EWL measures. An instrument that has much more widely and effectively been used is the increase of the statutory retirement age (OECD, 2017b, 2019, 2021; Romeu-Gordo & Sarter, 2020). Consequently, it is reasonable to ask, whether EWL policies are effectively solely delaying retirement by almost exclusively targeting financial pull factors (Buchholz et al., 2013). Several researchers would argue that the policies which are in fact needed to enable older workers to extend their working life are very different from those installed (Hofäcker et al., 2016; Romeu-Gordo & Sarter, 2020; Street & Ní Léime, 2020). According to Street and Ní Léime (2020), the internationally widespread instrument of delaying retirement mainly serves state fiscal interests, while individuals' needs are not sufficiently addressed. This has also raised concerns of a widening of social inequalities.

1.3.2 Widening of social inequalities?

"A reduction in the duration of claiming a pension is composed of two factors: delayed claiming a pension and earlier death" (Bellés-Obrero et al., 2022, p. 24).

During the past decades many researchers have raised voices to highlight that EWL policies may have aggravated social inequalities in a variety of outcomes (e.g. Buchholz et al., 2013; Hasselhorn, 2020; Hess, 2018; Hofäcker et al., 2016).

One main argument is that past retirement reforms restrict the control over the late career and the timing of the transition into retirement for some groups more heavily than for others (Hess, 2018). The change in normal retirement age is likely putting more of a burden on those groups of workers, who would prefer to retire early but have to delay retirement due to financial needs (Hess, 2018). In many cases, these are lower educated and low-skilled workers with less attractive jobs in terms of working and employment conditions, who have formerly been attracted by early exit pathways (Hess, 2018; Hofäcker et al., 2016).

The political delay of retirement and the obstruction of earlier exit paths for lower educated may have a side effect of an increase of social inequalities during the late career of employees. One argument is that existing inequalities in working conditions, employment conditions and health, may aggravate since the reforms may constrain older workers' choices regarding the timing of exits from employment.

Furthermore, especially lower educated, lower-skilled workers may lack the prerequisites to delay retirement. Lastly, the consequences of delaying retirement may be beneficial for some older workers and adverse for others. The following arguments lend weight to these concerns.

Adverse working conditions are socially structured. Lower educated and lower-qualified workers have worse physical working conditions and less job resources, such as control over their work, possibilities for development, material and immaterial rewards and social support (Dieker et al., 2019; Dragano et al., 2016; Dragano & Wahrendorf, 2016; Robroek et al., 2015; Schram et al., 2021; Schütte et al., 2015).

Poor employment conditions are socially structured. Particularly female and low-skilled workers are more prone to working in precarious jobs (Blossfeld et al., 2011; Eichhorst & Tobsch, 2015). A recent study using data from the German Study on Mental Health at Work (S-MGA) showed that poor employment conditions, such as job insecurity and an inadequate income are more prevalent in lower-skilled workers (Demiral et al., 2022).

The prerequisites of extending the working life are socially structured (push and maintain factors). Those with lower SES more often experience health problems (Dieker et al., 2019; Lampert et al., 2017; Mackenbach, 2006; Schram et al., 2021). Good health, however, is an important prerequisite to extend the working life and is likely a privilege of high SES groups (Hofäcker et al., 2016; Shi et al., 2022). Poor health on the other hand does not necessarily predict earlier exit from employment (Hasselhorn et al., 2022). Other factors such as work ability and opportunities to work may mediate the relationship between poor health and premature exits (Hasselhorn et al., 2022). Work ability from an occupational health perspective describes the balance or fit of workers' resources and their work demands (Ilmarinen, 2007). Hence, negative effects of poor health on the ability to work can be buffered by increasing older workers' resources and by adapting the work demands. The association between work ability and early exit from work is clearer than the association between health and early exit. Several studies have found low work ability to be a strong predictor of several early exit paths (Alavinia et al., 2009; Bethge et al., 2021; Boissonneault & De Beer, 2018; Jääskeläinen et al., 2016). Workers with low SES are more likely to experience low work ability (Aittomäki et al., 2003; Costa & Sartori, 2007).

The motivators of extending working life are socially structured (pull and need factors). Financial security is an important determinant of retirement timing (Hofäcker et al., 2016). In the normative framework of the 1970s and 1980s, financial incentives were important pull factors to motivate older, low-skilled, blue-collar workers to leave employment to make room for new labour market entrants (Hess, 2018; Hofäcker et al., 2016). With the reversal of this norm and the introduction of new measures

to 'extend the working life', financial insecurities have left many of those workers with no choice but to delay retirement beyond statutory retirement age (Hofäcker et al., 2016). The reduction of pull factors simultaneously increased the importance of the 'need factors' as determinants of retirement timing (Hofäcker & Radl, 2016). This may have aggravated social inequalities, since the choice about retirement timing has thereby effectively become more restricted for those with higher financial insecurities during the late career, which are often low-skilled and female older workers (Hess, 2018; Hofäcker et al., 2016).

The consequences of delayed retirement are socially structured. In a systematic review Baxter et al. (2021) showed that the beneficial or neutral effects of extending working life on health are stratified by certain demographic variables. Beneficiaries are predominantly male and older workers with the possibility of reducing their working time to part-time during the late career (Baxter et al., 2021). Conversely, low-quality and low-reward jobs increased the risk for adverse effects on general and physical health (Baxter et al., 2021). Again, such jobs are more prevalent among lower educated workers as described above. Even worse, in a recent study on the effects of the 1967 Spanish pension reform, Bellés-Obrero et al. (2022) found that delaying employment exit by one year increases the chance of dying between ages 60 and 69. The authors could attribute these negative consequences of delaying retirement to the loss of access to early exit paths to retirement (Bellés-Obrero et al., 2022). Again, these effects were socially structured: The effects on mortality were greatest for people with higher physical work demands and lower education (Bellés-Obrero et al., 2022). As a consequence, for the said groups, the period where pensions could be claimed is not only reduced by a delay of retirement but also by earlier death (Bellés-Obrero et al., 2022). These findings may, to some extent, also be applicable to Germany, where pension policy reforms consisted mainly of increasing the retirement age and restricting early exit routes. However, the described effects on mortality might be weaker in Germany since the increase of retirement age has been more gradual there. Furthermore, the Spanish pension replacement rate is high (80%), thus a stronger reliance on state pensions in Spain may aggravate effects of pension reforms.

This chapter set out how social inequalities in push, pull, need, and maintain factors to extend the working life are reflected in health and mortality risks of delayed retirement. In view of existing inequalities and the insufficiently nuanced labour market and pension policies one may assume that, "there are significant numbers of people who may be damaged by continuing to work" (Krekula & Vickerstaff, 2020, p. 38), which in turn may widen existing social inequalities.

1.4 Theoretical foundation

In this chapter, the theoretical considerations of study I-III of this dissertation will be outlined. The aims, methods, and results of the three studies will be described in chapter 2. The studies investigate the following questions.

- Study I: What is the contribution of work factors and the health-related lifestyle to educational inequalities in physical health among older workers in Germany?
- Study II: What is the contribution of work factors, health, and work ability to educational inequalities in early exits from employment in Germany?
- Study III: Are there social inequalities in the exposure to trajectories of precarious employment and their potential effect on mental health among older workers in Germany?

The theoretical model (chapter 1.4.1), concept (chapter 1.4.2) and framework (chapter 1.4.3) described, served as references to derive research questions, to describe the focus of each study and methodological considerations and lastly, to discuss the research findings against the background of further (unexplored) model/ framework components (see chapter 3). As an overall framework, I used the lidA conceptual framework on work, age and employment (for the German version see Hasselhorn et al., 2015; for an English version see Hasselhorn & Apt, 2015). It served as a guide to account for the complexity, individuality, procedural nature and structural dependency of health and labour participation at higher employment age. The lidA conceptual framework covers several domains on the macro-, meso- as well as micro-level and highlights their interrelation (see Hasselhorn et al., 2015; see Hasselhorn & Apt, 2015): social context, economy; labour market; private domain; social position; work content and organisation; health-related lifestyle; motivation; health; work ability; finances; legislation; employment exit. Each of the three studies of this dissertation were planned by first selecting subsets of variables from the lidA conceptual framework and second, based on the subsets, researching theoretical models, concepts, and frameworks with a narrower focus. These will be described in the following chapters.

1.4.1 Study I: social inequality in health

Introductory, the term social inequality was explained from a sociological perspective (see chapter 1.1). To understand social inequalities in health – often termed health inequalities – a social epidemiological approach may be adopted. The aim of social epidemiology is "to investigate whether, and if so to what degree, socially disadvantaged population groups are also disadvantaged with regard to their health" (Spallek et al., 2012, p. 6.e3). Two hypotheses on the aetiology of health inequalities have been proposed, the causation hypothesis (German: Kausation) and the selection hypothesis (German: Selektion) (Hoffmann et al., 2020). While causation describes the case where one's social position determines one's health, selection means that one's health (e.g., in childhood) determines one's social position (e.g., in later life) (Hoffmann et al., 2020). To some extent both hypotheses might hold true in different phases of the life course (Hoffmann et al., 2020). However, for older workers in their late careers, evidence

from longitudinal studies strongly suggests that the social position determines health and is thus in support of the causation hypothesis (Dieker et al., 2019; Schram et al., 2021).

The most popular theoretical model on the explanation of the association between social inequalities and health inequalities in Germany, stems from the author Mielck (Elkeles & Mielck, 1997; Mielck, 2005; Spallek et al., 2012). It follows the causation hypothesis by assuming that the socio-economic status causes poor health via differences in first, health affecting demands and resources and their (im)balance, second, differences in healthcare provision (and utilisation) and third, differences in health behaviours (Mielck, 2005; Mielck & Wild, 2021). The different paths are shown in Figure 1. This model was used to derive the research question for study I and conceptualise the statistical analyses (see chapter 2). The focus was on the model components A, B, D and E.

Figure 1

Model on the explanation of the association between social inequalities and health by Mielck (2005)
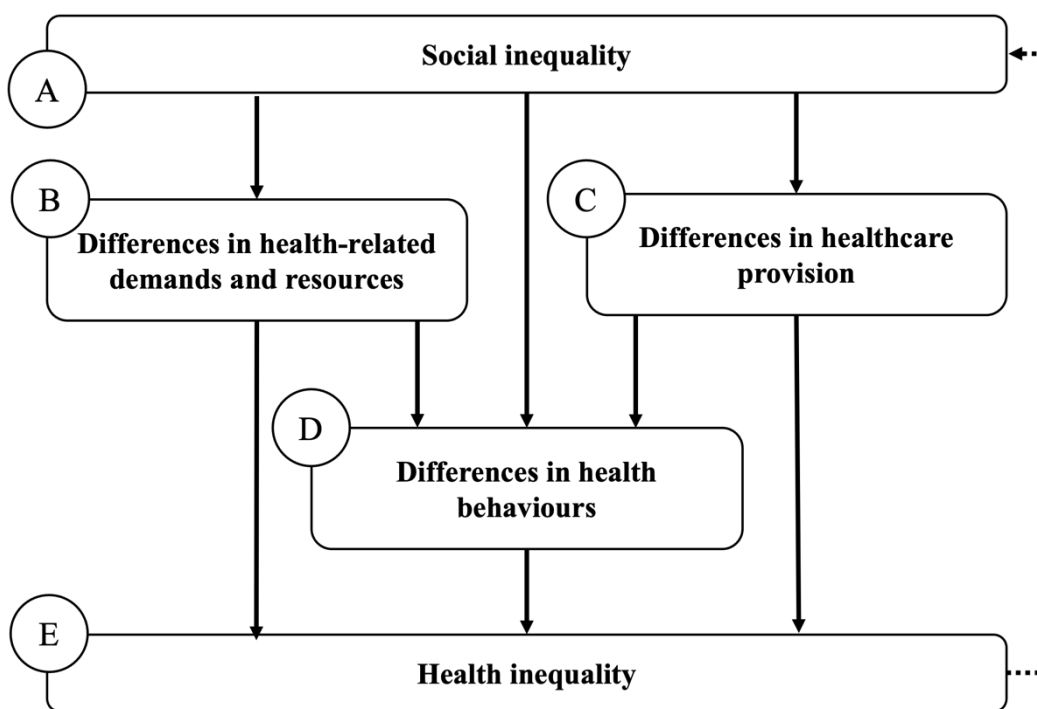
Adapted from *Soziale Ungleichheit und Gesundheit. Einführung in die aktuelle Diskussion* (p. 53), by A. Mielck, 2005, Hans Huber, Hogrefe Verlag (ISBN: 978-3-456-84235-6). Copyright 1. Auflage 2005 © 2005 Verlag Hans Huber, Hogrefe AG, Bern. Adapted with permission.

1.4.2   Study II: social inequality in early exit from employment

In this chapter, the theoretical foundation for the second study will be described. In chapter 1.3.1 the push-pull-need-maintain typology (Hofäcker & Radl, 2016) was briefly explained in order to highlight

that past policy reforms since the 1990s may have increased the importance of need and maintain factors over the more classical push and pull factors. It was also outlined that many reforms mainly targeted financial pull-factors. This theoretical concept is useful to classify the nature and context of driving forces of retirement as well as the timing and modality of retirement (or labour market exit). Furthermore, different stakeholders on the macro-, meso- and micro-level who interact in creating 'pushes', 'pulls', 'needs' and 'maintains' can be identified.

First, the nature of the driving forces of retirement timing can be classified according to two dimensions, which can be seen in Table 2 below. The first dimension indicates whether driving forces constitute economic (des)incentives for an employment exit (e.g., pension replacement rates), or employment opportunities (e.g., labour demand) (Hofäcker et al., 2016). The second dimension may be interpreted as indicating both the timing of retirement (early or late) as well as the political paradigm of early versus late retirement (Hofäcker & Radl, 2016). Financial incentives for early exit as they were widely promoted in the 1970s and 1980s can be classified as pull factors (Hofäcker & Radl, 2016). Financial incentives or sanctions to delay retirement can be classified as need factors. Concurrently with the political paradigm shift to stimulate late retirement, need factors gained importance (Hofäcker et al., 2016). Push factors can be defined as "institutional or structural features that impede the continued employment of older workers" (Hofäcker & Radl, 2016, p. 3). A lack of employment opportunities is just one example (Hofäcker et al., 2016), but also workplace characteristics and older workers' health fall into this category. Employment opportunities that facilitate an extended working life and thus late retirement, can be classified as maintain factors and comprise active ageing policies and the promotion of older workers' employability (Hofäcker & Radl, 2016). Similar to need factors, maintain factors have gained importance in the 'late retirement era' since the 1990s (Hofäcker et al., 2016).

Table 2

Theoretical concept on driving forces of retirement timing in the early and late retirement era by Hofäcker and Radl (2016)

	Early	**Late**
Economic incentives	Pull	Need
Employment opportunities	Push	Maintain

Adapted from "Retirement Transitions in Times of Institutional Change: Theoretical Concept," by D. Hofäcker and J. Radl, in D. Hofäcker, M. Hess and S. König (Eds.), *Delaying Retirement* (p. 17), 2016, Palgrave Macmillan UK (https://doi.org/10.1057/978-1-137-56697-3_1). Copyright 2016 by the Editor(s) (if applicable) and the Author(s). Adapted with permission.

Implicitly, the theoretical concept also suggests a certain modality of staying or leaving employment. While push and need factors tend to impede the degree of choice regarding retirement timing, pull and

maintain factors tend to improve it (Hofäcker et al., 2016). Pull factors are associated with early voluntary exit from employment, maintain factors with late voluntary retirement, whereas need factors drive involuntary late retirement (Hofäcker et al., 2016). Lastly, push factors are associated with involuntary early exit from employment (Hofäcker et al., 2016).

Moreover, these drivers of retirement timing can be classified according to actors or stakeholders. In this respect three categories are of relevance, namely institutional determinants (macro-/state-level), workplace determinants (meso-/firm-level) and individual determinants (micro-level) (Hofäcker et al., 2016). In short, Hofäcker and Radl (2016) describe that macro- and meso-level determinants of labour force exit construct opportunities and constraints under which individuals have a certain degree of choice, thereby highlighting the role of higher level contexts as facilitators, or barriers for individual choices and behaviours. Individual determinants comprise factors such as individuals' health, education and retirement preferences (König et al., 2016).

Table 3 comprises a selection of examples for each quadrant of the theoretical concept and for each stakeholder category. The examples shown in Table 3 derived from the descriptions by authors Hofäcker and Radl (2016), and were supplemented by examples from Jensen (2021) and König (2016).

The focus of study II was on work factors (workplace), health (individual), and work ability (workplace & individual), which may be regarded as either push factors or maintain factors depending on positive or negative expressions.

Table 3

Examples for institutional, workplace, and individual determinants of retirement timing and modality, assigned to the push-pull-need-maintain typology

	Early	Late
Economic incentives	Institutional pull: Low statutory retirement age; low normal retirement age; early exit paths to retirement; financial incentives for early exit (generous pension eligibility criteria and benefits) Workplace pull: Financial incentives for early exit Individual pull: Personal and spousal retirement preferences Assumed modality: voluntary	Institutional need: High statutory retirement age; restricted access to early exit pathways; low replacement rates of pensions; monetary sanctioning of early exits Workplace need: Defined contribution instead of defined benefit occupational pension plans Individual need: Financial need; fear of becoming isolated Assumed modality: involuntary
Employment opportunities	Institutional push: High unemployment; economic downturns; low levels of employment protection Workplace push: Poor quality work; physical and psychosocial strain; discriminatory practices	Institutional maintain: Anti-discrimination legislation; job opportunities Workplace maintain: Training and qualification measures; high quality jobs; work time (control); supportive workplace arrangements

	Individual push: Qualification deficit; low employability; poor health; low education	Individual maintain: High employability; good health; high education; personal and spousal retirement preferences
	Work & individual push: Low work ability	Work & individual maintain: High work ability
	Assumed modality: involuntary	Assumed modality: voluntary

1.4.3   Study III: social inequality in employment conditions and mental health

Despite growing attention to precarious employment, standard employment is still widespread and the norm in European countries (Weston & McMunn, 2023). There are varying reports of how precarious employment has developed over the past decades. Some claim a very flat growth (Weston & McMunn, 2023), some report noticeable increases (e.g., for Sweden) (Bodin et al., 2022). The difference in findings may be a result of differentiated developments of employment conditions between countries over the past decades, but also because precarious employment has been defined and measured in various ways, leading to diverging findings. Therefore, it is important to clarify the definitions of precarious employment used within this dissertation. This is best done by first illustrating the features of standard employment, then defining atypical employment and lastly elaborating on the definition of precarious employment and its difference to atypical employment.

Standard employment has various features that ensure continued security for employees. The first feature is contractual security, for example, through permanent contracts and income security (Flecker, 2017; ILO, 2016). Furthermore, standard employment is subject to social protection, for example, protection against the risks of unemployment and disability, and is also subject to labour laws (Flecker, 2017; ILO, 2016). Moreover, workers in standard employment typically have different options to claim their rights, for example, through collective bargaining and representation in trade unions (Flecker, 2017; ILO, 2016). According to Standing (Standing, 2007), this type of contract produces several forms of labour-related security: labour market security (e.g., adequate income opportunities), employment security (e.g., protection against dismissal), job security (e.g., opportunities to retain employment), work security (e.g., occupational health and safety), skill reproduction security (e.g., possibilities for further training and qualification), income security (e.g., adequate and stable income) and representation security (e.g., right to strike, representation through trade unions).

Non-standard or atypical employment constitutes a deviation from any of the standard employment dimensions (ILO, 2016) and will therefore be accompanied by limited labour-related security. For example, a person in temporary employment with an adequate income and social protection could be considered as atypically employed. Self-employment and marginal employment – whether they are permanently employed or not – are further examples for non-standard employment since both are partly exempted from social security contributions and benefits (ILO, 2016; Konle-Seidl, 2021).

Precarious employment is understood as a multi-dimensional construct of accumulated unfavourable employment quality characteristics (Bodin et al., 2020). Kreshpaj et al. (2020) suggest three dimensions that characterise precarious employment relations: employment insecurity, income inadequacy and a lack of rights and protection. The dimensions described by Kreshpaj et al. (2020) served as a reference for the definitions that were applied in the third study.

The pathways through which precarious employment is related to health are to this date not fully understood (Bodin et al., 2020). Benach et al. (2014), Julià et al. (2017), and Bodin et al. (2020), propose three pathways through which precarious employment relationships exert their effect on health: First, persons in precarious employment are more likely to also experience adverse working conditions, which may mediate the effects of employment conditions on health (*pathway 1 through work environment hazards*); second, the experience of precarious employment may constrain a person's choice over their own professional and personal life (*pathway 2 through the experience of precariousness, such as insecurity and powerlessness*); third, the effect of precarious employment on health may be transmitted by incomes below subsistence level, which in turn influence multiple other determinants of health (*pathway 3 through material deprivation*).

The theoretical framework for precarious employment by Bodin et al. (2020), which is displayed below (Figure 2), illustrates the different mechanisms through which precarious employment is related to health. In the past, scientists have repeatedly highlighted that precariousness is a subjective experience, rooted in objective employment conditions (c.f., Benach et al., 2014; c.f., Greenhalgh & Rosenblatt, 1984; c.f., Sverke et al., 2002).This subjectivity is illustrated by the series of intermediate variables linking precarious employment (objective terms) with health in the theoretical framework by Bodin et al. (2020). The illustration further highlights the role of the country-specific political and social contexts, which act as moderators of the exposure and effect of precarious employment (Blossfeld et al., 2011; Bodin et al., 2020; Padrosa et al., 2022). In study III, the three pathways were not explicitly investigated, but the theoretical framework served as a reference to discuss the findings. The focus of study III was on the association between the precarious employment relationship (instability and poor terms) and mental health.

Figure 2

Theoretical framework for precarious employment
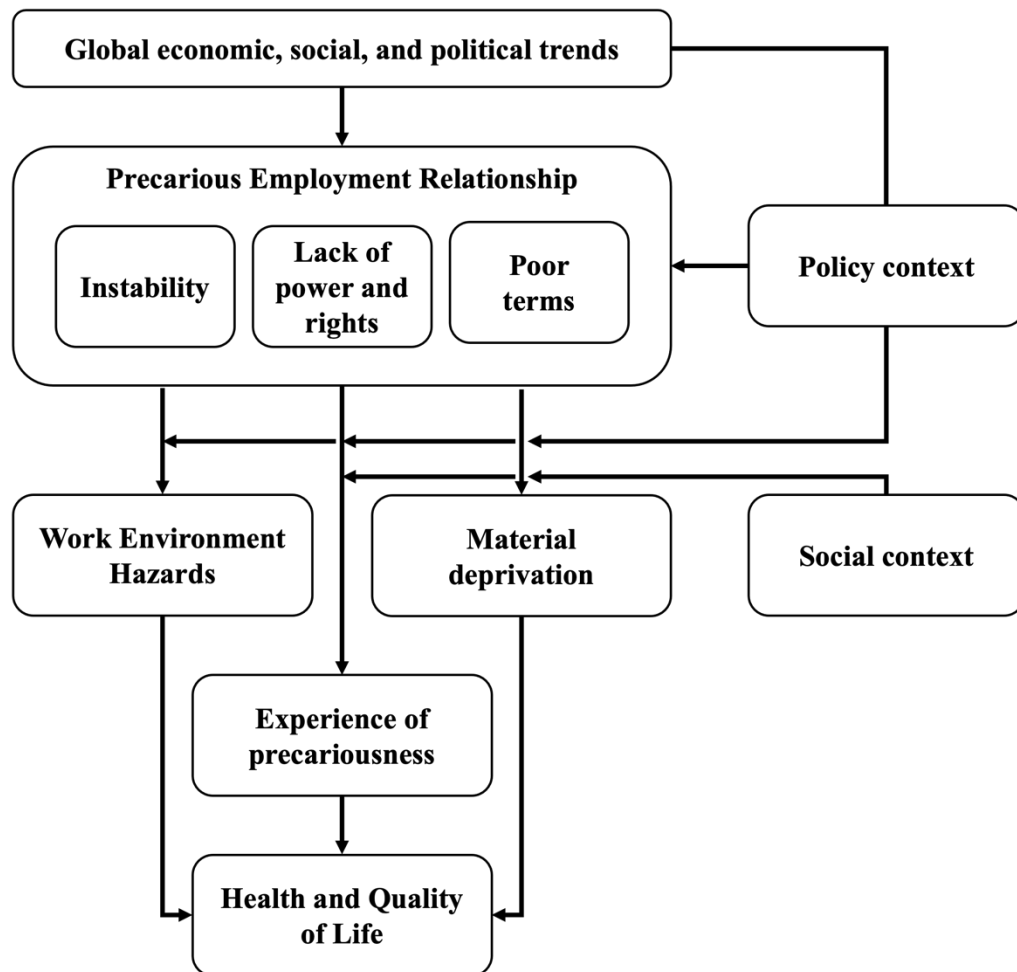
Adapted from "Precarious employment in occupational health – an OMEGA-NET working group position paper," by T. Bodin, Ç.Çağlayan, A. H. Garde, M. Gnesi, J. Jonsson, S. Kiran, B. Kreshpaj, T. Leinonen, I. S. Mehlum, E. Nena, C. Orellana, T. Peckham, N. Seixas, C. Vanroelen and M. Julià, 2020, *Scandinavian Journal of Work, Environment & Health*, *46*(3), p. 325 (https://doi.org/10.5271/sjweh.3860). CC BY 4.0 DEED.

1.5   Summary of evidence and research gap

This chapter provides a short overview of existing evidence regarding the contribution of work, employment, health, and the health-related lifestyle to social inequalities in health and labour participation. Each chapter 1.5.1 to 1.5.3 concludes with a description of the research gap.

1.5.1 Work factors, health behaviours, and social inequality in health

There is extensive evidence that health inequalities exist and that work factors and health behaviours are relevant contributing factors. Health complaints are much more prevalent among groups with lower SES (Lampert et al., 2017; Mackenbach, 2006). Among older workers, current evidence supports the causation hypothesis rather than the selection hypothesis (Dieker et al., 2019; Schram et al., 2021), which means that a person's SES is causally related to their health. Depending on the measurement of the SES and the health outcome, social gradients may be more or less pronounced (Hämmig & Bauer, 2013; Lahelma et al., 2006) or can be underestimated (Delpierre et al., 2009). To study causal associations a temporal order of cause and effect is vital (Hill, 1965). The last two arguments (i.e., SES operationalisation and temporal ordering) are decisive reasons to study the relationships between education and physical health over other indicators of exposure and outcome. While physical health inequalities exist in the expected direction for all of the three most common operationalisations of the SES (education, occupation, income), mental health inequalities are often only observed when using income as the indicator (Lahelma et al., 2006; Rohrbacher & Hasselhorn, 2023).

Many adverse work factors and health behaviours are more prevalent among lower SES groups. Lower-skilled workers commonly experience high physical demands and a lack of resources at work (Dieker et al., 2019; Dragano et al., 2016; Schram et al., 2021; Schütte et al., 2015). Similarly, health behaviours such as smoking, leisure-time physical activity and a high BMI (as a proxy) are more prevalent among lower SES groups (Beenackers et al., 2012; Hoebel et al., 2016; Lampert et al., 2013; Robroek et al., 2015). However, quantitative demands and efforts at work (according to the effort-reward-imbalance model) have been observed to be more prevalent among higher-skilled workers (Dieker et al., 2019; Dragano & Wahrendorf, 2016; Robroek et al., 2015).

To summarise: Both work factors and health behaviours have been shown to contribute to health inequalities among workers (Dieker et al., 2019). However, only very few longitudinal studies exist (Schmitz, 2016; Schram et al., 2021; Warren et al., 2008) that allow for causal inferences and, until September 2022 (submission date of first study), none that studied older workers in Germany existed.

1.5.2 Work factors, health, work ability, and social inequality in early employment exit

There is emerging evidence that many early exits from employment happen involuntary (Mäcken et al., 2021), since financial pull factors have been abolished for many groups of workers through a political paradigm shift from early to late exit (Hofäcker et al., 2016). For many older workers, financial necessities constitute a need factor, likely forcing them to delay retirement (Hess, 2018). However, early exits still occur and may likely be traced back to several push factors. There is evidence suggesting that adverse working conditions and poor health are important determinants of early exits from employment: Poor health is a risk factor for early exit from employment (Van Rijn et al., 2014) and this risk is larger among lower SES groups (Carr et al., 2018; Schuring et al., 2019). Similarly, there is evidence that

adverse working conditions, such as high physical and quantitative demands and a lack of job control increase the risk of early exits (d'Errico et al., 2021; Robroek et al., 2013). Again, many of these conditions are more prevalent among those with lower SES (Dieker et al., 2019; Robroek et al., 2015; Schram et al., 2021). Also low work ability, defined as the balance between work demands and workers' resources (Ilmarinen, 2007), has been shown to predict early exits from employment (Alavinia et al., 2009; Bethge et al., 2021; Boissonneault & De Beer, 2018; Jääskeläinen et al., 2016) and this effect is larger among lower SES groups (Aittomäki et al., 2003; Costa & Sartori, 2007).

So far, very few longitudinal studies have examined both (De Breij et al., 2020; Robroek et al., 2015; Schuring et al., 2019), the association between SES (the main exposure) and work factors, health, and work ability (the mediators) and the association between SES and early exits (the outcome) simultaneously. This is, however, vital to make inferences about the intermediates' contributions to social inequalities in early exit from employment. Furthermore, up to the submission date of the second study (January 2022), none had investigated work ability next to work factors and/or health, and none had focussed on older workers in Germany. More concisely, none of the existing studies has quantified the contributions of work, health, and work ability to social inequalities in early exits from employment among older employees in Germany (Rohrbacher & Hasselhorn, 2023).

1.5.3   *Social inequality in employment conditions and their effect on mental health*

Macro socio-political trends, most importantly globalisation, raise concerns of a progressive deterioration of employment conditions, since companies are trying to shift emerging market risks to employees via deregulation and flexibilisation (Blossfeld et al., 2011; Buchholz & Kolb, 2011). It appears that welfare states act as so-called 'institutional filters', whereby they moderate the effects of globalisation and growing international competition on workers (Blossfeld et al., 2011; Bodin et al., 2020; Padrosa et al., 2022). It has been suggested that depending on the nature of the welfare state, the development of precarious employment behaves differently, with some welfare states being more prone to a widening of respective social inequalities (Blossfeld et al., 2011). The German welfare state, also called Conservative, Bismarckian or Central European welfare state, is said to be more rigid compared to other expressions of welfare states, and thereby less able to absorb the risks of temporary employment and other forms of flexible employment (Blossfeld et al., 2011; Buchholz et al., 2009). Moreover, the strong work-orientation of this welfare regime is believed to highly disadvantage workers with fragmented careers, compared to well established workers following continuous full-time employment (insider-outsider logic) (Buchholz & Kolb, 2011).

The current evidence (on submission date of the third study in August 2023), suggests adverse effects of precarious employment on mental health (Rönnblad et al., 2019). However, there is a clear bias towards high-quality studies being conducted in Scandinavian countries and thus within socio-democratic welfare states (Rönnblad et al., 2019). Given the important role of the policy and social context

(Bodin et al., 2020), it is reasonable to doubt that these findings are equally valid for German (older) workers. For Germany, the availability of longitudinal studies that examine the relationship between precarious employment and mental health among workers is very limited. A design feature of the only two existing German studies on the topic (Demiral et al., 2022; Pförtner et al., 2022) that may be regarded as a drawback, is the inclusion of workers from many diverse age groups. Given the German context, different mechanisms may apply with respect to both exposure to, and the effect of precarious employment on mental health depending on workers' age and proximity to retirement (c.f., Rohrbacher et al., 2024). Thus, including various highly differing age groups – even when adjusting for age – might obscure the true effect sizes within generations. Furthermore, one of the two studies (Demiral et al., 2022) only measures exposure at one point in time, which may lead to exposure misclassification given the cumulative effect of precarious employment conditions and their evolution over time (Bodin et al., 2020; Vives et al., 2020).

To conclude, there is no German study (on the submission date of the third study in August 2023), that examines the longitudinal association between trajectories of precarious employment (measured at more than two points in time) and mental health focussing on employees of a single generation, for example, older workers from the German baby boom generation.

1.6 Objectives and research questions

1.6.1 Objectives

The aim of this dissertation is to add to existing knowledge about social inequalities related to working conditions, employment conditions as well as the health-related lifestyle and their effects on health and labour participation by addressing the above elaborated research gaps (chapter 1.5).

This includes pinpointing key target variables that contribute to the development of social inequalities during the late career of workers and to quantify this contribution. Moreover, the aim is to go beyond a description of social inequalities and aim for causal inference, which requires a longitudinal perspective. Lastly, the thesis will contribute to current debates around contemporary socio-political challenges and provide new evidence for future policy making.

1.6.2 Research questions

The following three research questions will be answered:

a) What is the contribution of work factors and the health-related lifestyle to educational inequalities in physical health among older workers in Germany?
b) What is the contribution of work factors, health, and work ability to educational inequalities in early exits from employment in Germany?

c) Are there social inequalities in the exposure to trajectories of precarious employment and their effect on mental health among older workers in Germany?

1.6.3 Studies

The following three studies are part of this dissertation and have been published in international peer-reviewed journals (see appendix A, B and C):

I. Rohrbacher, M., & Hasselhorn, H. M. (2023). The contribution of work and health-related lifestyle to educational inequalities in physical health among older workers in Germany. A causal mediation analysis with data from the lidA cohort study. *PLOS ONE*, *18*(8), e0285319. https://doi.org/10.1371/journal.pone.0285319

II. Rohrbacher, M., & Hasselhorn, H. M. (2022). Social inequalities in early exit from employment in Germany: a causal mediation analysis on the role of work, health, and work ability. *Scandinavian Journal of Work, Environment & Health*, *48*(7), 569–578. https://doi.org/10.5271/sjweh.4043

III. Rohrbacher, M., Hasselhorn, H. M., & Matilla-Santander, N. (2024). Associations between precarious employment trajectories and mental health among older workers in Germany: Vertical and horizontal inequalities. *Scandinavian Journal of Work, Environment & Health*, *50*(4), 290–299. https://doi.org/10.5271/sjweh.4160

A short summary is provided for each of the studies in chapter 2. All three publications are co-authored. The individual authors' contributions for each manuscript are documented and have been signed by all authors in a separate document. The first two studies (I and II), were written by Max Rohrbacher (MR) and Hans Martin Hasselhorn (HMH). With respect to study I, MR and HMH designed the study, MR performed all analyses, MR wrote the first draft of the manuscript and HMH contributed to its development. MR and HMH critically reviewed and revised the manuscript and approved the final version. With respect to study II both MR and HMH contributed to the conceptualisation, methodology, writing, review, and editing. MR was responsible for the formal analysis, visualisation and wrote the first draft of the manuscript. HMH was responsible for supervising the work.

Study three (III) was authored by MR, HMH and Nuria Matilla-Santander (NMS). All three authors designed the study. MR wrote the first draft of the manuscript and performed all formal analyses including visualisations. HMH and NMS contributed to the development of the manuscript. All three authors critically reviewed and edited the manuscript and approved the final version.

Respectively, the journals reflect the studies' emphasis. Study I and III were published in the Scandinavian Journal of Work, Environment and Health, which focuses on topics in the area of occupational and environmental health and safety including influential works on psychosocial and physical work factors, as well as health, ageing and work ability from an occupational epidemiological perspective

(Scandinavian Journal of Work Environment and Health [SJWEH], n.d.). Study II was published in the journal, PLOS ONE, which accepts papers from many research areas and has a focus on strong methodology (PLOS ONE, n.d.), and is well known for publishing articles in the area of public health and occupational health science.

1.6.4 Data and methods

For all studies, data from the German lidA (leben in der Arbeit) Cohort Study (www.lida-studie.de, Hasselhorn et al., 2014) was used. lidA is a prospective cohort study (longitudinal observational study), with currently four completed survey waves. The study, ongoing since 2009, is one of about ten representative cohort studies worldwide with a focus on work, age, health and labour market participation; it is representative for socially insured employees of the included age cohorts and is unique in Germany (Ferrie, 2014; Hasselhorn et al., 2014). At 3 to 4-year intervals, employees of the German baby boomer cohorts, namely those born in 1959, 1965 and 1971 (the latter only in wave 4) (wave 1 [2011], n = 6585; wave 2 [2014], n = 4244; wave 3 [2018], n = 3586; wave 4 [2022/23], n = 8884), were personally interviewed (Schröder et al., 2013; Steinwede et al., 2015, 2018). More information on the study design can be found in the cohort profile (Hasselhorn et al., 2014; Rauch et al., 2015) and methodological reports (Ruiz Marcos et al., 2023; Schröder et al., 2013; Steinwede et al., 2015, 2018). Materials and methods for each study are described in more detail in chapter 2. Hereafter, wave 4, which was largely conducted in 2022 but completed in 2023 will be referred to as 'wave 4 (2022)'.

2 Summary of the studies

2.1 Study I

Rohrbacher, M., & Hasselhorn, H. M. (2023). The contribution of work and health-related lifestyle to educational inequalities in physical health among older workers in Germany. A causal mediation analysis with data from the lidA cohort study. *PLOS ONE*, *18*(8), e0285319. https://doi.org/10.1371/journal.pone.0285319

2.1.1 Aim

The aim of the study is to quantify the contribution of work factors and the health-related lifestyle to educational inequalities in physical health among older workers from the German baby boom generation, via causal mediation analysis. Through a counterfactuals-based analysis approach, inferences shall be made on how health inequalities could be alleviated. The study is to fill the research gap outlined in Chapter 1.5.1.

2.1.2 Method

For this study data from the German lidA study (Hasselhorn et al., 2014) was used. Subjects eligible for inclusion were panel cases who responded in lidA wave 1 (2011, t_0), wave 2 (2014, t_1), and wave 3 (2018, t_3) (n = 3232), who were either full-time or part-time employed (n = 2759). Those working without a superior (n = 59) and subjects with missing values on the main exposure variable education (n = 14) and a missing longitudinal weight (n = 33) were excluded resulting in n = 2653 included subjects (53% female, 47% male). Subjects were 46 (born 1965) and 52 (born 1959) years old at baseline (2011) and were followed op for seven years (2018). All analyses were stratified by sex.

The statistical model assumptions were based on the model by Mielck (2005) on the association between SES and health presented in chapter 1.4.1 and current evidence suggesting work factors and health behaviours to be the dominant pathways in this association (chapter 1.5.1). As an adaption of the model, the component 'differences in healthcare provision' (Figure 1, component C), was not investigated as a potential pathway from the SES to health. The outcome physical health was assessed using the Short Form Health Survey (SF-12 PCS) (Ware et al., 1996). The main exposure was the educational level of persons, which combines scholarly and vocational education (Ahrens et al., 1998). Work factors and health behaviours were entered as mediators into the statistical models. As work factors, physical demands and rewards at work, influence at work, possibilities for development, and leadership quality were assessed. Apart from physical demands and rewards, all work factors were measured using the Copenhagen Psychosocial Questionnaire (COPSOQ) II middle version (Nübling et al., 2006). Rewards at work were measured using the reward short scale from the effort-reward-imbalance (ERI) instrument (Siegrist et al., 2014). Physical demands were measured via the number of working hours in awkward body postures, heavy lifting, and repetitive movements. Leisure-time physical activity, smoking and BMI were investigated as health behaviours. To ensure the temporal order of exposure, mediators and the outcome, the exposure was measured at t_0, work factors and health behaviours at t_1 and physical health at t_2. Work factors and health behaviours were analysed sequentially. This means that work factors were analysed conditioned on a base set of post-exposure and pre-mediator variables (baseline health, partner status, working hours) and health behaviours were analysed conditioned on the base set and the work factors (VanderWeele et al., 2014). Age at baseline and migrant status were used as the minimal sufficient adjustment set to calculate the effect estimates. These variables constitute background risks and therefore qualify as confounders.

A causal mediation analysis using an inverse odds weighting approach was used (Tchetgen Tchetgen, 2013). The method allows to decompose the Total Effect of the exposure on the outcome into a Natural Direct Effect (pathway through the mediators deactivated) and Natural Indirect Effect (effect through the mediators) (Oude Groeniger & Burdorf, 2020). To quantify the contribution of the mediators to the Total Effect, the so-called Proportion Mediated was calculated (VanderWeele, 2015).

To account for item non-response, Multiple Imputation by Chained Equations was used (White et al., 2011). To account for selective non-response a longitudinal weight was built by multiplying a cross-sectional post-stratification weight and a longitudinal non-response weight. To assess the potential influence of unobserved confounding Mediational E-values were calculated (Smith & VanderWeele, 2019).

2.1.3 Results

The analyses showed that lower education increased the risk of a health deterioration during a seven-year follow-up, highlighting the presence of educational inequalities in physical health. Compared to their higher educated counterparts, both low and moderately educated women had an approx. 1.5-fold higher risk (low vs. high: relative risk [RR] 1.55, 95% confidence Interval [CI] 1.42-1.68; moderate vs. high: RR 1.54, 95% CI 1.42-1.65), lower educated men an approx. 2-fold (RR 2.14, 95% CI 1.96-2.32) and moderately educated men a 1.6-fold higher risk (RR 1.59, 95% CI 1.46-1.71), to report poor health at follow-up.

Both, work factors and the health-related lifestyle contributed to educational inequalities in physical health. Health-related lifestyles showed larger contributions to health inequalities among older workers from the German baby boom generation. This was observed for men and women. Comparing low versus high educated women, work factors contributed 21% to educational inequalities in physical health. Health behaviours contributed additional 26% points. Comparing moderate versus high educated women, work factors contributed 0% and health behaviours additional 20% points to educational inequalities in health. Additional analyses suggest that BMI and possibilities for development may be key variables to level health inequalities among older female workers.

Among men, work factors explained 5% and health behaviours additional 24% points of educational inequalities in physical health between those with low and high education and respectively 6% and 27% points between those with moderate and high education. Additional analyses suggest that smoking and leisure-time physical activity may be key variables to level health inequalities among older male workers.

2.2 Study II

Rohrbacher, M., & Hasselhorn, H. M. (2022). Social inequalities in early exit from employment in Germany: a causal mediation analysis on the role of work, health, and work ability. *Scandinavian Journal of Work, Environment & Health*, *48*(7), 569–578. https://doi.org/10.5271/sjweh.4043

2.2.1 Aim

This study aims to quantify the contribution of work factors, health, and work ability to educational inequalities in early exit from employment among older workers from the German baby boom generation. The study is to fill the research gap outlined in Chapter 1.5.2.

2.2.2 Method

For this study, data from the lidA cohort study were linked with employment register data from the German Institute of Employment Research (IAB). Subjects were eligible to be included in the study if they had participated in the lidA survey wave 1 (2011, t_0), wave 2 (2014, t_1), and wave 3 (2018, t_2) and provided written consent for the usage of their employment register data at t_2 (n = 2560). Subjects with any kind of early exit or pension receipt before baseline measurement in 2011, as well as subjects with missing values on the main exposure variable education (n = 15) were excluded, resulting in n = 2438 included subjects.

In order to make the study findings of the second study internationally comparable, the early exit pathways were defined in line with previous studies on determinants of early exits from employment (Carlsson et al., 2023; Clausen et al., 2014; d'Errico et al., 2021; Lahelma et al., 2012; Lund & Labriola, 2006; Robroek et al., 2015; Ropponen et al., 2013; Samuelsson et al., 2013; Schuring et al., 2019; Thern et al., 2022, 2020). Disability pension (full or partial), long-term unemployment ($\geq$ 1 year) and an unspecified labour market exit (exit from social insurance $\geq$ 1 year) were defined as early exits from employment. The granularity of the employment register data was coarsened to a yearly modal state to match the self-reports of the survey data. The time to the first event between 2012 and 2017 was analysed. Subjects with no event were right-censored.

The SES was operationalised via educational level (scholarly and vocational) in three groups of low, moderate, and high educated (Ahrens et al., 1998). Work factors, health and work ability were entered as mediators into the statistical models. According to the typology by Hofäcker and Radl (2016) presented in chapter 1.4.2 these can be interpreted as push or maintain factors depending on their expression. As work factors, physical demands, quantitative demands, and influence at work were investigated. Quantitative demands and influence at work were measured using the COPSOQ II middle version (Nübling et al., 2006). Physical demands were measured via the time spent in awkward body postures, heavy lifting, and repetitive movements. Physical and mental health were measured using the Short Form Health Survey (SF-12) (Ware et al., 1996). Work ability was parametrized via the second dimension of the Work Ability Index (Ebener & Hasselhorn, 2019; Ilmarinen, 2007). This short measure was validated by Ebener and Hasselhorn (Ebener & Hasselhorn, 2019). Age, sex, and partner status were adjusted for. Both, the main exposure and the mediators were assessed at t_0. Given the stability of education at higher working age, the assumption of a temporal order of exposure and mediators is mild.

First descriptive analyses were conducted to examine sample characteristics and the number of early exit events. Second, a Cox Proportional Hazard Regression was run to investigate the cause-specific hazard of work factors, health, and work ability for the three early exit pathways. Third a causal mediation analysis using inverse odds weighting (Tchetgen Tchetgen, 2013) was conducted to obtain the Total Effect, Natural Direct Effects and Natural Indirect Effects and to quantify the contributions of the mediators by calculating the Proportion Mediated (c.f., chapter 2.1.2). In the sensitivity analysis a competing risk regression using the Fine & Gray (Fine & Gray, 1999) model was used instead of the Cox Proportional Hazard Regression.

2.2.3 Results

In total 210 early exit events were observed during the follow-up period of 2012-2017. The proportion of early exit events was highest in the group of low educated older workers (disability: 4.3%; unemployment: 3.7%; unspecified: 3.7%), followed by those with moderate education (disability: 2.6%; unemployment: 2.4%; unspecified: 3.3%) and high education (disability: 0.9%; unemployment: 1.3%; unspecified: 3.9%). Cox Proportional Hazard Regressions revealed a statistically significantly higher instantaneous rate to exit employment early through disability pensions for lower versus higher (hazard ratio [HR] 4.62, 95% CI 1.75-12.22) and lower versus moderately educated workers (HR 1.83, 95% CI 1.08-3.13). Furthermore, a higher instantaneous rate to exit employment early through long-term unemployment was found for low versus highly educated older workers (HR 2.85, 95% CI 1.20-6.79). No educational differences were found with regard to an unspecified labour market exit via withdrawal from social insurance.

Especially poor health and low work ability contributed to educational inequalities in exits via the disability pension pathway. Low work ability contributed 23% to educational inequalities between low and high educated persons and 38% between low and moderately educated persons. By additionally including both, poor physical and poor mental health the contribution increased to 27% (low vs. high) and 47% (low vs. moderate), respectively. Work factors did not statistically significantly contribute to educational inequalities in exits through disability pension.

Health and work ability combined contributed 43% to educational inequalities in exits through long-term unemployment between low and high educated, and 65% between low and moderately educated persons. Although work factors, especially educational differences regarding the influence at work, contributed to these inequalities when investigated separately, the addition of work factors to the model including health and work ability lead to a reduction of the proportion mediated. This was likely due to the inclusion of quantitative demands, which may disadvantage those with higher compared to lower education.

2.3 Study III

2.3.1 Aim

The study investigates the longitudinal relationship between precarious employment trajectories and mental health during employees' late career in Germany.

2.3.2 Method

Data from all four waves (2011, 2014, 2018, 2022) of the lidA study was used. Only panel cases with participation in all waves were eligible for inclusion. From those eligible, only subjects in either full-time, part-time, or marginal employment were included, resulting in a final sample size of n = 1636. Sensitivity analyses were conducted including subjects with up to two unemployment spells between the first and last wave.

   The outcome mental health was assessed at wave 4 using the mental component of the Short Form-12 Health Survey (SF-12 MCS) (Ware et al., 1996). A score from 0 to 100 was built and subsequently dichotomized using three different cut-offs (value 47.0 [25th percentile], value 45.6 [21st percentile], value 42.0 [14th percentile]). The cut-offs 45.6 and 42.0 were suggested to be indicative of depressive disorders (Vilagut et al., 2013) and clinical depression (Ware et al., 1995) respectively. Subjects with a score equal or below these values were regarded as cases with poor mental health.

   Precarious employment was measured multi-dimensionally using several items to cover the two dimensions, employment insecurity and income inadequacy (c.f., Kreshpaj et al., 2020). A summative scale was constructed following Jonsson et al. (2021) combining these items. The dimension 'lack of rights and protection' could not be operationalised, based on lidA data. Logistic Regression was used to test the association between precarious employment trajectories (2011-2022) and mental health (2022), applying a longitudinal weight to account for selective non-response. Age at baseline, sex, migrant status, baseline mental health, partner status and education, as well as occupation were selected as the minimal sufficient adjustment set for the estimations.

2.3.3 Results

Four trajectories were modelled, based on the model fit criteria Bayesian Information Criterion and Akaike Information Criterion: two constant non-precarious employment trajectories (including 49.8% of the sample), one constant borderline precarious employment trajectory (including 36.6 % of the sam-

ple) and one precarious employment trajectory with upward movement (including 13.6 % of the sample). Representation in the precarious employment trajectory was socially structured by vertical and horizontal characteristics, with higher prevalence among female, lower educated and lower-skilled workers. 20.2% of women and 5.5% of men were constantly precariously employed. Women following this trajectory were more likely (Odds Ratio 1.68-1.82 depending on the selected cut-off value) to report poor mental health at follow-up in 2022 than women in the non-precarious trajectories. This association was statistically significant. Among men, precarious employment was not found to be a risk factor for poor mental health (Odds Ratio 0.37-0.51).

3 General discussion

This chapter discusses the findings of the above three studies. It starts by repeating the main findings and thereby providing answers to the three central research questions of this dissertation (chapter 3.1). This is followed by comparing the new findings ('What are the new findings?') with previous findings from other studies ('What is already known about the subject?') including discussions about the plausibility and generalisability of the findings and lastly their implications ('What if?') (chapter 3.2). This is done separately for the role of work, the role of employment quality, the role of the individual, the role of health and work ability, the role of the life course and the role of policies. In chapter 3.3, strengths and limitations of the studies will be elaborated. The discussion ends with a conclusion and outlook for each of the six domains work, employment, individual, health and work ability, life course and policies (chapter 3.4).

3.1 Main findings

The aim of this thesis was to provide answers to the following three research questions:

a) What is the contribution of work factors and the health-related lifestyle to educational inequalities in physical health among older workers in Germany?

In summary, it can be stated that work factors are powerful in explaining educational inequalities in physical health among older female workers, but not among older male workers (Rohrbacher & Hasselhorn, 2023). The health-related lifestyle is powerful in explaining physical health inequalities among both sexes (Rohrbacher & Hasselhorn, 2023).

In study I, the largest contribution of work factors to health inequalities were observed among women, where they contributed 21% to physical health inequalities between low and high educated older employees (Rohrbacher & Hasselhorn, 2023). Additional analyses, in which all mediators were investigated separately, suggest that educational differences in possibilities for development and influence at work may be the main contributors to physical health inequalities in the domain of work factors

(Rohrbacher & Hasselhorn, 2023). Among men, the contribution of work factors was small accounting for max. 6% of health inequalities (Rohrbacher & Hasselhorn, 2023). Among both sexes, the addition of health behaviours explained additional approx. a quarter of health inequalities (Rohrbacher & Hasselhorn, 2023). Additional analyses highlighted the relative importance of the different health behaviours. Comparing low versus high educated women, BMI showed the largest contribution, while smoking was more important when comparing moderate versus high educated women (Rohrbacher & Hasselhorn, 2023). Among men, both smoking and leisure-time physical activity showed very large contributions to health inequalities (Rohrbacher & Hasselhorn, 2023). While this study was the first German study to quantify the contribution of work factors and health behaviours to educational inequalities in physical health among older workers via causal mediation analysis, and therefore provided new knowledge, it must be noted that only a timeframe of seven years during the late career of workers (from 2011-2018, workers were 46-53 years old or 52-59 years old) was investigated. Data on working conditions and health behaviours from earlier phases of the life course were not available and hence the study cannot account for accumulating (dis)advantages before this time frame. It may be assumed that past work factors play an important role in determining and/or interacting with future health behaviours and their effect on health. This will be further discussed below.

b)   What is the contribution of work factors, health, and work ability to educational inequalities in early exits from employment in Germany?

In summary, it can be said that health and work ability are powerful in explaining educational inequalities in early exits from employment in Germany (Rohrbacher & Hasselhorn, 2022). Work factors are less powerful in explaining these inequalities (Rohrbacher & Hasselhorn, 2022).

Study II highlighted the important role of poor physical health and low work ability as the main contributors to educational inequalities in early exits through disability pension and long-term unemployment. Differences in health and work ability combined, contributed up to 47% to educational inequalities in early exits through disability pension and up to 65% to educational inequalities in early exits through long-term unemployment (Rohrbacher & Hasselhorn, 2022). A time frame of six years (from 2011-2017, workers were 46-52 or 52-58 years old) was investigated. Compared to health and work ability the investigated work factors were less powerful in explaining social inequalities in early exits from employment (Rohrbacher & Hasselhorn, 2022). It may be hypothesized that only in the case of poor health and low work ability, early exits are both accessible (can do) and considered by workers despite accompanying economic and social disadvantages (must do). Thus, the role of work factors as a determinant of labour participation might be obscured by health and work ability. This will be further discussed below.

c) Are there social inequalities in the exposure to trajectories of precarious employment and their effect on mental health among older workers in Germany?

In summary, it can be stated that there are social inequalities in the exposure to precarious employment trajectories and their effect on mental health to the disadvantage of lower-skilled and female older workers (Rohrbacher et al., 2024).

Study III found that 13.6% of older employees followed a precarious employment trajectory with upward movement over the course of eleven years during the late career (Rohrbacher et al., 2024). 20.2% of women and 5.5% of men were precariously employed (Rohrbacher et al., 2024). Next to female sex, low education and a non-qualified manual as well as non-manual occupational status were further risk factors for the exposure to precarious employment (Rohrbacher et al., 2024). Women following this trajectory had increased odds (Odds Ratio 1.68-1.82) to report poor mental health at follow-up compared to their counterparts following non-precarious employment trajectories (Rohrbacher et al., 2024). This was not found for men. The results imply that both exposure to precarious employment and its health-adverse consequences are socially structured to the disadvantage of women and lower-skilled employees (Rohrbacher et al., 2024). The plausibility of the findings will be extensively discussed below.

3.2   What if? How could social inequalities look like in a counterfactual world?

Within the scope of this dissertation, social inequalities in health and labour participation and their relation to social inequalities in working conditions, employment conditions, health and health behaviours were studied.

First, the contribution of work factors and the health-related lifestyle to health inequalities (study I), then the contribution of work, health, and work ability to early exits from employment (study II) were studied using a counterfactual framework. When studying social inequalities, this approach helps to understand underlying mechanisms by which the SES is linked with health (or other outcomes), to estimate and quantify the contribution of certain determinants (the intermediates) to social inequalities in the outcomes, and to describe the extent to which these inequalities would reduce, given a counterfactual world where all differences in determinants would be levelled (c.f., Tchetgen Tchetgen, 2011; c.f., VanderWeele, 2015). In the present dissertation, this allows drawing conclusions on the relative importance of the putative mediators regarding the evolution of social inequalities during the late career of workers in Germany. Studies I and II highlight the *role of work, health, and the individual*.

Next, social inequalities in precarious employment conditions and their effect on mental health were studied (study III). In study III, the counterfactual framework to mediation analysis was not used. The focus of this study was to multi-dimensionally measure precarious employment and the evolution of employment conditions over an extended period of eleven years (2011-2022) during the late career of

workers using a latent class modelling approach. Study III highlights the *role of employment conditions* in relation to mental health from a longitudinal perspective, accounting for the dynamics of the exposure.

In addition to the *role of work, health, the individual* and *employment conditions,* the following chapters will discuss the *role of policies* and *the role of the life course. The role of policies and policy reforms* will be discussed as they constitute the context and structure in which individuals operate. Furthermore, *the role of individuals' agency* within this context will be discussed. Moreover, *the role of life course determinants* of health and labour participation must be elaborated on, to better understand social inequalities at older age and issues of causality.

Each of the following chapters will start with a discussion of the findings from the three studies against the background of existing evidence. Where appropriate, findings from all three studies will be discussed in synopsis. Each chapter will end with a short paragraph, guided by the question 'What if? How could social inequalities in health and labour participation look like in a counterfactual world?' Importantly, for all studies discussed below which are not using a counterfactual framework, the conclusions made on a 'counterfactual world' must inevitably be vaguer than for those using a counterfactual framework. In these cases, the chapter 'What if?' is focused on recommendations/ implications.

3.2.1   *The role of work*

What are the new findings? Studies I and II of this dissertation investigated the contribution of work to educational inequalities in physical health and early exits from employment, respectively. A noticeable contribution of work factors to physical health inequalities was observed among women but not among men (Rohrbacher & Hasselhorn, 2023). The combination of all investigated work factors, including physical demands, influence at work, possibilities for development, leadership quality and rewards at work contributed 21% to physical health inequalities between low and high educated older female workers (Rohrbacher & Hasselhorn, 2023). Further supplementary analyses, in which these work factors were investigated, individually pointed at possibilities for development and influence at work to be the most powerful work factors to explain physical health inequalities among women (Rohrbacher & Hasselhorn, 2023).

The contribution of work factors to educational inequalities in early exits from employment was not investigated stratified by sex, due to the relatively low number of exit events during the follow-up period. The findings suggest that work factors do not play a decisive role with respect to inequalities in early exits through disability pension (Rohrbacher & Hasselhorn, 2022). With respect to educational inequalities in early exits through long-term unemployment, physical demands and influence at work showed significant contributions when investigated individually, especially when comparing low versus

moderately educated individuals (Rohrbacher & Hasselhorn, 2022). However, differences in work ability and physical and mental health were again more powerful in explaining inequalities in exits through unemployment (Rohrbacher & Hasselhorn, 2022).

What is already known about the subject? Existing research clearly shows that poor physical and psychosocial working conditions are major determinants of health and labour participation. With respect to health as the outcome, numerous studies, systematic reviews, and meta-analyses have indicated adverse effects of poor physical and psychosocial working conditions. High physical demands have been shown to increase the risk for musculoskeletal disorders (Bernard & Putz-Anderson, 1997). A variety of psychosocial work demands have been shown to increase the risk of both poor mental (Rugulies et al., 2017; Seidler et al., 2022; Theorell et al., 2015) and physical health (Dragano et al., 2017; Kivimäki & Kawachi, 2015). With respect to labour market participation as the outcome, especially high physical and quantitative demands (d'Errico et al., 2021) as well as a lack of control (Knardahl et al., 2017; Robroek et al., 2013) may increase the risk of early exits from employment. However, predictors of early exits are less well studied than predictors of poor health.

Existing research clearly shows that poor physical and psychosocial working conditions are socially stratified. For most exposures the distribution follows a social gradient in the expected direction, with lower-skilled workers being more often subject to high physical demands (Dieker et al., 2019; Dragano et al., 2016; Montano, 2020; Schram et al., 2021) and a lack of psychosocial resources, such as influence and rewards at work (Dieker et al., 2019; Dragano et al., 2016; Götz et al., 2018; Schram et al., 2021; Schütte et al., 2015). However, current literature suggests an inverse gradient (with higher prevalence among higher-skilled) for some psychosocial demands, such as efforts at work and quantitative demands (Dieker et al., 2019; Dragano & Wahrendorf, 2016; Götz et al., 2018; Robroek et al., 2015).

So far, few studies combine both topics (i.e., the effects of the SES on the outcomes and the effects of work factors on the outcomes) by quantifying the contribution of work factors to social inequalities in health and labour participation. When submitted in 2022, study I was, to the knowledge of the author, the first longitudinal study in Germany to quantify the contribution of work factors to health inequalities via a counterfactual mediation approach (among older workers). Few longitudinal studies from other countries preceded this publication, with results suggesting work to mediate around one third of the association between SES and health (Dieker et al., 2019). Study I however, indicated that max. 21% of educational inequalities among older female workers and max. 6% among older male workers could be explained by work factors. For the differences in study findings, multiple potential explanations exist with the three main themes *methodological choices*, *workers' age* and *institutional filters*.

Methodological choices: First, it must be noted that a very limited selection of work factors was investigated. This selection was based on the strength of the associations between work factors and both the SES and health according to existing evidence. However, this selection is comparable to and in some cases even more extensive than those used in previous studies (Schmitz, 2016; Schram et al.,

2021; Warren et al., 2008). It is very likely that the addition of further work factors increases the overall contribution of work to health inequalities. Nonetheless, the most common physical and psychosocial work factors were included. Future research should consider an evidence-based expansion of included work factors. For example, those which may gain further importance in the future, such as long and irregular working hours, ambient temperature and new technology-related demands (Frank et al., 2023). Furthermore, the choice of the SES indicator and health indicator have an impact on resulting effect estimates – this is extensively discussed in study I (Rohrbacher & Hasselhorn, 2023). In short, the educational level may reflect – much more than current occupation and income – (dis)advantages from other domains, such as health behaviours and household context (Rohrbacher & Hasselhorn, 2023). Thus, the contribution of work to inequalities in health may be underestimated – especially at older age. Furthermore, the outcome, physical health may be less sensitive to the included predominantly psychosocial work factors compared to other health outcomes, such as mental or general health. Nevertheless, there are important reasons why these exposure and outcome variables were selected, which was explained in chapter 1.5.1.

Workers' age: The importance of work factors as contributors to health inequalities likely varies during the life course. Klocke et al. (2020) graphically describe how different factors contribute to increasing or decreasing health inequalities over the life course. The role of work factors as determinants of health inequalities starts to gain importance in early adulthood, where many enter their first employment (Klocke et al., 2020). The importance of work factors as determinants of health inequalities may diminish with increasing age as variables from other life domains gain importance (Klocke et al., 2020). Furthermore, the effect of education on health through work factors may itself be mediated by multiple other factors given that skill-based selection into hazardous workplaces will also affect lifestyles, living conditions, and social relations etc. – so called chains of risk (Kuh et al., 2003). Indeed, some studies show that adverse working conditions and unhealthy lifestyles co-occur (Heikkilä et al., 2013; van den Berge et al., 2021). While this is not evidence of risk chains, it shows that several risks accumulate among the same sub-groups of workers. Interestingly, a very recent German cross-sectional study investigated the contribution of working conditions to health inequalities among younger employees, apprentices, and trainees aged 15-24 years (Reuter et al., 2023). The authors found that job demands contributed 21.6% to educational differences in self-rated health, 52.1% to educational differences in musculoskeletal symptoms and 87.2% to educational differences in mental health problems. These findings correspond to some degree to the findings for older female workers of study I. While in study I, physical health and not self-rated health was used as the outcome, other authors suggest that both health variables are highly correlated (Singh-Manoux et al., 2006). Nevertheless, with contributions of up to 87.2% (in case of mental health) (Reuter et al., 2023), it seems that the hypothesis that work factors gain importance in early adulthood and lose importance at older age as explanatory variables for educational inequalities in health, may to some extent hold true. More longitudinal studies among various age groups of workers in Germany will be needed to gain certainty about this. Furthermore, the findings by

Reuter et al. (2023) support the assumption that psychosocial job demands may contribute noticeably less to inequalities in physical health than they do to inequalities in mental health – which is plausible. Moreover, it must be noted, that Reuter et al. (2023) investigated many more variables from the domain job demands, which may consequently increase the explanatory power of work factors in the statistical model.

Institutional filters: Likely, the difference in findings between study I and previous international findings, with respect to the contribution of work factors to health inequalities, may also be explained by national contexts such as welfare state and occupational health and safety characteristics. In a supplementary analysis by Schram et al. (2021) the authors showed that the contribution of work factors to educational inequalities in self-rated health was noticeably smaller in Northern and Central Europe compared to Southern Europe. It is well known that national/regional welfare contexts act as institutional filters of the effects of certain work-related exposures on several outcomes (Blossfeld et al., 2011); this has also been shown, for example, for the influence of health on labour market exit (e.g., Reeuwijk et al., 2017), for the effects of early-life unemployment on late-life unemployment (e.g., Brandt & Hank, 2014) and the effects of precarious employment on mental health (e.g., Padrosa et al., 2022).

Similar to the findings for inequalities in health, findings from study II suggest that work factors are less powerful than expected in explaining educational inequalities in early exits from employment among older workers in Germany (Rohrbacher & Hasselhorn, 2022). Submitted in 2021, study II was the first German study to quantify the contribution of work factors to inequalities in early exits via a counterfactual mediation approach. In this study, next to work factors, health and work ability (but not health behaviours), were additionally investigated as potential mediators. Previous studies suggested work factors to be more powerful in explaining early exits from employment (Robroek et al., 2015). Again, the reasons for the differences in study results follow the three themes *methodological choices*, *workers' age* and *institutional filters*.

Methodological choices: Effect estimates may largely vary depending on the measurements of exposure and outcomes. So far, most studies did not look at different early exit pathways, but a combined early exit outcome (for an overview see d'Errico et al., 2021). Furthermore, studies that differentiate between exit pathways have not conducted mediation analyses (e.g., d'Errico et al., 2021) to quantify the contribution of work factors to social inequalities in early exits, or have used slightly different intermediates (likely) depending on available data (e.g., Robroek et al., 2015). None has included work ability. Moreover, since study II was the first on this topic to use a counterfactual-based mediation approach with survival outcomes, effect sizes and mediation effects cannot be directly compared to results of similar non-linear models using difference-in-coefficients approaches (VanderWeele, 2015) as commonly applied in earlier mediation analyses.

Workers' age: Previous studies, which have also included younger workers, suggested larger contributions of work factors to inequalities in early exits (Robroek et al., 2015; Schuring et al., 2019). This would, in line with previous notes, speak for the greater importance of work factors as contributing factors to inequalities (in early exits) at a younger age. Also, a sequential mediation of the SES effect on early exits through adverse working conditions, then poor health, then low work ability in the style of a risk chain is plausible – which means, the importance of work factors explaining educational inequalities in early exits decreases with age because health and work ability increasingly become proxies of lifetime (dis)advantages with respect to working conditions. To date this can only be indirectly inferred from studies and systematic reviews indicating negative effects of adverse working conditions on health (see above in this chapter) on the one hand, and by studies suggesting a time-delayed and cumulative effect of (psychosocial) working conditions on health (Kulmala et al., 2014; Nilsen et al., 2019) on the other hand.

Institutional filter: At last, welfare states and social insurance regulations may co-determine or moderate the strength of the association between workplace determinants and early exits from employment via legal eligibility criteria. This may result in poor health and low work ability being the (visible) decisive factors for early exits. For example, in Germany access to a disability pension is based on employees' work ability and was restricted in 2001 (for a discussion and further sources see Rohrbacher & Hasselhorn, 2022). This may lead to factors such as health and work ability becoming statistically more relevant in respect to certain exit routes compared to countries where access to early exits is more generous.

Furthermore, a systematic review of evidence on the association between psychosocial work factors and both retirement intentions and actual retirement timing only shows a clear picture in case of work-related resources: Favourable working conditions in terms of resources are positively associated with later retirement plans and actual later retirement (Browne et al., 2019); psychosocial demands on the other hand were predominantly associated with earlier retirement plans, but most studies showed a null effect when it comes to actual retirement (Browne et al., 2019). This may be a further indication, that the association between work and labour market participation is complex and may be moderated by macro- and meso-level regulations. It may be assumed that those with high-resources jobs may generally experience a context of advantage (e.g., in terms of social position, material and social resources) and they both can and want to retire late.

High psychosocial work demands were associated with earlier retirement plans (Browne et al., 2019) – this is plausible. However, most studies showed a null effect when it comes to actual retirement (Browne et al., 2019). This could be due to different reasons: for example, workers with higher quantitative demands are more often in higher-skilled, high-pay jobs. Thus, despite high quantitative demands, there might be financial incentives to retire late. On the other hand, those with high quantitative demands in lower-skilled, low-pay jobs may be forced to delay retirement, also due to financial reasons.

Thus, macro- and meso-level influences may blur the association between work and labour participation.

What if? Both inequalities in physical health and early exits from employment could be reduced by improving working conditions, especially when targeted at lower educated workers. Interventions should focus on work-related resources.

In a scenario where educational differences in the investigated work factors, namely physical demands, influence at work, possibilities for development, leadership quality and rewards at work, were levelled, existing physical health inequalities among women in the late career could reduce by 21% (Rohrbacher & Hasselhorn, 2023). Among women, possibilities for development and the influence at work may constitute key target variables to alleviate health inequalities (Rohrbacher & Hasselhorn, 2023).

Regarding inequalities in early exits, health and work ability were the most powerful explanatory variables (Rohrbacher & Hasselhorn, 2022). However, improving working conditions may improve health, and improved health among lower and moderately educated persons will likely alleviate social inequalities in early exits, through both disability pension and long-term unemployment (Rohrbacher & Hasselhorn, 2023). Despite the prominent role of health and work ability, work factors, namely physical demands and influence at work may be important levers to reduce early exits through long-term unemployment among lower educated older workers and consequently alleviate respective inequalities (Rohrbacher & Hasselhorn, 2022).

Generally, with respect to work factors, findings from study I and II highlight the important role of job resources when it comes to both health and labour participation. This is supported by further literature, suggesting that the improvement of work-related resources may help older workers to actually extend the working life rather than delaying retirement: For example, Browne et al. (2019) showed that high job satisfaction and high job control are associated with both later retirement plans and actual later retirement. Furthermore, Stengård et al. (2022) highlight that especially control over working tasks, opportunities for learning and using one's skills, as well as rewards at work may support older workers in extending their working life.

3.2.2 The role of employment quality

"Women often experience multiple and contradictory pressures during late careers. (…) As a result, women have a higher risk of experiencing extended employment as a forced and stressful trajectory" (Turek et al., 2022, p. 18)**.**

What are the new findings? 20.2% of female employees and only 5.5% of male employees in Germany followed a precarious employment trajectory during the late career (Rohrbacher et al., 2024).

Only among women and not among men, membership in the precarious employment trajectory versus non-precarious employment was associated with increased odds (Odds Ratio 1.68-1.82) of reporting poor mental health at follow-up (Rohrbacher et al., 2024).

What is already known about the subject? Past concerns of an intensifying insider-outsider logic of the German welfare system and labour market through globalisation processes and subsequent policy and employer responses (Blossfeld et al., 2011) have been supported by further, more recent literature and a longitudinal study (Eichhorst & Tobsch, 2015; Pförtner et al., 2022). Labour market reforms to restructure employment since the 1990s have shown effects through a rise of the employment rate since the 2000s and declining unemployment since 2005 (Eichhorst & Tobsch, 2015). In parallel, an increasing dualisation can be observed whereby employment at the margin (outsiders) becomes more flexible and employment at the core (insiders) remains fairly stable and secure (Eichhorst & Tobsch, 2015).

Pförtner et al. (2022) describe this dualisation as "a structural shift of discrimination against (potential) employees in the secondary sector with regard to employment insecurity, income adequacy, and adequate rights and social protection" (p. 359). While the flexibilisation of the labour market seems to improve job opportunities, especially in smaller firms and the service sector, this comes at the expense of more difficult transitions into standard employment and unfavourable working and employment conditions for those at the margins (Eichhorst & Tobsch, 2015).

Selection into precarious employment is typically structured by age, gender and education, but also nationality, with disadvantages for younger, female and low-skilled workers as labour market outsiders (Blossfeld et al., 2011; Eichhorst & Tobsch, 2015). Eichhorst and Tobsch (2015) highlight that while the largest share of workers in Germany still experience standard employment as the norm, there is "a small group [which] cumulates longer phases of non-standard work" (p. 87). Partly as a result of the long-standing German male breadwinner model, persisting structures and norms make women still more susceptible to precarious employment conditions (Brady & Biegert, 2017). Much of the growth of precarious employment can be traced back to the increasing employment rate of women during the last decades and their concentration in part-time employment (Brady & Biegert, 2017). The educational level of the workforce on the other hand has steadily improved (Brady & Biegert, 2017), hence, the hypothesis that an increasing share of workers with lower education has led to a growth of precarious employment, cannot be supported. Rather, this suggests that the growth of low-quality employment was politically induced, i.a., to activate the unemployed and to increase women's and older workers' labour participation.

The vulnerable position of women on the labour market increases their "risk of experiencing extended employment as a forced and stressful trajectory" (Turek et al., 2022, p. 18). However, recent German studies on the association between precarious employment and mental health have found stronger negative associations (i.e., as the prevalence of precarious employment or precariousness increases, health decreases) among men than among women of a wide age range (Demiral et al., 2022;

Pförtner et al., 2022). Study III of this thesis on the other hand found negative associations between precarious employment trajectories and mental health only among women. In the following paragraphs, possible explanations are described. Although the pathways between poor employment quality and mental health are not fully understood, the synopsis of recent studies sheds light on why women and particularly older women may be prone to precarious employment and its effects on mental health. To summarise: women experience accumulating employment-related mental health risks during the life course.

Firstly, women are more likely to undertake unpaid care work. Care work has direct and indirect effects on health. Especially the care of adults may increase the risk of poor mental health. Despite growing labour participation among women in recent years, inequalities in the division of unpaid work persist in many countries (Craig & Mullan, 2011), across the working life (McMunn, 2023) and particularly in Germany (Jessen et al., 2022; OECD, 2017a). Inequalities in the division of childcare and housework even intensified during the COVID-19 pandemic (Jessen et al., 2022). At the same time – partly as a result of women's weaker ties to the labour market due to unpaid care work – growing labour participation is accompanied by a growing share of women working in precarious employment conditions (Brady & Biegert, 2017). Women are more likely to exit paid work in order to take on unpaid work (Shi et al., 2022) and are therefore discriminated against upon labour market entry by less secure employment conditions (Buchholz et al., 2009) and by occupational downgrading upon return after temporary absences (Fasang et al., 2013; McMunn, 2023). While both men and women enter the labour market with similar resources, parenthood marks an important cutting point for women, but not for men in terms of labour participation (McMunn, 2023). Rather than just gender, the interaction of gender and parenthood – or more general: gender and unpaid care – may be decisive in terms of subsequent employment patterns (McMunn, 2023). In conservative welfare regimes, prevailing national family policies and the traditional male breadwinner model, reinforce gender inequalities in labour market participation through taxation, childcare provision and financial support as well as traditional gender roles (Dudel et al., 2021; Hess, 2018; Lain et al., 2022; McMunn, 2023). It is thus the combination of context factors, which allows for the persistence of gender inequalities in (un)paid labour.

Direct consequences are mental health risks associated with the care itself, especially the care of adults. With data from 19 annual waves of the longitudinal Household, Income and Labour Dynamics in Australia (HILDA) Survey, Ervin et al. (2023) showed that among persons aged 25-64 the care for adults was negatively associated with mental health of women but not that of men, while childcare was positively associated with women's but not men's health. This finding is in support of an earlier systematic review of the authors, which showed that women are at greater risk for poor mental health than men due to the unequal division of combining unpaid labour hours and paid employment between sexes (Ervin et al., 2022). It adds however, by showing that the care of adults, which more often occurs during the late career, may be particularly detrimental to women's mental health. In support of this finding, a

recent South Korean study showed that women were more prone to employment precariousness, unpaid family work and their negative consequences for job satisfaction and self-rated health using sequence analysis (Kang et al., 2023). McMunn (2023) furthermore elaborates that the care of adults increases not only the risk of psychological symptoms but also the risk of adiposity and metabolic disorders.

Indirect consequences are mental health risks associated with discontinuous and precarious employment. Transitions to unpaid care, for example, maternity and adult care influence subsequent employment trajectories and pension eligibility. Interrupted careers and the deprivation of material, social and time resources through unpaid work, increase the risk of psychological distress (McMunn, 2023). A study by Wahrendorf et al. (2018) using data from the English Longitudinal Study of Ageing (ELSA) showed that work and family experiences during adulthood impact employment patterns at higher working age. The authors highlight that stronger ties to employment during an earlier career stage increase the likelihood of stable employment at a later career stage, noting that this might reflect cumulative advantages during working life (Wahrendorf et al., 2018). Conversely, weaker ties to paid work, divorce and (single) motherhood seem to increase the likelihood of poor health (McMunn, 2023) and economic vulnerability (Ogg & Rašticová, 2020). The differential effects on (mental) health depending on the character of care work and the timing of absences from paid work are vital to note. Current evidence suggests that adult care rather than the child care (Ervin et al., 2023; Pinquart & Sörensen, 2003) and late career breaks rather than earlier career breaks, may be detrimental to mental health (McMunn, 2023). Very early parenthood poses an exception (McMunn, 2023). Also the quality of employment into which women re-enter employment after periods of absences or reduced labour participation seems to matter, with more gradual adjustments to working-hours (e.g., return via part-time) being likely more advantageous for mental health and well-being (McMunn, 2023).

Secondly, women are more likely to experience low pay and low pension (entitlement) which negatively affects health. In countries where the gender division of child care is large, gender pension gaps are also large (Ogg & Rašticová, 2020). In Germany, women earn on average 18% less per hour than men (Destatis, 2022). Male dominated labour is typically better paid than jobs requiring a similar set of skills in female-dominated occupations (McMunn, 2023). The gender pay gap even widens after childbirth (McMunn, 2023). The retirement income of women is approximately one third below that of men (Destatis, 2023). The occupations most affected by low pay are typically those in which employment growth has been accompanied by an increase in precarious employment conditions (Eichhorst & Tobsch, 2015). Women are overrepresented in these occupations, often in jobs in the service sector, partly due to the extended possibility for marginal employment through so-called 'mini-jobs' (Romeu-Gordo & Sarter, 2020). A lack of collective bargaining in female dominated occupations additionally adds to wage dispersion between sexes (Eichhorst & Tobsch, 2015). Importantly, studies indicate that low pay and insufficient pension coverage have adverse effects on self-reported health (Eichhorst & Kalleberg, 2023). Furthermore, among all dimensions of precarious employment, inadequate income

might be a particularly important risk factor for mental health (Burr, 2023; Demiral et al., 2022). Because of the strong relation between current pay and employment continuity and later pension entitlement in the German setting (Buchholz & Kolb, 2011; Lain et al., 2022), psychological distress may aggravate with proximity to retirement among precariously employed individuals.

Thirdly, women are more likely to be 'isolated workers'. Lone work may increase the risk of poor health. A recent South Korean study found that women are more likely to be in lone work, which means working without supervision (Han et al., 2023). The two main occupations characterized by lone work were service and sales workers (Han et al., 2023). Concurring with this finding, additional analyses from the lidA study (not published) showed that a very large share of older women subject to precarious employment were either employed in personal services (approx. 42%) or commercial and business service (approx. 43%). It is thus likely that for some of these workers, lone work increases the vulnerability to precarious employment conditions. Partly overlapping with these findings are results from Eichhorst and Tobsch (2015), who described customer service clerks, salespersons, personal and protective service workers, sales and service elementary occupations, as well as teaching associate professionals to be those occupations which are most affected by the growth in atypical employment; in summary, they can be classified as low- to medium-skilled service workers with direct customer contact and public sector employees. Moreover, female dominated occupations with a high prevalence of lone work might be associated with higher mental health risks, such as long working hours and isolation from superiors and co-workers (Hughes & Ferrett, 2011; Song et al., 2014; Vander Elst et al., 2017), while typical 'male occupations' with a high prevalence of lone work might be associated with risks more strongly associated with poor physical and general health, such as agriculture and transportation (e.g., Dahl et al., 2009; Katzmarzyk et al., 2009; Patel et al., 2010).

Fourthly, women are less likely to be granted or make use of benefits, rights, and protection. A representative Swedish study showed that, especially among women, precarious employment (compared to standard employment) reduced the probability to make use of sickness absence benefits due to common mental health disorders while this association was weaker among men (Hernando-Rodriguez et al., 2023). The authors had three explanations for their findings based on their own data and existing evidence. First, a low degree of unionisation is associated with lower use of sickness absence benefits, which was consistent with previous findings from Germany and Norway (Hernando-Rodriguez et al., 2023). Precariously employed workers were more likely to have low unionisation levels and low unionisation. A second explanation was based on legal uncertainty about entitlements to sickness absence benefits (Hernando-Rodriguez et al., 2023). Lastly, women might be less likely to use sickness absence benefits because they perceive greater responsibility to colleagues in their jobs, but also because more objectively, women have higher representation in occupational sectors with high social responsibility for others, such as education, social work or health (Hernando-Rodriguez et al., 2023). In summary,

precariously employed (female) employees may be disadvantaged in terms of access to and knowledge about sickness absence benefits. Additionally, the sense of and the objective high responsibility for others may constitute barriers to make use of benefits.

Fifthly, if older women are more likely to be exposed to precarious employment, they are more likely to be exposed to poor working conditions. Poor physical and psychosocial working conditions, but also health-adverse chemical and biological exposures are more prevalent in atypical employment (Wahrendorf & Siegrist, 2023). Long and irregular working hours, a lack of control at work, noise, heat, radiation and many more adverse working conditions are associated with such disadvantaged jobs (Wahrendorf & Siegrist, 2023). Poor working conditions weaken workers' self-efficacy and are detrimental to health (Wahrendorf & Siegrist, 2023). The adverse health effects of poor working conditions were also described in previous sections of this thesis. Thus, those in precarious employment relations are more likely to experience adverse working conditions and in turn, poor working conditions may increase the vulnerability to health risks associated with poor employment conditions.

Lastly, the perception of precariousness may be stronger among women due to the interaction of employment conditions, household conditions, and the welfare state (Lain et al., 2019)**.** A recent qualitative study from the UK suggests that older workers' perception of precarity depends on intersecting life domains (Lain et al., 2019). With respect to older workers' sense of precarity, household influences may act as incubators or buffers; difficulties to amass sufficient pension incomes, for example, due to absences from employment in order to care for relatives, and a lack of control over employment and retirement may severely affect the way employment is perceived (Lain et al., 2019). The authors conclude that particularly female older workers approaching retirement are at risk of having a heightened sense of precarity (Lain et al., 2019).

Not only household conditions but also welfare systems seem to moderate the association between certain features of precarious employment and mental health. For example, studies in Central European and Southern European welfare states found stronger effects of job insecurity on mental health than studies conducted in Scandinavian countries (Eichhorst & Kalleberg, 2023). Not only the welfare regime but also the educational and training system may play a role by fostering workers employability; the labour market may play a crucial role by offering suitable employment opportunities. For example, highly-skilled workers likely experience flexibility differently than lower-skilled workers, due to both the modality of this flexibility (voluntary vs. involuntary) (Brady & Biegert, 2017) and the opportunities on the labour market (likelihood of future employment), or as Street and Ní Léime (2020) phrased it: "One woman's flexibility is another's precarity" (p. 90).

In chapter 1.4.3., three pathways were presented through which precarious employment is related to health: *pathway 1 through work environment hazards, pathway 2 through the experience of precariousness, such as insecurity and powerlessness, and pathway 3 through material deprivation*. The theoretical framework by Bodin et al. (2020) also highlights the important role of the social and policy context. In summary, the findings of study III in synopsis with findings from previous studies support that all three pathways linking precarious employment to mental health likely co-exist and that their respective importance depends on the socio-political, family and household context. In this respect, the synopsis of previous evidence highlights the disadvantage of older female workers during the late career. Study III supports previous findings, suggesting that there is a selective disadvantage with respect to the exposure to and the effects of precarious employment: women are disadvantaged compared to men. Financial insecurities might be the dominant pathway linking older female workers employment conditions to mental health in Germany.

What if? Given that both exposure to precarious employment and its effects of on mental health are unequally distributed, one may infer that the German welfare system allows for selective flexibilisation and precariousness of employment. Unlike non-precarious employment trajectories, precarious employment increases the risk of mental health deterioration (Rohrbacher et al., 2024). Far more women (20.2%) than men (5.5%) were exposed to constant precarious employment conditions and only among women and not among men did these trajectories negatively affect mental health (Rohrbacher et al., 2024). Women in precarious employment differ from men in precarious employment, particularly with respect to income, with many more women having an inadequate income during eleven years of assessment, while both sexes showed similar patterns in terms of contractual relation insecurity (Rohrbacher et al., 2024).

First, given these results it can be inferred that particularly income inadequacy, but also the contractual relation insecurity, for example, via temporary employment, should be reduced to prevent negative consequences for women's mental health during the late career. It is desirable to implement policies that more strongly account for the highly gendered unpaid care duties. Recent studies show that particularly elderly care may have negative health consequences for women (Ervin et al., 2023; McMunn, 2023; Pinquart & Sörensen, 2003). Apart from the physical and psychosocial demands associated with care, this might also be due to growing employment insecurities associated with fragmented careers. Ideally, both childcare and elderly care should be equally divided between women and men to avoid women's disadvantage with respect to employment discontinuity and its effect on pension eligibility. Furthermore, repeated exits from employment due to care work should be compensated through adequate material gratification, continued social insurance and pension credits. To implement such measures, unions are vital since both macro- (policies) and meso- (employers) level structures favour the persistence of dualisation and selective flexibilisation. Thus, union coverage should be increased. However, several authors ascribed unions in Germany to have acted in favour of labour market insiders

by not challenging the segmentation of the labour market strongly enough and agreeing to a deregulation at the margins (Brady & Biegert, 2017; Eichhorst & Tobsch, 2015). Unions should instead counteract a growing dualisation of the labour market.

3.2.3 The role of the individual

"Structures may influence an individual's actions, but individuals in turn influence the nature of structures" (Higgs et al., 2003, p. 775).

What are the new findings? Study I showed that health behaviours are very powerful in explaining educational inequalities in physical health among older workers in Germany (Rohrbacher & Hasselhorn, 2023). Among women, health behaviours contributed 26% to physical health inequalities between low and high educated and 20% between low and moderately educated (Rohrbacher & Hasselhorn, 2023). Among men, health behaviours contributed 24% to physical health inequalities between low and high educated and 27% between low and moderately educated (Rohrbacher & Hasselhorn, 2023). Due to the sequential mediation approach, where first, baseline health, then the work factors and lastly the health behaviours were entered into the statistical models, the magnitude of the described contribution of health behaviours can be interpreted as their contribution independent of work factors and baseline health (Rohrbacher & Hasselhorn, 2023). This is a major strength of the study, given the likely risk chain in which the effect of scholarly and vocational education on current health is at least partially mediated by past (baseline) health, the effect of which is at least partially mediated through working conditions, the effects of which are at least partially mediated through health behaviours. The complete set of mediators contributed 65% (low vs. high education) and 59% (low vs. moderate education) to physical health inequalities among women and 85% (low vs. high education) and 64% (low vs. moderate education) to physical health inequalities among men (Rohrbacher & Hasselhorn, 2023). Additional analyses, in which the individual health behaviours where investigated depending on baseline health but not on work factors, pinpointed certain health behaviours to be most powerful in explaining physical health inequalities. Among women, BMI showed the largest contribution (Rohrbacher & Hasselhorn, 2023). Among men, smoking and physical activity showed the largest contribution (Rohrbacher & Hasselhorn, 2023).

What is already known about the subject? Health behaviours and proxies thereof, such as smoking, physical activity and BMI are important determinants of health (Abbafati et al., 2020; Stenholm et al., 2016). Many health-related lifestyle factors are modifiable (Ng et al., 2020). The interaction of work and health behaviours may be experienced as enriching and/or conflicting (Sonnentag et al., 2023).

The interaction of work factors and health behaviours may explain the prominent role of health behaviours in explaining educational inequalities in physical health in study I (Rohrbacher &

Hasselhorn, 2023). Previous studies and a meta-analysis have shown that health-adverse working conditions and health behaviours co-occur and often cluster among the same individuals (Heikkilä et al., 2013; van den Berge et al., 2021). However due to the cross-sectional data basis of many studies investigating the interplay between work and the health-related lifestyle, it is difficult to establish causality due to a missing temporal separation of exposure and outcome. In fact, spill-over effects may be present in both directions, i.e., work factors may enrich or conflict with health behaviours and vice versa (Sonnentag et al., 2023). However, from an occupational health and social epidemiologic perspective, the direction work to health behaviours may be of greater interest, given that work is an important setting for behavioural change (Poland et al., 1999; Robroek et al., 2021). Furthermore, from a (health) sociological perspective, individuals agency (e.g., behaviours and choice) are considered to be constrained within institutional structures (e.g., pension regulations) (Williams, 2003), which highlights the existence of and the need for a hierarchy when it comes to addressing health behaviours and their consequences.

Recent studies support the notion of an (spill-over) effect of working conditions (cross-sectional: Wiertsema et al., 2023) and employment conditions (longitudinal: Baek et al., 2023), as well as their combination (cross-sectional: Jung et al., 2021) on health behaviour, and also suggest a partial mediation of the work factors' effect on health through health behaviours (overview of systematic reviews: Riopel et al., 2021; systematic review: Siew et al., 2022). Furthermore, the cross-sectional study by Wiertsema et al. (2023) suggests that context factors, in this case labour market security, moderate the association between work factors and health behaviours. Workers with higher job autonomy were more physically active in their leisure time, but this association was alleviated in countries with higher labour market security, indicating a beneficial effect for those with lower job autonomy (Wiertsema et al., 2023). Using longitudinal panel data from Korea, Beak et al. (2023) found that precarious employment significantly increased the odds for current smoking among women and reduced the odds of regular exercise among men. Moreover, longer duration in precarious employment increased the odds of smoking and lowered the odds of regular exercise among men (Baek et al., 2023). Thus, current evidence highlights the influence of work and employment on health behaviours and suggests a partial mediation of the effects of work on health through health behaviours. However, other authors stress the mutual effects of both domains and highlight that health behaviours also influence work and working both positively and negatively (Sonnentag et al., 2023).

Nevertheless, there is growing support of the statement with which study I was concluded: "Improving working conditions is likely an important prerequisite [of promoting healthy behaviours and reducing health inequalities]" (Rohrbacher & Hasselhorn, 2023, p. 2). Moreover, recent findings support the model assumptions by Mielck (2005), according to which the causal pathways indicate a partial mediation of (work-related) demands and resources on health through health behaviours, which also gives further strength to the sequential mediation approach applied in study I.

A topic that has so far not been explicitly addressed within this dissertation is the role of the agency-within-structures mechanism (c.f., Elder et al., 2003; c.f., Struffolino & Zaccaria, 2020). It is important because institutional structures, such as pension schemes, constitute opportunities and constraints for agency, such as individual preferences, choices and behaviours (e.g., regarding labour participation) (Struffolino & Zaccaria, 2020). Hence, although findings such as those from study I pinpoint at variables that seem first and foremost in the responsibility of individuals, one has to be aware that the context determines the extent to which this is actually the case – thus, to what extent choices are individualized or institutionalized (c.f., Struffolino & Zaccaria, 2020). For example, many individuals are constrained with respect to their retirement preferences and behaviour, because EWL policies (macro-level) have made it more difficult for individuals to retire before statutory pension age. The phenomenon that this might have constrained lower SES-groups more heavily is, for example, reflected in a switch from a linear to a u-shape relation between education and the expected retirement age over the past decades, where both low and high educated persons expect to retire late (Hess, 2018). It might also be reflected in the many differentiated pathways that health might lead to early or late retirement, also depending on SES indicators (for an overview of pathways see Hasselhorn et al., 2022) and the observation that the role of work factors regarding health inequalities (Rohrbacher & Hasselhorn, 2023; Schram et al., 2021) and inequalities in early exits (Robroek et al., 2015; Rohrbacher & Hasselhorn, 2022) is relatively small, depending on the country or European region.

A study by Celidoni and Rebba (2017) using longitudinal SHARE data on older workers in 11 countries (including Germany), found that health behaviours, namely smoking, drinking behaviour, engagement in activities and contact to doctors, improved upon retirement entry. The authors indicate that these effects varied depending on healthcare system (macro), job characteristics (meso), individual characteristics (micro) such as gender, education and net wealth as well as early-life conditions (Celidoni & Rebba, 2017). For example, on the meso-level, the discontinuance of time pressure, time constraints, and physical demands upon retirement may explain the reduced probabilities of being inactive, increased probabilities of engagement in physical activities and reduced probabilities of smoking, respectively (Celidoni & Rebba, 2017). This suggests that individual health behavioural change is facilitated or constrained by macro- and meso-level structures. This also highlights the importance of more nuanced policy reforms that account for macro- and meso-level contexts over the life course. As will be elaborated more extensively in in the next chapter on the role of health, those with lower SES, who often experience more adverse working conditions might struggle to extend their working life and might also benefit most from earlier exit opportunities.

Despite the neo-liberal framing of welfare reforms to increase individuals' choices and freedoms (Krekula & Vickerstaff, 2020), a recent study suggests that the European-wide policy reforms to delay retirement have actually institutionalised rather than individualised choices (Struffolino & Zaccaria, 2020) through constraining choices and making exit patterns more uniform (despite differences in pre-requisites). For many older workers this means that the desirable state of being retired (because of

increased control over life) (Shi et al., 2022) is shifted backwards and so is the gain in control over life. This seems to translate also qualitatively to older workers experience as a "shifting of the goalposts" (Lain et al., 2019, p. 2231).

What if? Health behaviours contributed approx. 25% to educational inequalities in physical health among older workers in Germany (Rohrbacher & Hasselhorn, 2023). This proportion varied slightly depending on sex and comparison groups (low vs. high education: 26% [women], 24% [men]; low vs. moderate education: 20% [women], 27% [men]) and quantifies the extent to which health inequalities could be reduced in a counterfactual world in which educational differences in health behaviours were levelled (Rohrbacher & Hasselhorn, 2023).

First, practically, this suggests that improvements of health behaviours through health promotive measures could be a powerful tool to mitigate educational inequalities in physical health during the late career. By elaborating both, on the model by Mielck (2005) (see Figure 1, chapter 1.4.1) and shortly on the agency-within-structure mechanism, as well as on current evidence, it was highlighted that health behaviours can at least in part be considered as a consequence of work factors, mediating their effects on health; and that the responsibility of individuals for their health behaviour is at least partly institutionalised, which is, shaped by structures. Therefore, secondly, this suggests that improving working conditions (see previous chapter 3.2.1) and implementing welfare policies which account for the diversity of life courses is an important prerequisite to facilitate health behavioural change and to reduce inequalities in health (see following chapter).

3.2.4 The role of health and work ability

What are the new findings? Study I, II and III found social inequalities in health.

Study I and III – health as an outcome: Study I highlighted the important role of health behaviours in forming educational inequalities in physical health among older workers in Germany (Rohrbacher & Hasselhorn, 2023). Working conditions contributed considerably to physical health inequalities among women but not among men, while the contribution of health behaviours was similarly high (around one fifth to one quarter) among both sexes (Rohrbacher & Hasselhorn, 2023). Explanations, why at this stage of the career, health behaviours may be more powerful to explain physical health inequalities than work factors, were extensively discussed in chapter 3.2.1 (the role of work) and 3.2.3 (the role of the individual). Next, study III indicated that precarious employment is an important determinant of health among older female workers in Germany. The study indicated that the exposure to a precarious employment trajectory is highly gendered and structured by educational attainment (Rohrbacher et al., 2024). Particularly among women, lower educated and among non-qualified manual and non-manual occupations, the prevalence of precarious employment was high (Rohrbacher et al., 2024). Negative effects on

mental health were only evident among women (Rohrbacher et al., 2024). Possible explanations were extensively discussed in chapter 3.2.2 (the role of employment quality).

Study II – health and work ability as determinants: Study II showed that mental and physical health, as well as work ability were very powerful in explaining educational inequalities in early exits from employment (Rohrbacher & Hasselhorn, 2022). Work ability appears to be the most important contributor to inequalities in disability pension, while both health and work ability were the most important contributors to inequalities in exits through long-term unemployment (Rohrbacher & Hasselhorn, 2022).

What is already known about the subject? Health is an important determinant for early exits from employment. Working conditions and health (as well as their interaction) are likely the most important meso- and individual-level push-factors for early exits from employment (Head et al., 2023). The influence of health on early exits and early retirement has been shown by multiple studies and systematic reviews (Carr et al., 2018; Reeuwijk et al., 2017; Scharn et al., 2018; Turek et al., 2022; van den Berg, Elders, et al., 2010; van den Berg, Schuring, et al., 2010; Van Rijn et al., 2014).

Given the context of policies to delay retirement and other influences during the late career, the association between health and labour participation may become increasingly complex. It can be assumed that other variables, for example, material and social resources as well as the family and welfare context may mediate or moderate this relationship (Scharn et al., 2018; Van Rijn et al., 2014). In fact, a recent discussion paper presents evidence that poor health may also lead to late retirement, but also that good health may lead to both early and late retirement (Hasselhorn et al., 2022). This evidence also suggests that the different pathways linking health to early or late retirement are socially structured by age (i.e., the ability and opportunity to work or retire may change depending on age), income (i.e., early exits in good health are accessible for those with sufficient material resources; late exits with poor health may be partly due to the financial pressure to delay retirement) (Hasselhorn et al., 2022), occupation and education (i.e., lower-skilled workers are more likely to exit employment for health reasons) (Carr et al., 2018; Schuring et al., 2019).

However, not every health limitation may necessarily affect labour participation. Large shares of workers with health impairments may well be able to continue working given sufficient work ability, which is dependent on both, individuals' resources and the working demands (Hasselhorn et al., 2022). Hence, both health and work ability constitute important variables to target if the goal is to extend the working life. The crucial role of work ability regarding the timing of an exit from employment has been shown in several studies (Alavinia et al., 2009; Bethge et al., 2021; Boissonneault & De Beer, 2018; Jääskeläinen et al., 2016). Likewise studies have shown that the impact of functional limitations on the ability to work can be mitigated through work adjustments (e.g., Boot et al., 2013; Torp et al., 2012; Vanajan et al., 2020).

Introductory (chapter 1.3.2), I described how both the prerequisites and motivators for an extended working life are socially stratified using the push-pull-need-maintain typology by Hofäcker and Radl (2016). Study II highlights the important role of health and work ability as push factors for lower educated older employees (Rohrbacher & Hasselhorn, 2022). Health (as an outcome) is central in our lives and good health is socially structured (Lampert et al., 2017; Mackenbach et al., 2008). The role of work, employment, and health behaviours in relation to health have been highlighted in the previous chapters (chapter 3.2.1-3.2.3), as has the existence of social inequalities in health. Given current socio-political macro-trends, including demographic ageing and globalisation, but also technological advances, climate change, and global pandemics, the sustainability of welfare systems will remain under increasing pressure. In view of existing health inequalities and how they are aggravated through EWL policies, alternative policy approaches are necessary to improve the ability and opportunity to extend the working life for older workers.

What if? The combination of poor health and low work ability contributed 27% to social inequalities in disability pension and 43% in long-term unemployment between low and highly educated older workers (Rohrbacher & Hasselhorn, 2022). These percentages quantify the extent to which inequalities in the respective early exit pathway could be reduced if differences in health and work ability between higher and lower educated were levelled.

Some OECD countries, such as the Netherlands and Denmark have already linked official retirement age with life expectancy (Head et al., 2023), other countries such as Germany are considering doing the same. While on average the life expectancy is steadily increasing, the rate of increase is not equally distributed between all SES groups (Krekula & Vickerstaff, 2020; Mielck & Wild, 2021). Furthermore, the sole focus on the quantity of (working) life years disregards the importance of the quality of (working) life years, which is partly determined by a person's health status. Thus, the (short-term) benefits of linking the retirement age with life expectancy to improve the sustainability of pension systems may be questioned if it would – as researchers have highlighted (e.g., Alvarez et al., 2021; Krekula & Vickerstaff, 2020) – come at the expense of growing social inequalities.

To mitigate existing inequalities, it is important to address the determinants of health and health as a determinant. With respect to health as an outcome, the quality of work, employment, and lifestyle are key levers to do so, as has been delineated in the previous chapters. A vast number of studies highlight important work-related determinants of health that constitute levers for preventive measures. For example, physical strenuous work (Bernard & Putz-Anderson, 1997), effort-reward-imbalance, passive and strenuous jobs (Dragano et al., 2017; Kivimäki & Kawachi, 2015; Rugulies et al., 2017; Seidler et al., 2022; Theorell et al., 2015), shift work (Torquati et al., 2019; Vyas et al., 2012) and poor employment conditions (Matilla-Santander et al., 2022; Rönnblad et al., 2019), only to name a few. Moreover, study I of this thesis provides new evidence suggesting that possibilities for development and influence at work are important work-related resources and promising variables to counteract health inequalities

among older female workers in Germany (Rohrbacher & Hasselhorn, 2023). Next to improving working conditions, health promotive measures to address health behaviours such as smoking, leisure-time physical activity and BMI are promising to level inequalities in health (Rohrbacher & Hasselhorn, 2023), as has been described in the preceding chapter 3.2.3.

Lastly, the relation between employment conditions and (mental) health will increasingly gain importance due to the growth of precarious employment forms (Frank et al., 2023). More evidence from longitudinal studies in Germany is needed to discuss the generalisability of the findings from study III, which were discussed in chapter 3.2.2.

3.2.5 *The role of the life course*

"Late-life employment is structured in ways that tend to re-produce life-course advantages and disadvantages" (Turek et al., 2022, p. 18).

What are the new findings? This thesis highlights the importance of taking a life course perspective on the mutual effects of work, employment, health behaviours, health, and labour participation. Although in part strong effects were found between the investigated exposures, intermediates, and outcomes, unexpected findings and in part small effect estimates, as well as the synopsis of current evidence indicate that early life exposures may have formative effects on later life experiences.

What is already known about the subject? Throughout this thesis, certain concepts and principles of the life course literature were mentioned with respect to the effect of work, employment, and the health-related lifestyle on health and labour participation. In chapter 1.1 ('Work-related social inequalities from a European perspective') an overview over pension and labour market reforms during the baby boomers' life course was given to place the three studies of this dissertation in a broader context and highlight the life course *principle of time and place* (c.f., Elder et al., 2003). In chapter 1.2 ('Older employees in Germany'), the scarring effect of early life events on later outcomes such as health and labour participation was shortly outlined to introduce the life course concepts of *sensitive periods and risk accumulation* (c.f., Kuh et al., 2003). These concepts were revisited in chapter 3.2.2 ('The role of employment quality'), discussing the disadvantage of women with respect to employment (quality) trajectories. In chapter 3.2.1 ('The role of work') and chapter 3.2.2 ('The role of the individual'), the life course concept of *risk chains* (c.f., Kuh et al., 2003) was discussed with respect to the partial mediation of work factors on health through health behaviours, as well as work factors on early labour market exit through health and work ability. Throughout the thesis the phrase *cumulative (dis)advantage* (c.f., Dannefer, 2003) was repeatedly used to express the clustering of risks, either longitudinally, cross-sectionally, or both, for certain SES groups and the associated potential for a widening of inequalities over the life course. In chapter 3.2.2 ('The role of the individual') the life course *principle of agency* (within-structures) (c.f.,

Elder et al., 2003) was shortly elaborated to highlight that individual choices and actions operate within structural/ contextual opportunities and constraints.

What if? The selected concepts and principles helped to discuss the findings of this dissertation, both expected and unexpected ones. The importance of the life course perspective in the context of this dissertation should be highlighted with respect to two major aspects:

Firstly, given the access to only limited time frames of individual level data, the methodological task to establish causality is very challenging. Facilitated access to data across individuals' life courses would help researchers to do so, as will modern methods, such as sequence analysis (to identify longitudinal patterns), latent class modelling approaches (to identify clusters of subjects or exposures) and the application of job exposure matrices (powerful tool in case of limited individual-level information) (c.f., Wahrendorf et al., 2023). Given the often-limited follow-up time in longitudinal studies, the importance of certain determinants of health and labour participation should always be interpreted against the background of time and place and the impact of preceding life sequences and transitions.

Secondly, to mitigate social inequalities in health and labour participation, interventions to address the determinants studied in this thesis should start early during the life course given the current knowledge about sensitive periods, as well as chains and accumulation of risks. Furthermore, when it comes to policy reforms and workplace interventions, the role of individual behaviour should be evaluated against the background of structural opportunities and constraints.

There are continued advances in the domain of life course research. An introduction to life course epidemiological models is given by Kuh et al. (2003); an introduction to life course principles is provided by Elder et al. (2003); an extensive overview over life course research is given by Shanahan et al. (2016); Hasselhorn (2020) applies a life course view on social inequalities in the transition from work to retirement. A recent publication by Editors Wahrendorf et al. (2023), closely links contemporary challenges for occupational health (science) with topics of life course research including advances in, and challenges for methodology.

3.2.6   *The role of policies*

"Policies towards extended working lives are built on a set of assumptions that too often ignore the realities of ageing populations and which, as such, are likely to reinforce patterns of social insecurity and precarity in society at large" (Krekula & Vickerstaff, 2020, p. 31).

As an introduction to this thesis, I have described past labour market and pension policy reforms starting approximately at the time when German baby boomers were born until 2023. To make pension systems more sustainable in times of demographic ageing and the labour market more fit for international competition, the labour-related risks accompanying these macro-trends have been increasingly shifted to

individuals. Some authors have called this process 'neoliberal responsibilisation' (c.f., Lain et al., 2022). A shift from a defined-benefit to a defined-contribution pension system, the gradual increase of the official retirement age, the restriction of formerly popular early exit pathways and the flexibilisation of employment relations are examples of such measures. These reforms have created contexts in which some individuals, particularly those who have been previously incentivised to exit employment early, are pressured to work longer, often despite poor health and due to financial necessity (Lain et al., 2022).

EWL policies have focused primarily on dissuasive rather than incentive measures, more strongly restricting access to welfare and pensions than supporting older workers' employability, targeting pull factors rather than push factors out of employment (Hofäcker et al., 2016; Lain et al., 2022; Street & Ní Léime, 2020). Life courses have become increasingly de-standardised, retirement increasingly de-institutionalised, labour market risks more individualised, existing social inequalities in health and labour participation are aggravating and also new inequalities are produced (Krekula & Vickerstaff, 2020; Lain et al., 2022). In this context some authors describe a de-institutionalisation of retirement, often referring to reduced pension provision and an increase of individual responsibilities through the transition to a multi-pillar pension system over the past decades (Lain et al., 2022). In parallel, other authors highlight that the choice about retirement timing has become increasingly institutionalised, referring to individuals' decreasing control over the time and nature of retirement (Struffolino & Zaccaria, 2020). In synopsis, the current retirement literature supports the notion that EWL policies may have missed the original target of extending working life but merely delayed retirement (Street & Ní Léime, 2020).

Lain et al. (2022) use the term 'precarious work-endings' to describe the break of traditional class identities as a result of de-standardised late careers. This break has been influenced by socio-political trends such as the globalisation and has been marked by a lack of labour-related security, inadequate pensions, and the growth of elementary jobs to compensate for reduced welfare and pensions provision (Lain et al., 2022). A similar description is used by the German sociologist Andreas Reckwitz (2019) who illustrates the emergence of a new precariat, a group of workers which has not profited from the last decades' educational expansion and from the growth of the service sector, which is now disadvantaged in terms of material and cultural resources as well as working and employment conditions. Simultaneously, this group, which in large parts could formerly identify as the working class, are increasingly losing this reputation in post-industrial late modern societies (Reckwitz, 2019). This notion is supported by other authors in the field of work and health. They caution that in systems, in which welfare problems are individualised and EWL policies are – contrary to the fact – framed as improving (all) individuals' freedom and choices with regard to labour participation, negative state- and firm-level developments (e.g., economic downturn, unemployment, precarious employment), are increasingly perceived as personal failures by both society and by those affected (Krekula & Vickerstaff, 2020). Further authors (Brady & Biegert, 2017; Turek et al., 2022) highlight that previous labour market reforms have mostly affected the bottom of the labour market, leading to a 'precarisation' of late-life employment

and a new 'working poor class'. This may be more pronounced in welfare regimes with comparably high rigidity, such as in Germany (Brady & Biegert, 2017; Buchholz et al., 2009).

Throughout this thesis, the potential of current EWL policies to widen existing social inequalities in the prerequisites, the motivators and the consequences of a prolonged working life has been elaborated on. Through unification of pension regulations (institutionalisation of choices) on the one hand, and deregulation of employment conditions (individualisation of labour market risks) on the other hand, it appears that some SES groups experience particular disadvantage. This is not only affecting individuals' sense of security but also individuals' attitudes, beliefs, and emotions towards macro- and meso-level institutions in a negative way, as qualitative studies from the Netherlands suggest (van Hekken et al., 2022; van Solinge & Henkens, 2017). It should thus be in the interest of politics and employers to alleviate social inequalities. Particularly, less educated older workers may be affected, but also older women who were for a long time encouraged to "follow the (modified) male breadwinner model and to trust the promise that their husbands and/or their acquired welfare state rights would look after them in old age" (Lain et al., 2022, p. 151), but in many cases lack self-determination during the late career due to reduced retirement entitlements and eligibility.

What if? There is potential for future policy reforms to reduce educational inequalities in early exits. Ability and opportunity to work are decisive factors for extending the working life. However, both the ability and opportunity to extend the working life are socially structured – higher-skilled workers have better work ability and employability (Turek et al., 2022). While the official retirement age is rising, early exits from employment are still much more common among lower educated older workers and reduced health and work ability are decisive in this respect (Rohrbacher & Hasselhorn, 2022; Van Rijn et al., 2014). Given the current policy context, educational inequalities in early exits might further grow (Turek et al., 2022).

Poor quality work, poor health, low work ability and qualification deficits are important push-factors for an involuntary exclusion from the labor market (Jensen, 2021). This can be addressed through:

- Improving work ability: for example, by reducing work-related health risks (preventing harm; c.f., Rugulies et al., 2023) and promoting work-related resources (promote the positive; c.f., Rugulies et al., 2023);
- Improving work opportunity: for example, by promoting older workers' employability. Such measures should be specifically addressed at lower educated workers (Hofäcker et al., 2016). Additionally, creating appropriate work opportunities is an important prerequisite.
- Rapid re-integration: Higher flexibility with respect to employment contracts should not be introduced at the expense of individuals' labour market security, but should be combined with rapid

re-integration measures and training opportunities following the Scandinavian 'flexicurity' approach, where high labour market flexibility is combined with high state-guaranteed security (Hofäcker et al., 2011).

Rigó and Lunau highlight that active labour market policies (ALMP) support workers' integration into the labour market and create improved employment opportunities (Rigó & Lunau, 2023). The authors summarise cross-country evidence on the effects of certain ALMP measures (Rigó & Lunau, 2023): Job search assistance has positive effects on individuals' self-efficacy, mental health and the labour market, through improved person-job match (Rigó & Lunau, 2023); subsidised public employment may improve material and social resources through temporary job opportunities (Rigó & Lunau, 2023); subsidised private employment may also provide training opportunity and on-the-job skills (Rigó & Lunau, 2023). But also passive labour market policies (PLMP) will remain relevant to provide protection for older workers (Rigó & Lunau, 2023). To facilitate a transition from disadvantageous to advantageous working conditions, for example, via job changes, the costs associated with (temporary) unemployment should be reduced (Rigó & Lunau, 2023). The benefits of such changes and also the negative effects of reluctant staying despite poor working conditions are extensively described by Garthe (2022).

There is potential for future policy reforms to reduce educational inequalities in health. As highlighted in previous chapters, improving working conditions and health behaviours constitute important levers to reduce educational inequalities in health in times of extended working lives. Later retirement may have severe health-adverse effects for some workers, particularly those with low SES (Bellés-Obrero et al., 2022; Burdorf et al., 2023). A study by Bellés-Obrero (Bellés-Obrero et al., 2022) suggests that the ability to reduce working time has the potential to alleviate the health-adverse effect of postponing retirement (Bellés-Obrero et al., 2022).

Policies to improve the quality of work for older workers have been implemented by Finland and Belgium in the past years (Street & Ní Léime, 2020). These might serve as examples for future German policies. The policies focus on improving working conditions and older workers' work ability and employability (Street & Ní Léime, 2020). Another helpful tool could be temporary income substitution if health conditions make it necessary to change to a lower paid job (Street & Ní Léime, 2020). Furthermore, a reduction regarding inequalities in work stress have been attributed to the aforementioned ALMP measures (Rigó & Lunau, 2023). It is thus likely that policy measures to reduce social inequalities in early exits from employment and measures to reduce inequalities in health are mutually reinforcing.

Future policy reforms require a biographical perspective. Gendered conditions regarding working life courses have been insufficiently addressed by public policies (Ní Léime & Street, 2016). In chapter

3.2.2 ('The role of employment quality'), it was described how employment-related health risks accumulate during women's careers and translate into poor health and a lack of control during the late career. Precarious and discontinuous employment clusters in many female-dominated professions, for example, in the personal service and business service sector.

First, the amount and availability of, as well as the awareness about care credits should be increased as some authors suggest (Jessen et al., 2022). Both society and politics should push the equal distribution of care work between men and women, for example, by incentivising non-transferable father-specific leaves and reducing the stigma of male care (McMunn, 2023).

Furthermore, high statutory minimum wages have been a successful tool to decrease income and pension inequalities between men and women (Jessen et al., 2022; Rigó & Lunau, 2023). Moreover, from an occupational health perspective, a reversal from defined-contribution to defined-benefit pension schemes might be advisable in order to mitigate the individualisation of employment risks (Ogg & Rašticová, 2020). Defined contribution schemes have adverse effects, particularly among women, who more often experience fragmented careers due to unpaid care work (Jessen et al., 2022; McMunn, 2023; Ogg & Rašticová, 2020). In this respect the Dutch flat-rate pension system seems to reduce gender inequalities (Ogg & Rašticová, 2020) and could serve as an example for future German pension reforms. The Dutch pension system comprises three main pillars, of which one constitutes a basic old-age pension available to all residents upon reaching statutory retirement age (OECD, 2017b). Such pension schemes have a strong redistributive effect (Hofäcker et al., 2016) and could reduce the impact of precarious and discontinuous careers on pension eligibility and thus reduce financial insecurities during the late career, particularly for women involved in unpaid care work.

Throughout this thesis, the role of the life course, or more specifically, the potential effect of earlier life experiences on later life outcomes were highlighted. To counteract cumulative disadvantage across the life course, policy measures to address employment quality and stability and their effect on pension eligibility should be addressed beginning early in life (Bennett & Möhring, 2015; Head et al., 2023). This does not only apply to disadvantages structured by sex, but also by education (Lain & Phillipson, 2019).

3.3   Strengths and limitations

This paragraph will provide a short overview of major strengths and limitations of the three studies of this dissertation, addressing the availability and quality of data and the statistical analyses applied in the studies.

The data. For all three studies data from the German lidA study was used (for the cohort profile see Hasselhorn et al., 2014). As a prospective cohort study including a large representative sample of socially insured employees in Germany born 1959 and 1965 – the birth cohort 1971 was not investigated

– lidA is very suitable to investigate causal associations between work-, health-, and labour participation-related variables. The narrow focus on the two cohorts of older workers can be seen as a strength. The interdependence of work, health, and employment is dynamic over the life course as has been highlighted in previous sections of this dissertation. Depending on the phase of the life course, the quantitative contribution of investigated determinants to social inequalities in health and labour participation does likely vary. Consequently, the present results are more robust to the impact of time, the timing of exposures and the socio-political context as confounding variables, given that the investigated cohorts may have experienced such trends in similar life phases, as Table 1 highlights. A disadvantage of the narrow focus in terms of age and country/nation is that the results are only generalisable to employees with similar demographic characteristics and experiencing similar welfare state and labour market contexts.

Next, all studies analyse longitudinal data from lidA study waves 1 to 3 (2011, 2014, 2018) or 1 to 4 (2011, 2014, 2018, 2022). This longitudinal perspective can be seen as a strength. However, from a life course perspective the observed time frame is very limited. Information on exposures during earlier life phases, for example, on work factors, employment quality trajectories, and health are not captured. This could explain, for example, why inequalities in health and labour participation could only be partially explained in the mediation analyses (studies I and II). Furthermore, regarding study III, especially women from the baby boom generation might be at risk for discontinuous and low-quality employment for extended periods, possibly beginning with the birth of the first child. However, these earlier life phases were not captured and hence, many important years of exposure cannot be covered by the trajectory analysis in study III.

The statistical analyses. A major strength of all three studies is the longitudinal assessment of variables allowing for their temporal ordering. Two complex modern statistical methods were used to answer the research questions. First, a counterfactuals-based mediation analysis using inverse odds weighting (Tchetgen Tchetgen, 2013) (study I and II): This effect decomposition method is very suitable to disentangle social inequalities and to infer relevant variables to alleviate such inequalities (Siegrist & Marmot, 2023; VanderWeele, 2015). Secondly, in study III, Group-Based Trajectory Modelling (GBTM) (Nagin, 2005) was used. This method is suitable to capture the dynamics of exposures or outcomes over extended periods of time (Nagin, 2005; Nagin & Odgers, 2010).

A further strength of all three studies is the use of sensitivity analyses to investigate the robustness of results. In study I, the very recently proposed Mediational E-Values (Smith & VanderWeele, 2019) were calculated to examine the potential influence of unobserved confounding. In Study II, the causal association between work factors and health and labour participation was investigated, using both Cox Proportional Hazard Regression and competing risk regression, applying the Fine & Gray model (Fine & Gray, 1999), since three competing exit routes were investigated. Lastly, in study III using data from all four lidA survey waves, results applying a longitudinal non-response weight were compared with

unweighted results and a second set of analyses was conducted allowing unemployed to be included in the sample.

Another strength is that item- and unit non-response were accounted for. In study I and III, stabilized longitudinal weights to account for selective unit non-response were applied specifically for each study depending on the selected study waves and sample. Using inverse probability weighting (c.f., Seaman & White, 2013), weights were created on the level of the individuals and not on an aggregate level (e.g., for educational or occupational groups). Therefore, the approach accounts for each individual's probability to participate depending on multiple personal characteristics measured in relation to the sampling frame (for more details see Rohrbacher & Hasselhorn, 2023). Lastly, by using multiple imputation with chained equations (White et al., 2011), item missingness was accounted for (study I).

However, regarding the statistical analyses there were also several limitations, which mainly concern study II, the first among the three that was submitted. The study only contained a small set of mediators. A strength was that all mediators were selected based on evidence about the strength of their associations with both the main exposure and the outcome (Rohrbacher & Hasselhorn, 2022). A drawback of study II was the inclusion of quantitative demands in the models, in which all work factors (and health and work ability) were investigated. Quantitative demands likely disadvantage those with higher SES and thus contribute negatively to inequalities in early exits. Future studies should only include variables that positively contribute to inequalities in the outcome.This was done and discussed in study I (Rohrbacher & Hasselhorn, 2023), which was submitted secondly. A further limitation of study II was that the mediators were explored and results displayed not only en-bloc, but also individually. However, a sequential approach, where larger sets of mediators are investigated collectively in a pre-determined order is recommended, because only the model using all mediators en-bloc is robust to unmeasured common causes of the mediators (Hossin et al., 2019). A preferred sequential approach could have first included all work factors (not including quantitative demands) then health, then work ability. The improved approach was used in study I, although with a different set of variables. Still, inverse odds weighting analyses investigating mediators individually can and should be provided supplementary, as they can be very informative.

Lastly, study II focused largely on push factors out of employment. This decision was justified in the respective paper (Rohrbacher & Hasselhorn, 2022). However, future studies should additionally focus on pull, need, and maintain factors. Examples of relevant items are provided in Table 3.

3.4 Conclusion and outlook

This chapter concludes the dissertation. First, the key findings ('the facts') of this dissertation (chapter 2 and 3.1) are presented and placed in context by delineating the main discussion points ('the thoughts') from the preceding chapter 3.2. Lastly, I will provide 'the outlook'. The conclusion and outlook are organised following the chapters in the discussion section (chapter 3.2), that is, not by research papers

but by the role of work, employment quality, individual, health and work ability, life course, and policies. To structure this last chapter, for each domain a text box is used (Table 4-9). Depending on the respective domain, the outlook has a stronger focus on either implications for research or implications for practice.

Table 4

Conclusion and outlook regarding the role of work

> **The facts:** Work factors contributed 21% to physical health inequalities between low and high educated older female workers, but only 5% to physical health inequalities between low and high educated older male workers (Rohrbacher & Hasselhorn, 2023). Additional analyses suggested possibilities for development and influence at work to be the most powerful of studied work factors to explain health inequalities among women. With respect to educational inequalities in early exits through long-term unemployment, physical demands and influence at work showed significant contributions when investigated individually. However, health and work ability were more powerful explanatory variables.
>
> **The thoughts:** International study findings only partly concur. This is likely because of the varying age range of studied subjects, the moderating role of national welfare state and labour market contexts as institutional filters and the diverging set of exposures and outcomes depending on data availability. The findings are safely generalisable to German baby boomers from the birth cohorts 1959 and 1965, but should be interpreted with caution for other cohorts and welfare contexts.
>
> **The outlook:** Generally, with respect to work factors, findings from study I and II highlight the importance of job resources when it comes to inequalities in both health and labour participation. This is supported by previous evidence. Possibilities for development and the influence at work should be improved in jobs where older female workers with low education are highly represented.

Table 5

Conclusion and outlook regarding the role of employment quality

> **The facts:** 20.2% of women and only 5.5% of men followed a precarious employment trajectory over 11 years during the late career (Rohrbacher et al., 2024). Only among women and not among men, membership in the precarious employment trajectory versus non-precarious employment was associated with increased odds (Odds Ratio 1.68-1.82) to report poor mental health at follow-up (Rohrbacher et al., 2024).
>
> **The thoughts:** Women experience accumulating employment-related mental health risks during the life course. The care of adults, low pay, lone work, a lack of rights and protection, poor working

conditions and unfavourable welfare and household conditions may contribute to the disadvantaged role of older women with respect to both, exposure to poor employment quality and its short-term and long-term effects on mental health. This may particularly apply for countries in which the 'male breadwinner' norm is still structurally anchored.

The outlook: Future policies should account for the highly gendered unpaid care duties, but also create further incentives to reinforce equal distribution of care work between sexes, also with respect to adult care. Union coverage should be increased to strengthen employees' rights and protection. Unions should intensify their efforts to protect employees at the margins of the labour market.

Table 6

Conclusion and outlook regarding the role of the individual

The facts: Among women, health behaviours contributed 26% to physical health inequalities between low and high educated and 20% between low and moderately educated older workers (Rohrbacher & Hasselhorn, 2023). Among men, health behaviours contributed 24% to physical health inequalities between low and high educated and 27% between low and moderately educated (Rohrbacher & Hasselhorn, 2023). Among women, BMI showed the largest contribution, among men, smoking and physical activity showed the largest contribution to physical health inequalities (Rohrbacher & Hasselhorn, 2023).

The thoughts: Current evidence suggests individual health behavioural change is facilitated or constrained by macro- and meso-level structures. For example, previous findings indicate that several health behaviours may improve upon retirement entry (Celidoni & Rebba, 2017). Furthermore, there are mutual spill-over effects of working conditions and health behaviours.

The outlook: Thus, improving working conditions and implementing welfare policies, which account for the diversity of life courses, may be an important prerequisite to facilitate health behavioural change, to reduce inequalities in health and to enable longer working lives.

Table 7

Conclusion and outlook regarding the role of health and work ability

The facts: Study I showed that working conditions and particularly health behaviours are powerful in explaining educational inequalities in physical health (Rohrbacher & Hasselhorn, 2023), while study III highlighted the negative consequences of poor employment quality trajectories on mental health (health as an outcome) (Rohrbacher et al., 2024). Study II showed that mental and physical

health, as well as work ability are very powerful in explaining educational inequalities in early exits from employment (Rohrbacher & Hasselhorn, 2022) (health as an exposure).

The thoughts: Extending working life may be beneficial for higher SES groups and have health-adverse effects for lower SES groups, given the eminent role of health and work ability in this respect. A large proportion of workers with health impairments may well be able to continue working given sufficient work ability, but strengthening work ability is not sufficiently addressed by the current EWL policies.

The outlook: To mitigate existing inequalities, it is important to address the determinants of health and health as a determinant. Significant improvements in working and employment conditions, as well as health behaviours seem necessary to reduce health inequalities. Subsequently, this may contribute to alleviating social inequalities in early exits from employment. Promising work- and employment-related factors to address: physically strenuous work, effort-reward-imbalance, passive and strenuous jobs, shift work, inadequate pay, contractual relation insecurity; promising health behaviours to address: smoking, leisure-time physical activity (and BMI).

Table 8

Conclusion and outlook regarding the role of the life course

The facts: Some unexpected findings and in part small effect sizes in studies I, II and III, as well as the synopsis of current evidence suggest that early life exposures may have formative effects on late life experiences, such as poor health and early exits during the late career.

The thoughts: Since data on determinants of health and labour participation is often restricted to limited time frames in prospective cohort studies, the quantitative contribution of certain exposures, such as poor working and employment conditions and adverse health behaviours to inequalities in health and labour participation should always be interpreted against the background of time and place and the impact of preceding life sequences and transitions.

The outlook: Improved availability of data on individuals' life courses would help researchers to explore mechanisms that link exposures to outcomes across the life course. Facilitated access to administrative data as well as the collection of retrospective life course data within quantitative surveys would support such efforts. Life course data in combination with the application of methods, such as sequence analysis and trajectory modelling may help to grasp the dynamics of cause and effect during different phases of the life course. Lastly, to mitigate social inequalities in health and labour participation, interventions to address the determinants studied within this thesis should start early during the life course**.**

Table 9

Conclusion and outlook regarding the role of policies

The thoughts: EWL policies have focused primarily on dissuasive rather than incentive measures, more strongly restricting access to welfare and pensions than supporting older workers' employability, targeting pull factors rather than push factors out of employment. Throughout this thesis, the potential of current EWL policies to widen existing social inequalities in the prerequisites, the motivators and the consequences of a prolonged working life have been elaborated on. While choices (regarding labour participation) have been increasingly institutionalised, labour market risks have been increasingly individualised.

The outlook: From an occupational health and socio-epidemiological perspective, this trend should be reversed by institutionalising labour market risks and individualising choices. Further measures could be used to enable older employees to extend their working life as this dissertation and previous literature suggests. Inequalities in early exits could be reduced i.a., by improving work ability, improving work opportunity, rapid re-integration, job search assistance and by facilitating the transition from disadvantageous to advantageous working conditions. Inequalities in health could be reduced i.a., by improving the quality of work and employment, by opportunities to reduce the working time and by temporary income substitution. Policies should account for life course trajectories structured by sex and education and reduce existing inequalities between men and women and educational groups. Exemplary measures: more generous care credits; incentives to support the equal distribution of care work between men and women; high statutory minimum wages and basic old-age pension; reversal from defined contribution to defined benefit pension schemes. Evidence on the potential cost-effectiveness of such measures must be obtained from intervention studies.

This dissertation provides new evidence on social inequalities in health and labour participation during the late career of older employees in Germany. The use of high-quality comprehensive quantitative survey data from the German lidA study, partly in combination with employment-register data, as well as the use of modern statistical methods allow to grasp the complexity of the mechanisms linking work and employment conditions with health and labour participation among older employees.

In summary, it was shown that particularly low educational attainment, but also female sex are associated with a higher risk of being disadvantaged in terms of health and labour participation during the late career. The contribution of work and employment conditions, health (behaviours), and work ability to social inequalities in health and labour participation varies depending on measures of exposure, outcome, and social position. In synopsis, the findings support the notion that "longer work lives come at the expense of people with the effects of cumulative disadvantage across the life course" (Lain & Phillipson, 2019, p. 71).

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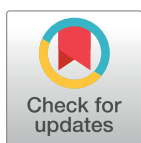
Appendix

Appendix A: Study I

Rohrbacher, M., & Hasselhorn, H. M. (2023). The contribution of work and health-related lifestyle to educational inequalities in physical health among older workers in Germany. A causal mediation analysis with data from the lidA cohort study. *PLOS ONE*, *18*(8), e0285319. https://doi.org/10.1371/journal.pone.0285319

PLOS ONE

The contribution of work and health-related lifestyle to educational inequalities in physical health among older workers in Germany. A causal mediation analysis with data from the lidA cohort study

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Abstract

Objectives

The objective of the study was to investigate the contribution of work factors and health-related lifestyle to educational inequalities in physical health among older workers in Germany by applying causal mediation analysis with longitudinal data.

Methods

Data from the German lidA study was used. 2653 persons (53% female, 47% male) aged 46 (born 1965) and 52 (born 1959) at baseline were followed up for seven years with exposure and outcome assessments in 2011 (t0), 2014 (t1) and 2018 (t2). The total effect of education on physical health was decomposed into a natural direct effect (NDE) and a natural indirect effect (NIE) by using a sex-stratified causal mediation analysis with an inverse odds weighting approach. Baseline health, partner status and working hours were entered as a first set of mediators preceding the putative mediators of interest. All analyses were adjusted for age and migrant status.

Results

Independent of the first set of mediators, work factors explained 21% of educational inequalities in physical health between low and high educated women and 0% comparing moderate versus high educated women. The addition of health behaviors explained further 26% (low vs. high education) and 20% (moderate vs. high education), respectively. Among men, net of the first set of mediators, work factors explained 5% of educational inequalities in physical health between low and high educated and 6% comparing moderate versus high educated persons. Additional 24% (low vs. high education) and 27% (moderate vs. high education) were explained by adding health behaviors to the models.

Conclusions

To reduce educational inequalities in physical health among older workers in Germany, interventions to promote healthy behaviors are promising. Improving working conditions is likely an important prerequisite.

Introduction

In many European countries the life expectancy is increasing and has contributed to demographic aging [1]. Driven by demographic aging, many European countries have adapted their social policies in order to extend the working life (EWL) [2, 3]. In Germany, early exits out of employment have increasingly been sanctioned, e.g. by restricting eligibility criteria for disability pension and by reducing the duration and amount of unemployment benefits; in parallel, the statutory retirement age has been raised and, continued employment has been incentivized [4]. These current EWL policies, which are mainly focused on (financial) pull-factors, unequally impact groups of different socioeconomic status (SES) [3, 4]. As opposed to high-skilled and high-earning workers at higher working age, those with lower SES have not benefitted equally from advances in health [1] and are therefore still at higher risk of health-related early exit from employment [5, 6]. Researchers therefore suggest that the combined effect of unequal health improvements and the unequal impact of retirement policies may aggravate existing health inequalities [7, 8].

Social inequalities in health

Over the past decades, strong evidence of health inequalities in populations has accumulated. Most health complaints are more prevalent in lower SES groups and social inequalities in health are found at all ages with varying magnitude depending on the country [9, 10].

When examining health inequalities, the choice of the social status indicator as well as health indicator plays an important role. Emerging empirical evidence [11, 12] strongly suggests a longitudinal effect of the SES on health, supporting the causation hypothesis when older workers are investigated. However, these findings cannot be generalized to all health outcomes and the magnitude of the health gradient seems to depend on the operationalization of the SES [13].

Common operationalizations of the SES are education, occupation, and income [14]. Of the three, education may be the most suitable to investigate causal effects on health at higher working age. This is because scholarly education and vocational qualifications are obtained during the early career phase and the construct is very stable at higher working age [15]. Therefore, the assumption of temporal order of cause and effect is more easily fulfilled using education compared to current occupation and income.

While self-reported general health (SRH) and physical health exhibit gradients in the expected direction for all operationalizations of SES, this does not apply to common mental health disorders [13]. Studies using education to operationalize SES indicate weak and inconsistent associations between education and common mental health disorders [13, 16]. This may be one of the reasons why a number of existing studies on educational inequalities in health, focus on SRH as the outcome [cf. 11, 12]. SRH has been shown to be suitable for international comparison and to predict mortality and morbidity [17, 18]. However, there are multiple reasons why the (further) investigation of educational inequalities in physical health, rather than SRH, could be of interest, especially when examining older workers in Germany:

- Firstly, SRH and physical health are strongly related [19], but the latter may be a more objective measure than SRH [20] and more specifically assessing physical functioning at work and limitations of activities of daily living–and thus allowing for more precise conclusions.

- Secondly, some authors highlight that social inequalities in health may be underestimated when SRH is used as the outcome, because the association between health problems and SRH is stronger among higher educated persons [20].

- Lastly, in a previous study, educational differences in physical health explained a large proportion of social inequalities in early exit from employment [6]. Thus, investigating factors that contribute to physical health inequalities may provide further knowledge to extend the discussion of inequalities in early exits.

Work, health-related lifestyle, and SES

Findings from studies based on cross-sectional as well as longitudinal data have stressed the role of work factors and health-related lifestyle contributing to health inequalities [11, 12, 21], thereby supporting the theoretical model on the explanation of health inequalities by Elkeles and Mielck [22]. A mediating role of work factors in the relationship between SES and health can be indirectly inferred from evidence indicating a higher prevalence of adverse working conditions among groups of low SES on the one hand, and evidence on the negative effects of adverse working conditions on health [23, 24] on the other hand. Physical demands are more prevalent among low-skilled individuals [11, 12, 21]. Similarly, lower skilled workers more often report a lack of resources such as influence at work, possibilities for development, job rewards and good leadership quality [11, 12, 21, 25]. However, an inverse gradient has been frequently observed for quantitative demands and efforts at work [6, 11, 26, 27].

With respect to health behaviors, there is a clear social gradient for smoking, leisure-time physical inactivity and high body weight, all more prevalent in lower SES groups [26, 28–30].

Research need and study objectives

The assumption of mediation of the effect of SES on health by work factors and health behaviors is furthermore supported by a growing body of research applying mediation analysis [11]. However, longitudinal studies are still scarce and the mediation hypothesis has mainly been tested using a difference in coefficients approach which does not sufficiently take exposure-mediator interactions into account [see 11 for a systematic review of studies]. So far, to our knowledge, only three longitudinal studies have investigated the contribution of work factors and/or health behaviors to social inequalities in health among older workers [12, 31, 32]. Among these studies, the study by Schram et al. [12] was the first to simultaneously examine mediation by work factors and health behaviors. This was done by using causal mediation analysis. The study showed that among older European employees, 38% of the effect of low versus high education on SRH (RR 1.48, 95% CI 1.37–1.60) was mediated by working conditions (physical demands, lack of job control and lack of rewards combined) and 16% by health behaviors. However, their sensitivity analyses indicated that the effect mediation through working conditions and health behaviors varies by European region. Health behaviors contributed considerably more to health inequalities in Northern (Sweden, Denmark) and Western/Central Europe (Belgium, The Netherlands, France, Germany, Switzerland, Austria) compared to Southern countries (Greece, Spain, Italy) and the contribution of working conditions was large in Southern countries, lower in Western/Central Europe and non-existent in Northern countries. The study only contained a small subsample of older workers in Germany (around

10% of those from Western/Central European region) so that the specific contribution of work factors and health behaviors to health inequalities in Germany remains unclear.

To conclude, models and evidence indicate that work factors and health-related lifestyle mediate the effect of SES on health. This, however, has to our knowledge never been investigated longitudinally for older workers in Germany. The use of education as the SES indicator is suitable in this setting, given the stability of the construct at higher working age. Furthermore, as elaborated above, using physical health as the outcome may be advantageous in this context. Lastly, using causal mediation analysis with an Inverse Odds Weighting (IOW) approach [33] allows to study multiple mediators simultaneously, even in the presence of exposure-mediator interactions on the outcome [12, 34, 35].

Thus, the aim of the study is to investigate the contribution of work factors and health-related lifestyle to educational inequalities in physical health among older workers by applying causal mediation analysis with longitudinal data.

Materials and methods

Study design and participants

3232 subjects, who participated in all three existing waves (t0 = 2011, t1 = 2014, t2 = 2018) of the German lidA-study, were eligible for inclusion in the current study. lidA is a prospective cohort study investigating the topics, work, age, health, and labor market participation among persons from the German baby boom generation. Persons from two birth cohorts (born 1959 and 1965) have been interviewed every 3 or 4 years (2014, N = 4244; 2018, N = 3586) by computer assisted personal interviews (CAPI) given their initial participation in 2011 (N = 6585). The primary response rate, which is the ratio of achieved interviews at wave 1 (t0) (n = 6,637) to the operational sample (n = 24,322) was 27.3%. 6585 valid interviews were achieved. Descriptive statistics revealed only small deviations between the gross sample and respondents [36]. All outcome rates reported in line with the standard definitions by the American Association for Public Opinion Research (AAPOR), can be found in a methods report [36] and are similar to other representative employee surveys, e.g. the German Study on Mental Health at Work (S-MGA) [37].The lidA study is representative of older socially insured employees of the two cohorts with respect to sociodemographic characteristics, such as sex, education, and occupation [36, 38]. Self-employed and sworn civil servants were not included in the study. Further information on the study design can be found elsewhere [36, 38]. As can be seen in Fig 1, those with an employment status other than full-time or part-time were excluded from the sample, in order to assume similar exposure time to working conditions across the sample. Additionally, those without a superior were excluded, since two of the investigated covariates included assessments of the superior. Lastly, cases with missing values on the main exposure (education) were excluded. To account for potential selection bias a longitudinal non-response weight was calculated, which is described in further detail below. Subjects for which the weight could not be computed (n = 33) were also excluded, resulting in a final study sample of N = 2653 (53% female, 47% male).

All data was collected in accordance with the Declaration of Helsinki (1964) and its later amendments. Participants were informed about the aims and procedures of the study. Participation required oral consent at each study wave. The Ethics Committee of the University of Wuppertal approved the protocol for the lidA Cohort study [5 December 2008 (Sch/Ei Hasselhorn) and 20 November 2017 (MS/BB 171025 Hasselhorn)].

Measurements

In Fig 2 the assumed causal model is presented with confounders depicted in red boxes. "t0" indicates baseline assessment in 2011, "t1" first follow up in 2014 and "t2" second follow up in
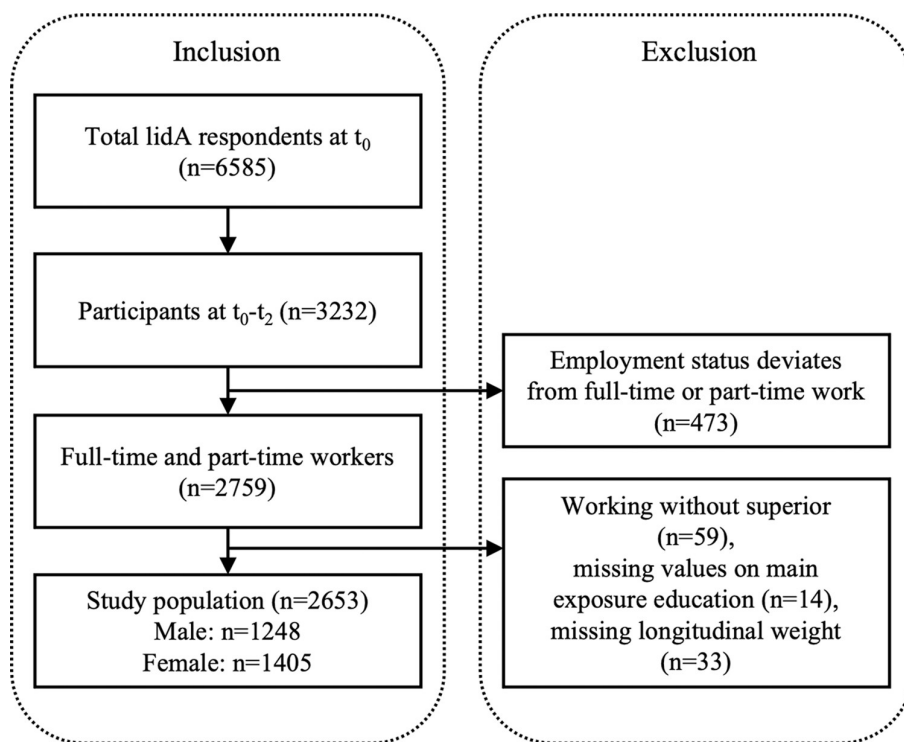
Fig 1. Summary of inclusion and exclusion criteria.

2018. To ensure that all focal mediators succeeded the exposure and preceded the outcome, mediators were measured at t1, the exposure was measured at t0 and the outcome at t2. Further post-exposure variables, namely baseline health, partner status and working hours, which likely precede the focal mediators, were entered into the model as described in the section on statistical analyses and were measured either at t0 or t1.
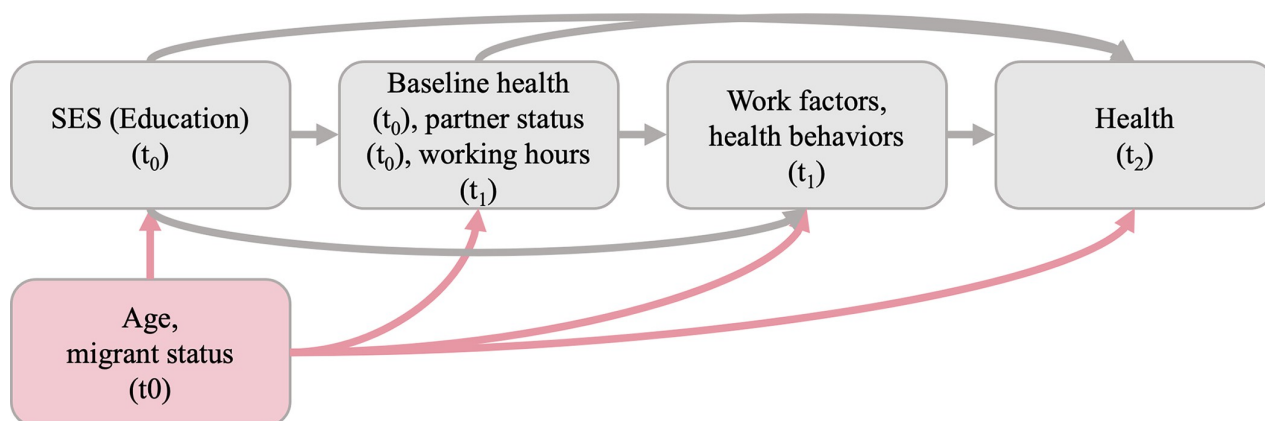
Fig 2. Assumed causal model for sex-stratified analysis.

Physical health (t2)

Physical health was measured using the Short Form Health Survey (SF-12 PCS) (e.g. limitations "climbing several flights of stairs", "[. . .] limited in kind of work or other daily activities [. . .] as a result of your physical health") [39, 40 p. 90–91]. A sum score ranging from 0 to 100 was computed following the procedure described by Nübling et al. [41]. The sum score was subsequently dichotomized as the Shapiro-Francia test indicated a significant deviation from normal distribution (V' = 41.011, p-value >0.01). The inspection of normality tests and diagnostic plots showed that the distribution was moderately left skewed, with skewness of -0.71 at baseline (t0) and -0.53 at follow-up (t2). We used the 25th percentile at t0 to determine subjects with poor physical health, which corresponds to a cut-off of 45 on a scale from 0–100. Previous studies have also used the 25th percentile as cut-off to determine a poor physical health status [42]. Values of 50 or less on the SF-12 PCS scale may be indicative of a physical condition [40].

Educational attainment (t0)

Our main independent variable was the educational level, which combined education and vocational training [43]. We trichotomized the variable into the three categories low (primary, lower secondary and upper secondary general education, cf. ISCED-97 1-3A), moderate (upper secondary vocational education and post-secondary non tertiary education, cf. ISCED-97 3B-4A), and high education (tertiary education, cf. ISCED-97 5–6).

Baseline health, partner status and working hours (t0, t1)

Baseline physical health (t0), partner status (not single/single) (t0) and working hours (full-time/part-time) (t1) were entered as a first set of mediators to precede work factors and health-related lifestyle. The sequential approach is explained in the section about the statistical analysis below.

Work factors (t1)

Time exposed to awkward body postures, heavy lifting, and repetitive movements was used to assess physical demands at work. Exposure to any of these dimensions for more than 25% of working hours was considered as high physical demands and exposure below that limit as low physical demands.

Influence at work, possibilities for development and leadership quality were each measured with three items from the German version of the Copenhagen Psychosocial Questionnaire (COPSOQ II, middle version) [44] and subsequently transformed into three separate sum scores ranging from 0–100. In this study, high scores indicate adverse exposure. Validation of the COPSOQ questionnaire in Germany indicated good psychometric properties of the single scales [44].

Rewards at work were measured by the reward short scale from the ERI instrument [45]. The short scale combines seven items (e.g., "I receive the respect I deserve from my superior or a respective relevant person") to a total score ranging from 7.00 to 28.00. For the current analysis, the sum score was inverted so that a value of 28.00 reflects a total absence of rewards.

Health-related lifestyle (t1)

Leisure-time physical activity, smoking and BMI were included as health-related lifestyles. Leisure-time physical activity was initially assessed with four response categories and dichotomized for the current analysis. Answer categories "I read, watch TV and do jobs that don't involve much movement and are not physically demanding" and "I walk, cycle or exercise at

least 4 hours a week. This includes walking, light gardening, but not commuting to work."
were recoded into "no or light physical activity". Answer categories "I do at least 3 hours of
physical exercise per week such as running, jogging, gymnastics, swimming, ball games, heavy
gardening or other heavy physical activities." and "I do intensive sports several times a week
like running, swimming, cycling." were recoded into "moderate or high physical activity".
Smoking was recoded into three categories dividing the sample into "non-smokers", "former
smokers" and "current smokers". The BMI (weight in kg / body height in m^2) was trichoto-
mized into "normal (< 25)", "overweight (≥ 25-< 30)" and "obese (≥ 30)".

Confounder

Age at baseline (46 [born 1965] or 52 [born 1959]) and migrant status (non-migrant/migrant)
were used as the minimal adjustment set to calculate TE, NDE and NIE. Age and migrant sta-
tus constitute background risks for physical health. Adjustment might reduce confounding.

Statistical analysis

First descriptive statistics were displayed. All analyses were sex-stratified because previous
analyses had shown the differentiated effect of work factors and health behaviors on health
among women and men [9, 32, 46].

To investigate mediation effects we conducted a causal mediation analysis with inverse
odds weighting [33]. The Total Effect (TE) of the main exposure (education) on physical health
was decomposed into a Natural Direct Effect (NDE) and Natural Indirect Effect (NIE). NDE
describes the effect of the exposure on the outcome with the pathway through the investigated
intermediate(s) being deactivated [34, 35]. We note that the interpretation of the NDE is
always relative to the mediators under study. The NIE describes the effect of the exposure on
the outcome through the studied mediator(s) (without the direct effect element) [35, 47]. To
account for potential selection bias, we computed a longitudinal non-response weight. The
weight consists of two components, first a cross-sectional post-stratification weight and sec-
ondly, a non-response weight. Both components were multiplied to create a longitudinal
weight:

$$Longitudinal\ weight = weight_{t0} \times weight_{selected}$$

The post-stratification weight ($weight_{t0}$) accounts for unequal selection probability by
design and unequal participation probability at baseline (t_0). For this weight an inverse proba-
bility weighting (IPW) was used for multiple socio-demographic variables including age, edu-
cation, nationality and place of residence based on model-based selectivity analysis [36]. More
detailed information about the procedure can be found elsewhere [36]. For selection into our
final analysis sample, which only includes participants of all three waves, working full-time
and part-time, with a superior (n = 2,653) we calculated a stabilized IPW ($weight_{selected}$) [c.f.
48] for the variables age, education and migrant status. Mean weighting factors by educational
level and sex are provided in the supplement (S1 Table).

To achieve the described effect decomposition, we followed the analysis steps described by
Nguyen et al. [34]: First, an Inverse Odds Weight (IOW) was created by taking the inverse of
the predicted log odds for each individual from an exposure model [34], which involved edu-
cation as the dependent variable and the mediator(s) and confounders as independent vari-
ables. We used multinomial logistic regression for the exposure model. Subsequently,
individuals from the exposed group (first the low educated, then the moderately educated)
were assigned the IOW multiplied with the longitudinal non-response weight, while the refer-
ence group was assigned the longitudinal non-response weight only. The TE was then

calculated using a general linear model with Poisson distribution, log link function and robust error variance [34, 49]. This is preferred over logistic regression in the presence of common (> 10%) outcomes to avoid an overestimation of the NDE [50, 51]. The NDE was calculated with the same model but including the IOW. This way the mediator is never entered into either of the outcome models. The NIE was calculated by subtracting the NDE from the TE. Using the following formula for ratio measures [52], the proportion of the TE mediated was then calculated for the relative risks (RR):

$$Proportion\ mediated\ (PM) = \frac{RR^{NDE} \times (RR^{NIE} - 1)}{(RR^{NDE} \times RR^{NIE} - 1)}$$

All effect estimates and 95% CIs were computed using 1000 bootstrap replications. The described steps were conducted for each mediator individually and for all mediators combined using Stata V15.1 (College Station, TX: StataCorp LLC). The Stata code for the procedure, which was based on influential previous studies [34, 50, 53], is provided as a supplement (S1 File). Missing values were handled by Multiple Imputation by Chained Equations [54]. In the total sample, 12.1% of all observations had at least one missing value, which was mainly attributable to missingness on the job rewards variable. Hence, we regarded 10 imputations as sufficient and efficient [cf. 54]. The imputation model included all analysis variables as well as self-perceived general health as auxiliary variable.

To identify NDE and NIE several assumptions have to be made: These are no unmeasured confounding of the 1) exposure-mediator relationship, 2) mediator-outcome relationship and 3) exposure-outcome relationship as well as 4) no exposure induced confounding of the mediator-outcome relationship [35]. Although the panel design of our study is an advantage to separate cause and effect, the temporal ordering of exposure, mediators and outcome also introduces further risk for violation of some of these assumptions. Especially the fourth assumption may be violated in the presence of variables that are affected by the exposure and precede the focal mediators. We have identified three candidate variables which are likely exposure-induced mediator-outcome confounders, namely baseline health, partner status and working hours. To prevent violation of assumption four by these variables we followed a sequential mediation approach [55] to jointly assess mediation through the focal mediators (work factors, health behaviors), dependent on these preceding post-exposure confounders, which now constituted a first set of variables to be included in the mediator vector, as suggested by VanderWeele et al. [56]. Sequentially, work factors were then added to the mediator vector in a second step and both work factors and health behaviors in the third step. Supplementary, we assessed the mediation effects for all putative mediators individually based on the first set of mediators, including baseline health (S2 and S3 Tables).

Sensitivity analysis

We calculated mediational E-values [57] to assess how strong potential unobserved confounders would have to be associated with both, the mediators under investigation and the outcome conditional on the measured confounders to explain away the NIE and to shift the 95% CI to include a relative risk (RR) of 1. This is a mediational analogue to the E-value introduced by VanderWeele et al. [57, 58] and can be calculated as follows, based on the observed RR for the NIE:

$$Mediational\ E - value = RR^{obs} + \sqrt{RR^{obs} \times (RR^{obs} - 1)}$$

Results

Tables 1 and 2 show the characteristics of the female and male study sample, respectively. Among both women and men, those with low education had a higher prevalence of poor physical health at baseline and follow-up. The social gradient in physical health was stronger among men. However, relatively more women with low education compared to those with high education changed from having good health at baseline to poor health at follow up, which amplified the gradient at follow-up among women. The social gradient among men remained relatively stable. Regarding work factors a clear social gradient in the expected direction was observed for physical demands and possibilities for development among women (Table 1) and for physical demands among men (Table 2). Regarding health-related lifestyles the social gradient in BMI stood out among women (Table 1) and in smoking and leisure-time physical activity among men (Table 2).

In Table 3, results from the mediation analyses among the female subsample are displayed. Compared to women with high education, those with low education had a 1.55-fold (95% CI 1.42–1.68) and those with moderate education a 1.54-fold (95% CI 1.42–1.65) higher risk of reporting poor physical health at follow-up (total effects). Comparing low versus high educated women, the first set of mediators, including baseline health, partner status and working hours mediated 18% of the TE (RR^{NIE} 1.07, 95% CI 1.04–1.10). The second set of mediators, additionally including all work factors, explained 39% of the TE (RR^{NIE} 1.16, 95% CI 1.10–1.21). Hence, independent of the first set of mediators (39%-18%), all work factors combined explained 21% of the TE comparing low versus high educated. The complete set of mediators, additionally including all health behaviors, mediated 65% of the TE (RR^{NIE} 1.30, 95% CI 1.19–1.42). Thus, independent of work factors, baseline health, partner status and working hours, health behaviors explained 26% of the TE. Independent of the complete set of mediators the effect of low versus high education on physical health among women was RR^{NDE} 1.19 (95% CI 1.03–1.35).

Comparing women with moderate versus high education, the first set of mediators mediated 39% of the TE (RR^{NIE} 1.16, 95% CI 1.14–1.17). The addition of all work factors to the first set of mediators did not increase the PM (RR^{NIE} 1.16, 95% CI 1.14–1.18). The complete set of mediators, additionally including all health behaviors, mediated 59% of the TE (RR^{NIE} 1.26, 95% CI 1.23–1.29). Hence, independent of all other mediators, health behaviors explained 20% of the TE comparing moderate versus high educated women. Independent of the complete set of mediators the effect of moderate versus high education on physical health among women was RR^{NDE} 1.22 (95% CI 1.12–1.32).

Additional analyses (S2 Table) of the female sub-sample investigating all work factors and all health behaviors individually dependent on the first set of mediators (baseline health, partner status, working hours), indicate that influence at work and possibilities for development (only between low and highly educated) as well as BMI and smoking (the latter only between moderate and highly educated) may be dominant mediators, showing the largest NIE.

Table 4 shows the results from the mediation analyses among the male subsample. Compared to men with high education, those with low education had a 2.14-fold (95% CI 1.96–2.32) and those with moderate education a 1.59-fold (95% CI 1.46–1.71) higher risk of reporting poor physical health at follow-up (total effects). Comparing low versus high educated men, the first set of mediators, namely baseline health, partner status and working hours, mediated 56% of the TE (RR^{NIE} 1.43, 95% CI 1.36–1.49). The magnitude of the mediated effects increased by 5% to 61% (RR^{NIE} 1.48, 95% CI 1.39–1.57) when all work factors were added to the first set of mediators. The complete set of mediators, additionally including all health behaviors, mediated 85% of the TE (RR^{NIE} 1.83, 95% CI 1.70–1.96) comparing low versus

Table 1. Characteristics of the female study sample by level of education before multiple imputation (n = 1 405).

Characteristics	Education			
	low	moderate	high	
Total n = 1405	n = 227	n = 894	n = 284	Missing values
	n(%) or M(SD)	n(%) or M(SD)	n(%) or M(SD)	n(%)
Age at baseline (t0)				0
46 (born 1965)	92 (40.5%)	516 (57.7%)	154 (54.2%)	
52 (born 1959)	135 (59.5%)	378 (42.3%)	130 (45.8%)	
Migrant status (t0)				0
non-migrant	193 (85.0%)	789 (88.3%)	232 (81.7%)	
migrant	34 (15.0%)	105 (11.7%)	52 (18.3%)	
Partner status (t0)				5 (0.4%)
not single	180 (79.3%)	762 (85.6%)	250 (88.3%)	
single	47 (20.7%)	128 (14.4%)	33 (11.7%)	
Working hours (t1)				0
part-time (< 35 hours/week)	137 (60.4%)	473 (52.9%)	140 (49.3%)	
full-time	90 (39.6%)	421 (47.1%)	144 (50.7%)	
Physical health (t0)				22 (1.6%)
good	155 (69.5%)	626 (71.4%)	239 (84.5%)	
poor	68 (30.5%)	251 (28.6%)	44 (15.5%)	
Physical health (t2)				13 (0.9%)
good	127 (57.0%)	553 (62.5%)	215 (75.7%)	
poor	96 (43.0%)	332 (37.5%)	69 (24.3%)	
Physical demands (t1)				0
low	84 (37.0%)	413 (46.3%)	149 (52.5%)	
high	143 (63.0%)	480 (53.7%)	135 (47.5%)	
Influence at work (t1) 1 (highest)– 100 (lowest)	67.4 (26.2)	65.8 (25.3)	56.2 (25.2)	2 (0.1%)
Possibilities for development (t1) 1 (highest)– 100 (lowest)	43.9 (23.6)	36.6 (19.6)	30.9 (19.6)	0
Leadership Quality (t1) 1 (highest)– 100 (lowest)	40.7 (20.7)	41.7 (20.0)	41.6 (20.0)	13 (0.9%)
Rewards at work (t1) 7 (highest)– 28 (lowest)	10.1 (3.9)	10.3 (3.6)	10.6 (3.4)	134 (9.5%)
BMI (t1)				38 (2.7%)
normal	68 (30.4%)	363 (42.0%)	141 (50.5%)	
overweight	84 (37.5%)	318 (36.8%)	99 (35.5%)	
obese	72 (32.1%)	183 (21.2%)	39 (14.0%)	
Smoker (t1)				1 (0.1%)
never	80 (35.2%)	379 (42.4%)	159 (56.0%)	
former	66 (29.1%)	266 (29.8%)	65 (22.9%)	
current	81 (35.7%)	248 (27.8%)	60 (21.1%)	
Leisure-time physical activity (t1)				0
moderate or high PA	66 (29.1%)	318 (35.6%)	114 (40.1%)	
no or light PA	161 (70.9%)	576 (64.4%)	170 (59.9%)	

Valid column percentages displayed; Data are presented as mean (SD) for continuous measures, and n (%) for categorical measures.

Table 2. Characteristics of the male study sample by level of education before multiple imputation (N = 1 248).

Characteristics	Education			
	low	moderate	high	
Total n = 1248	**n = 298**	**n = 615**	**n = 335**	Missing values
	n(%) or M(SD)	**n(%) or M(SD)**	**n(%) or M(SD)**	**n(%)**
Age at baseline (t0)				0
46 (born 1965)	158 (53.0%)	346 (56.3%)	192 (57.3%)	
52 (born 1959)	140 (47.0%)	269 (43.7%)	143 (42.7%)	
Migrant status (t0)				
non-migrant	245 (82.2%)	528 (85.9%)	287 (85.7%)	
migrant	53 (17.8%)	87 (14.1%)	48 (14.3%)	
Partner status (t0)				3 (0.2%)
not single	259 (86.9%)	558 (91.0%)	308 (92.2%)	
single	39 (13.1%)	55 (9.0%)	26 (7.8%)	
Working hours (t1)				0
part-time (< 35 hours/week)	5 (1.7%)	14 (2.3%)	21 (6.3%)	
full-time	293 (98.3%)	601 (97.7%)	314 (93.7%)	
Physical health (t0)				11 (0.9%)
good	178 (60.3%)	471 (77.6%)	294 (88.6%)	
poor	117 (39.7%)	136 (22.4%)	38 (11.4%)	
Physical health (t2)				16 (1.3%)
good	151 (52.2%)	416 (68.3%)	269 (80.5%)	
poor	138 (47.8%)	193 (31.7%)	65 (19.5%)	
Physical demands (t1)				0
low	133 (44.6%)	337 (54.8%)	226 (67.5%)	
high	165 (55.4%)	278 (45.2%)	109 (32.5%)	
Influence at work (t1) 1 (highest)– 100 (lowest)	59.3 (27.9)	59.1 (26.5)	51.2 (23.6)	0
Possibilities for development (t1) 1 (highest)– 100 (lowest)	38.8 (19.0)	35.0 (19.3)	31.3 (18.4)	0
Leadership Quality 1 (highest)– 100 (lowest)	40.4 (18.8)	41.6 (18.6)	42.8 (18.0)	10 (0.8%)
Rewards at work (t1) 7 (highest)– 28 (lowest)	10.1 (3.5)	9.9 (3.3)	9.7 (3.2)	83 (6.6%)
BMI (t1)				5 (0.4%)
normal	39 (13.1%)	111 (18.2%)	97 (29.2%)	
overweight	161 (54.0%)	332 (54.2%)	162 (48.6%)	
obese	98 (32.9%)	169 (27.6%)	74 (22.2%)	
Smoker (t1)				0
never	83 (27.9%)	220 (35.8%)	180 (53.7%)	
former	94 (31.5%)	208 (33.8%)	88 (26.3%)	
current	121 (40.6%)	187 (30.4%)	67 (20.0%)	
Leisure-time physical activity (t1)				1 (0.1%)
moderate or high PA	97 (32.6%)	244 (39.7%)	170 (50.9%)	
no or light PA	201 (67.4%)	371 (60.3%)	164 (49.1%)	

Valid column percentages displayed; Data are presented as mean (SD) for continuous measures, and n (%) for categorical measures.

Table 3. Decomposition of the total effect (TE) of education on physical health into natural direct effect (NDE) and natural indirect effect (NIE) using baseline health, work factors and health behaviors as mediators. Imputed female subsample (n = 1 405). Adjusted for age and migrant status.

	Low vs. high education			Moderate vs. high education		
	RR	95% CI[a]	PM[b] %	RR	95% CI[a]	PM[b] %
Total effect of education on physical health	1.55	1.42–1.68		1.54	1.42–1.65	
Mediation by baseline health[c]						
NIE	1.07	1.04–1.10	18	1.16	1.14–1.17	39
NDE	1.45	1.32–1.58		1.33	1.23–1.43	
Mediation by baseline health[c] & work factors						
NIE	1.16	1.10–1.22	39	1.16	1.14–1.18	39
NDE	1.34	1.21–1.48		1.33	1.22–1.43	
Mediation by baseline health[c] & work factors & health behaviors						
NIE	1.30	1.19–1.42	65	1.26	1.23–1.29	59
NDE	1.19	1.03–1.35		1.22	1.12–1.32	

[a]obtained from bootstrapping (1 000 reps); [b]Proportion mediated (PM) = $RR_{NDE}*(RR_{NIE}-1)/(RR_{NDE}*RR_{NIE}-1)$

[c]plus partner status and working hours

[RR = relative risk; CI = confidence interval].

highly educated. Thus, independent of work factors, baseline health, partner status and working hours, health behaviors explained 24% of the TE. Independent of the complete set of mediators the effect of low versus high education on physical health among men was RR^{NDE} 1.17 (95% CI 1.03–1.31).

Comparing men with moderate versus high education, the first set of mediators mediated 31% of the TE (RR^{NIE} 1.13, 95% CI 1.11–1.15). The second set of mediators, additionally including all work factors, explained 37% of the TE (RR^{NIE} 1.16, 95% CI 1.13–1.19). Thus, net of first set of mediators all work factors combined explained 6% of the TE comparing moderate versus high educated men. The complete set of mediators, additionally including all health behaviors, mediated 64% of the TE (RR^{NIE} 1.31, 95% CI 1.26–1.35). Thus, independent of all

Table 4. Decomposition of the total effect (TE) of education on physical health into natural direct effect (NDE) and natural indirect effect (NIE) using baseline health, work factors and health behaviors as mediators. Imputed male subsample (n = 1 248). Adjusted for age and migrant status.

	Low vs. high education			Moderate vs. high education		
	RR	95% CI[a]	PM[b] %	RR	95% CI[a]	PM[b] %
Total effect of education on physical health	2.14	1.96–2.32		1.59	1.46–1.71	
Mediation by baseline health[c]						
NIE	1.43	1.36–1.49	56	1.13	1.11–1.15	31
NDE	1.50	1.30–1.70		1.40	1.28–1.52	
Mediation by baseline health[c] & work factors						
NIE	1.48	1.39–1.57	61	1.16	1.13–1.19	37
NDE	1.45	1.30–1.61		1.37	1.25–1.49	
Mediation by baseline health[c] & work factors & health behaviors						
NIE	1.83	1.70–1.96	85	1.31	1.26–1.35	64
NDE	1.17	1.03–1.31		1.21	1.10–1.32	

[a]obtained from bootstrapping (1 000 reps)

[b]Proportion mediated (PM) = $RR_{NDE}*(RR_{NIE}-1)/(RR_{NDE}*RR_{NIE}-1)$

[c]plus partner status and working hours

[RR = relative risk; CI = confidence interval]

other mediators, health behaviors explained 27% of the TE. Independent of the complete set of mediators the effect of moderate versus high education on physical health was RR^{NDE} 1.21 (95% CI 1.10–1.32). Additional analyses (S3 Table) of the male sub-sample investigating all work factors and all health behaviors individually dependent on the first set of mediators (baseline health, partner status, working hours), indicate that BMI (only between moderate and highly educated), smoking and physical activity may be dominant mediators, showing the largest NIE.

Sensitivity analysis

We calculated mediational E-values [57] for our main analyses displayed in Tables 3 and 4. Overall all mediational E-values took relatively high values (S4 and S5 Tables) indicating that moderate to strong unmeasured confounding would be necessary to explain away the observed NIE. The following form of statements was adopted from Smith et al. [57] and VanderWeele et al. [58]. Comparing low to high educated women (S4 Table), an unmeasured confounder associated with both the mediators (baseline health, work factors and health behaviors) and physical health with approximate RR of 1.92 each, above and beyond the measured covariates, would completely explain away the observed indirect effect, but weaker confounding could not (S4 Table). To shift the 95% CI to include a RR of 1 an unmeasured confounder associated with both, the mediators and physical health with an approximate RR of 1.67 each, above and beyond the measured covariates, could suffice, but weaker confounding could not (S4 Table). For the analysis comparing low versus high educated men, unmeasured confounding would have to be even stronger, with mediational E-values of RR 3.06 to explain away the NIE and RR 2.79 to shift the 95% CI to include a RR of 1 (S5 Table).

Discussion

Our analysis showed that educational inequalities in physical health are present among older workers in Germany. Both low and moderately educated women had an approximate 1.5-fold higher risk of reporting poor physical health at follow-up compared to their highly educated counterparts. Among men these educational differences in physical health were slightly more accentuated with approximate 2-fold higher risk comparing low versus highly educated and approximate 1.6-fold risk comparing moderately versus highly educated persons.

Using a sex-stratified causal mediation analysis via inverse odds weighting, we could quantify the extent to which work factors and the health-related lifestyles mediate the effect of education on physical health, hence contribute to educational inequalities in physical health, dependent on baseline health, partner status and working hours (i.e. the first set of mediators) controlling for age and migrant status. Among women the first set of mediators explained 18% of the educational differences in physical health (i.e. the TE) between low and high educated. Independent of the first set of mediators, work factors could explain 21% of the TE. By addition of health behaviors, a further 26% of the TE could be explained. The full set of mediators explained 65% of the TE. Comparing moderate to high educated women the first set of mediators explained 39% of the TE. The magnitude of the mediated effect did not increase when adding work factors but increased by additional 20% by adding all health behaviors. The full set of mediators explained 59% of the TE. Among men the first set of mediators already explained 56% of the educational differences in physical health between low and highly educated. Additional 5% of the TE was explained by including work factors and additional 24% by also including health behaviors. The full set of mediators explained 85% of the TE. Comparing moderate to high educated men, the first set of mediators explained 31% of the TE. Work factors added 6% to the proportion mediated and health behaviors additional 27%. The full set of mediators explained 59% of the TE.

Comparison with existing evidence

Supporting current evidence on social inequalities in health, our study showed that both work factors and health behaviors contribute to health inequalities [11, 12]. Unlike the few existing studies examining the contribution of work factors and/or health behaviors to social inequalities in health among older workers with longitudinal data [12, 31, 32], we used the SF-12 physical component summary [39] to assess physical health as the outcome.

In a previous systematic review, Dieker et al. [11] reported that work factors explained 14–38% of social inequalities in self-rated health in longitudinal studies. This aligns with our study only with respect to physical health inequalities between low and highly educated women, where, independent of baseline health and other post-exposure variables, work factors explained 21% of physical health inequalities. Among men this contribution amounted to maximum 6%. Also, when compared to recent findings by Schram et al. [12] using longitudinal SHARE (Survey of Health, Ageing, and Retirement in Europe) data from 16 countries, our results indicate a much smaller contribution of work factors and a larger contribution of health behaviors to health inequalities. This may have several reasons related to the measurement of exposure and outcome, differences concerning the analytical approaches and cross-country differences in the contribution of work factors and health behaviors to health inequalities.

First, the weaker contribution of work factors could be due to our choice of the exposure–education may reflect health behaviors more strongly than working conditions [13]–and our choice of the outcome–health behaviors may be more important than work factors in explaining inequalities in physical health [59]. Although this was an unexpected result, some authors report similar findings with respect to the contribution of work factors. For example Schmitz [31] concluded that "[. . .] baseline health, educational attainment, and mid-career earnings growth [. . .] exert a stronger influence on health at older ages than current job demands [. . .]" [31, p.18]. Similarly, Warren et al. [32] found that job characteristics only contributed to a SRH decline among women but not among men. Also, in our study the contribution of work factors to educational inequalities in health was largest among women. A further possible explanation could be that the effect of psychosocial work factors–four out of five work factors in our analysis may be regarded as such–on physical health is time-delayed and cumulative, perhaps even mediated through health behaviors (e.g., smoking, physical activity, body weight) whose influence on physical functioning is more immediate. This assumption is also supported by findings from studies applying a life course perspective to examine the effects of work-related stress on physical functioning [60, 61]. Yet another explanation, in line with Schmitz [31], could be that the effects of education and baseline health overscore the influence of the current job demands on health among older workers.

Hence, a second major explanation of our study results in comparison to previous findings could be that by including the baseline physical health status in a first set of mediators preceding working conditions, past exposures to adverse working conditions may be reflected by the initial health status with which participants entered the study. Therefore, the addition of current working conditions may have contributed less to health inequalities than expected.

Finally, with respect to the contribution of the investigated mediators to educational inequalities in health, cross-country differences are important to note. E.g., our findings correspond to some degree to a sensitivity analysis provided by Schram et al. [12], where the contributions of work factors and health behaviors were investigated stratified by European region. Similar to their findings for Northern (37%) and Western (31%) countries we found that health-related lifestyles explained 26% of health inequalities between low versus high educated women and 24% between low versus high educated men. In our study however, this proportion can be interpreted as the contribution of health behaviors independent of work factors

and baseline health. With respect to the contribution of work factors, our findings deviate from those for Western countries (including a subsample of German older workers) in the study by Schram et al. [12] but are in fact similar to their findings for Northern countries, where work factors seem to play a minor role in explaining educational inequalities in health [12]. In our study this mainly applies to the inequalities among men. The contribution of work factors was larger comparing low versus high educated women.

Findings from our additional analyses (S2 and S3 Tables) furthermore corroborate previous cross-sectional findings which indicated that educational inequalities in smoking are more pronounced among men, and inequalities in overweight and obesity are more pronounced among women [9]. The additional analyses also showed that among women, out of all investigated work factors, possibilities for development contributed by far the most to educational inequalities in physical health when analyzed separately, dependent on baseline health. This also aligns with previous cross-sectional findings on occupational inequalities in (mental) health [21, 25].

Strengths and limitations

This study adds to the existing evidence in multiple ways. To our knowledge this is the first longitudinal study among older workers in Germany applying a causal mediation analysis to investigate the contribution of physical and psychosocial work factors as well as health-related lifestyles to educational inequalities in physical health. One of the strengths is the narrow focus on older workers of the German baby boom cohorts, 1959 and 1965. We found that our results differed from those of a previous study investigating (self-rated) health inequalities in European regions [12], especially with respect to the contribution of work factors. This implies that the explanation of health inequalities may not only vary between European regions (Northern, Western/Central, Southern, Eastern) but also strongly within those regions and in dependence of deployed health outcomes. Hence, our findings may not be applicable to other countries.

A further strength is the use of specific indicators of the SES and health as well as providing a rationale for this choice. In the past, authors have repeatedly stressed that measures of the SES [13] as well as health [13, 62] are not interchangeable and that the pathways between SES and health may vary depending on the selected indicators [13]. The contribution of the investigated intermediates to physical health inequalities may vary depending on the selection of the SES indicator. E.g., by using occupational class as the main exposure, we assume that work factors would gain more importance as mediators. This however comes with a greater risk of reverse causation.

Using the IOW approach, we were able to investigate multiple mediators simultaneously irrespective of a possible exposure-mediator interaction on the outcome, which we regard as a strength, especially when assessing SES indicators as the main exposure. Nonetheless, the application of causal mediation analysis is accompanied by several no-confounding assumptions. The panel design of our study is a strength and allows to temporally order exposure (X), mediators (M), and outcome (Y). However, inherent with the temporal order of the study variables is the risk of exposure-induced confounding of the mediator-outcome association. Importantly, studying health inequalities among older workers requires consideration of the initial health status with which participants entered the study, but this baseline health is itself affected by education (X) and has effects on M and Y. Therefore, to prevent violation of the assumption about the absence of exposure-induced confounding, we included baseline health in a first set of mediators. We then followed a sequential mediation approach to jointly assess mediation through the focal mediators (M) dependent on this first set of mediators [55, 56]. The joint assessment changed the causal diagram in a way that there is no more confounder of

the mediator-outcome association affected by the exposure [56], but rather the effect of the exposure is assumed to mediate through both, the first set of mediators including baseline health and the focal mediators or through either of them. While this approach allows us to identify NDE and NIE even in the presence of an exposure-induced mediator-outcome confounder, strong no-unmeasured confounding assumptions are still necessary for the causal interpretation of the results [56]. For the so called sequential ignorability assumption [63] to hold, the absence of unmeasured confounding of exposure-mediator, mediator-outcome, and exposure-outcome associations is required. These however are strong assumptions, even in settings where the treatment/exposure can be randomized [33] as residual unobserved confounding of the mediators and the outcome cannot be ruled out. Many researchers therefore strongly recommend conducting sensitivity analysis to examine the impact of unobserved confounding [52, 57, 63, 64]. As data on unmeasured confounding is by definition unavailable, most available methods require the investigators to specify a large number of sensitivity-analysis parameters [56] and re-run the mediation analyses under varying levels of unobserved confounding. This is sometimes difficult to interpret in practice and also computationally demanding, especially when investigating multiple mediators with multiply imputed data. We therefore calculated mediational E-values as an approximate sensitivity analysis for unmeasured mediator-outcome confounding as suggested by Smith et al. [57] in order to quantify how strong unobserved confounding would have to be to explain away the indirect effects. We found that rather strong confounding would be necessary for all the main analyses, above and beyond the measured covariates, in order to explain away the NIE or shift the 95% CI to include a RR of 1. We are, however, not aware of specific variables that could take these values, which were not already accounted for.

Lastly, selective dropout of participants during follow-up and the application of several inclusion criteria may have introduced selection bias. To address potential selection bias, a longitudinal non-response weight was used.

Implications

From an ethical perspective the findings provide reasons for discussion because the control over health-related lifestyles is first and foremost in the hands of the workers themselves. Nonetheless, one may argue that improvements of working conditions may also lead to healthier lifestyles. A previous study showed that adverse working conditions and unhealthy behaviors cluster among lower educated individuals [65]. Hence, the existence of work-related risk factors may increase the occurrence and effect of lifestyle-related risk factors and vice versa. (Night) shift work constitutes a prime example for the interaction of work factors and health behaviors. It affects health directly, through the desynchronization of the circadian rhythm and indirectly, through social desynchronization and health-related lifestyle changes [66]. Aside from this example, a meta-analysis by Heikkilä et al. [67] also provides evidence of the association between psychosocial work stress and the co-occurrence of unhealthy lifestyles, including overweight, current smoking and physical inactivity during leisure time.

Therefore, interventions promoting healthy behaviors should go hand in hand with interventions targeting adverse working conditions. Our findings suggest that promoting healthy behaviors, if targeted specifically at low and moderately educated, may be a promising approach to reduce educational inequalities in physical health among older workers in Germany. A reduction of physical health inequalities may in turn help to counteract a widening of social inequalities in early exits into long-term unemployment [6]. Secondly, educational inequalities in physical health could be reduced by improving working conditions. Especially low educated women should be targeted. Independent of baseline health, partner status and

working hours, work factors accounted for 21% of physical health inequalities between low and highly educated women. Separate analyses indicate that those with lower education should be granted improved possibilities for development in order to reduce existing inequalities.

Furthermore, from a scientific standpoint, it again becomes apparent that a life course perspective should be adopted when investigating health inequalities. Educational inequalities in physical health during the late working career may likely not be fully explained by older workers' current circumstances alone. In the present study, especially among men, the first set of mediators, including baseline health, already explained more than 50% of the educational inequalities in health at follow-up between low and high educated persons. Thus, education, but also the baseline health status of participants may reflect the accumulation of health risks during the many preceding years in multiple (dis-)advantaging contexts [cf. 68, cf. 69]. This implies on the one hand that, where possible, data on determinants of health should be collected starting early in life. On the other hand, in the many cases where this is not possible due to time-, financial and data-protection- constraints, researchers should continue to discuss the consequences of their choices of SES indicators and health outcomes on the generalizability of their findings. For future studies investigating the contribution of work factors and health-related lifestyles to physical health inequalities among older workers, we recommend the (additional) use of different SES indicators, such as the occupational class, to examine how the importance of the intermediates may change.

Conclusion

Work factors and the health-related lifestyle contribute to educational inequalities in physical health among older workers in Germany. The findings indicate that health-related lifestyles are more powerful to explain educational inequalities in physical health than work factors among both sexes, possibly due to the choice of our SES indicator, the choice of the health outcome and the time-delayed and cumulative effect of work factors on physical functioning. To attenuate these health inequalities, interventions promoting healthy behaviors should go hand in hand with interventions addressing adverse working conditions and should be targeted specifically at lower and moderately educated persons. Additional analyses suggest that among women, BMI and possibilities for development, and among men, smoking and physical activity constitute key variables to target.

Supporting information

S1 Checklist. STROBE statement—Checklist of items that should be included in reports of *cohort studies*.
(PDF)

S1 Table. Mean weighting factors by education and sex.
(DOCX)

S2 Table. Decomposition of the total effect (TE) of education on physical health into natural direct effect (NDE) and natural indirect effect (NIE) using baseline health, work factors and health behaviors individually as mediators. Imputed female subsample (n = 1 405). TE and significant NIE and respective proportion mediated (PM) marked in bold. Adjusted for age and migrant status. [RR = relative risk; CI = confidence interval].
(DOCX)

S3 Table. Decomposition of the total effect (TE) of education on physical health into natural direct effect (NDE) and natural indirect effect (NIE) using baseline health, work factors and health behaviors individually as mediators. Imputed male subsample (n = 1 248). TE

and significant NIE and respective proportion mediated (PM) marked in bold. Adjusted for age and migrant status. [RR = relative risk; CI = confidence interval].
(DOCX)

S4 Table. Mediational E-values for the female sub-sample to quantify the minimum strength of the association that an unmeasured confounder would need to have with both the outcome and the mediators to fully explain away the NIE.
(DOCX)

S5 Table. Mediational E-values for the male sub-sample to quantify the minimum strength of the association that an unmeasured confounder would need to have with both the outcome and the mediators to fully explain away the NIE.
(DOCX)

S1 File. Stata code for mediation analysis using inverse odds weighting with imputed data; example for comparing low versus high educated men using all putative mediators.
(PDF)

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Author Contributions

Conceptualization: Max Rohrbacher, Hans Martin Hasselhorn.

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Appendix B: Study II

Rohrbacher, M., & Hasselhorn, H. M. (2022). Social inequalities in early exit from employment in Germany: a causal mediation analysis on the role of work, health, and work ability. *Scandinavian Journal of Work, Environment & Health*, *48*(7), 569–578. https://doi.org/10.5271/sjweh.4043

Social inequalities in early exit from employment in Germany: a causal mediation analysis on the role of work, health, and work ability

by Rohrbacher M, Hasselhorn HM

A causal mediation analysis highlights the role of low work ability and poor physical health accounting for large proportions of social inequalities in early exit from employment into disability pension and long-term unemployment, respectively. Preventive measures addressing these intermediates may counteract a widening of inequalities between groups of low versus moderate socioeconomic status (SES) to a larger degree than inequalities between low versus high SES groups.

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This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/35708627

Additional material
Please note that there is additional material available belonging to this article on the *Scandinavian Journal of Work, Environment & Health*-website.

Social inequalities in early exit from employment in Germany: a causal mediation analysis on the role of work, health, and work ability

by Max Rohrbacher, MSc,[1] Hans Martin Hasselhorn, MD [1]

Rohrbacher M, Hasselhorn HM. Social inequalities in early exit from employment in Germany: a causal mediation analysis on the role of work, health, and work ability. *Scand J Work Environ Health*. 2022;48(7):569–578. doi:10.5271/sjweh.4043

Objective The aim of this study was to investigate the contribution of work factors, health, and work ability to social inequalities in early exit from employment among older employees in Germany.

Methods Longitudinal data from the representative German lidA Cohort study was linked with employment register data to obtain maximum information on exit routes out of paid employment. Information of N=2438 respondents, aged 46 and 52 at baseline, were obtained for a follow-up of six years (2011–2017). Causal mediation analysis with inverse odds weighting was conducted using discrete-time survival outcomes and baseline measurements of the socioeconomic status (SES: education), work factors, health, and work ability.

Results Older employees with low SES were at an increased risk of exiting employment early by receiving disability pension and through long-term unemployment but not through an unspecified labor market exit when compared to those with high and moderate SES. Low work ability accounted for up to 38% of the social inequalities in work exits into disability pension. Less-than-good physical health accounted for up to 59% of inequalities in work exits into long-term unemployment. Work factors contributed considerably to inequalities in exits through unemployment but not disability pension.

Conclusions This study finds social inequalities in early exits through disability pension and long-term unemployment among older employees in Germany, predominantly attributable to differences in work ability (disability pension) and physical health (unemployment). Investments in work ability and promotion of physical health may constitute promising approaches to counteract an increase of these inequalities.

Key terms inverse odds weighting; longitudinal cohort; older worker; social inequality.

In Germany, as in many other European countries, low-skilled workers drop out of the labor market earlier than highly-skilled workers (1). Recent pension reforms that aim to increase the statutory retirement age and sanction early exit routes out of paid employment will therefore affect this group more heavily, both in the short-term (eg, through loss of income) and the long-term (eg, through reduction in pension claims), when compared to those with higher socioeconomic status (SES) (2), thereby aggravating social inequalities in the work-retirement transition. For older employees with a lower SES, early exits from paid employment are rarely voluntary (1, 3) but may be the consequence of cumulative exposures to unfavorable working conditions, poor health and low work ability.

Socioeconomic inequalities in health are well documented (4). In Germany, this applies to both physical and mental health (5). Recent studies among older workers, strengthen the assumption of causation, ie, a low SES causes poor health (6). Health in turn plays a crucial role in the retirement behavior of older workers (7–10). Poor self-perceived general health, but also poor mental and physical health have been shown to be important risk factors for premature exits from paid employment due to disability pension and unemployment (9). Consistently, the risk of a health-based selection out of employment is most pronounced for those with a low SES (7, 8).

Not only health but also certain work factors are strongly associated with SES. Socioeconomic differences

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are frequently reported for physical but also psychosocial demands, such as quantitative demands and job control (6, 11, 12). Several studies have examined the effect of different work factors on premature exits from employment. Most recently, a study with data from the German Study on Mental Health at Work (S-MGA) found that employees exposed to awkward body postures, heavy lifting and high work pace were at an increased risk of early exit from employment (13). An earlier study based on data from the Survey of Health, Ageing, and Retirement in Europe (SHARE) demonstrated that a lack of job control increased the risk for disability pension, unemployment, and early retirement (14).

Next to health and the working conditions, the fit of the worker's resources and the work demands, which may be termed work ability (15), plays a crucial role in the timing of exit. Although evidence is scarce, workers with low SES seem to be at higher risk of experiencing low work ability (16, 17). Again, emerging evidence from Scandinavia, The Netherlands and most recently from Germany and the USA stress the predictive value of low work ability for early exits from work, most notably receiving disability pension (18–20), but also other exit routes, such as unemployment and inactivity prior to retirement (21).

Disability pension and unemployment are frequent early exit routes among older workers in Germany as other options, such as early old age pension, are only accessible to those aged ≥63 years with very long social security contributions (≥45 or ≥35 years with deductions) (22–25). Another possible early exit route is often termed economic inactivity and is characterized by an unspecified early labor market exit (cf, 8, 11, 25).

So far, few studies have placed focus on the contribution of work factors, health, and work ability to social inequalities in early exit from employment during the later career of older workers. Existing studies on the topic have primarily focused on a different or reduced set of mediators in the pathway of the SES and early exit from paid employment and none included work ability (8, 11, 26). Moreover, none of the studies has a specific focus on older workers in Germany. Recent advancements in causal mediation analysis (27) are well suited to analyze pathways linking the SES to early exits. The so-called inverse odds (ratio) weighting (IO[R]W) (28) is fit for non-linear regression models including survival outcomes, agnostic with regard to exposure-mediator interactions on the outcome, and can accommodate multiple mediators simultaneously (unlike other counterfactual-based approaches) (29).

Using the IOW approach, we thus aim to examine the extent to which the effect of the SES (here: education) on early exit from paid employment operates through work factors, health, and work ability.

Based on the current evidence (8, 11, 26), we assume that the relevance of these pathways varies by the type of exit route and when comparing different social strata.

Methods

Study design and population

We use data from the German lidA study, which is a prospective cohort study on work, age, health and labor market participation. It is representative of socially insured older employees from the German "baby boom" generation with respect to sociodemographic variables such as sex, education and occupation, covering the birth cohorts 1959 and 1965 (30, 31). A detailed description of the study design and survey methods can be found elsewhere (30, 31). Currently the study comprises three waves with a baseline measurement in 2011 (N=6585) and two follow-ups (2014, N=4244; 2018, N=3586). The survey data was linked to employment register data from the Institute for Employment Research (IAB) of the German Federal Employment Agency to enrich information on employment histories and thereby on the potential exit routes and the timing of exit. This data covers information on employment status (excluding disability) of all employees subject to social insurance, thereby excluding sworn civil servants and self-employed.

All subjects who provided written consent for the usage of their employment register data during the last available survey wave were initially included in the present study (N=2560). The follow-up period was six years (2011–2017) with annual data on exits. Subjects who entered long-term unemployment or started to receive a disability pension in or before 2011, as well as subjects who experienced an unspecified labor market exit at some point in 2011 and subjects with missing data on the main exposure variable (education; N=15) were excluded, resulting in N=2438 matching cases between the two data sources (see supplementary material, www.sjweh.fi/article/4043, figure S1 for inclusion and exclusion criteria). Thus, the analysis only included subjects who were event-free at study baseline.

Early exit from paid employment

Three competing exit routes were defined, for which annual information was available: disability pension, long-term unemployment, and unspecified early labor market exit. Information on disability pension and unemployment events were obtained from the lidA survey data. If subjects received disability pension in 2018, they were asked to report when (year) they first entered the disability pension scheme. If subjects were unemployed in 2018, they were asked to report when

(year) they left their last employment.

Information on unspecified early labor market exits was obtained from the employment register data. An unspecified early labor market exit was defined by a discontinuation of the individual's employment history in the register data (ie, exit from social insurance/gap spell). Only if subjects spent most of at least one year in this status (modal state), they were assigned this exit.

The time to the first event was recorded. Register data was available until 2017. Subjects with no event after exposure measurement in 2011 until the end of the follow-up period (2012–2017) were censored.

Socioeconomic status

SES was operationalized by the level of education, using a combined score of education and vocational training (32). The score was subsequently categorized into three classes of low (primary, lower secondary and upper secondary general education, cf. ISCED-97 1–3A), moderate (upper secondary vocational education and post-secondary non tertiary education, cf. ISCED-97 3B–4A), and high education (tertiary education, cf. ISCED-97 5–6).

Work factors

In total, we assessed three work factors which, based on current evidence (6, 11–14), seemed to be plausible mediators between the SES and early exit from employment: physical demands, quantitative demands, and influence at work (as a proxy of job control). Physical demands were assessed with three items measuring the time exposed to awkward body postures, heavy lifting, and repetitive movements. Subjects exposed to any of the three dimensions for >25% of the working time were regarded as having high physical demands. Quantitative demands (low/high) and influence at work (low/high) were measured with items from the German version of the Copenhagen Psychosocial Questionnaire (COPSOQ) (33). The scales have been validated and show good psychometric properties (33). The resulting sum scores for each domain were subsequently dichotomized at the median.

Health

Physical and mental health were assessed using the Short Form Health Survey (SF-12) (34). Two separate sum scores were calculated for both health scales following Nübling, Andersen and Mühlbacher (35). Subsequently, they were dichotomized at the median, dividing the sample into groups of less than good versus good (mental or physical, respectively) health.

Work ability

The second dimension of the Work Ability Index (WAI2) (15) was used to parameterize work ability. WAI2 assesses the work ability in relation to mental and physical work demands with two items. A third item measuring whether subjects are mainly mentally or physically active in their jobs was used to weigh the responses to the first two items. The resulting sum score (2 [no work ability] to 10 [high work ability]) was dichotomized. The cut-off point was set at 8, defining subjects with low (<8) and high (≥8) work ability. Ebener & Hasselhorn (36) validated the short measure and illustrated the advantages of its application in occupational health research.

Confounding variables

Age was assessed by the participants' birth year, resulting in two groups aged 46 (born 1965) or 52 (born 1959) at baseline (2011). Sex (male/female) and partner status (partnership/single) were dichotomous.

All covariates including the main exposure education were assessed at baseline in 2011. Since all included subjects were aged 46 or 52 at entry, it can be assumed that education preceded their work factors, health, and work ability at the time of the study.

Statistical analysis

Firstly, descriptive statistics were used to present the baseline characteristics of the study population and the number of early exits during the 6-year follow-up by educational level (table 1). Secondly, we estimated the main effects of the SES and the potential mediators on early exit from employment using Cox proportional hazard analyses (table 2). The proportional hazard assumption was checked based on Schoenfeld residuals (37). A respective $P>0.05$ indicates that the assumption of proportional hazards holds.

To examine the mediating effects of work, health, and work ability we applied an IOW approach to decompose the total effect (TE) of education on the outcome (ie, the survival time to the first exit event) into a natural direct effect (NDE) and natural indirect effect (NIE) (28, 29) (figure 1, tables 3–4). The NDE captures the effect of education on the outcome if the pathway through the mediator of interest was disabled, NIE the effect of education through the intermediate and TE the sum of NDE and NIE (38). The definitions of these effects estimates are based on the counterfactual framework (38, 39). We compared groups with low versus high and low versus moderate educational level.

In line with previous studies applying the IOW approach (12, 29, 40), the IOW estimation of NDE and NIE consisted of the following steps. First, a multino-

Table 1. Baseline characteristics of the study sample and labor force exit during the 6-year follow-up (N=2438 [a]).

Characteristics	Educational level			
	Low (N=509)	Moderate (N=1 394)	High (N=535)	Data missing
	N (%)	N (%)	N (%)	N (%)
Sex				0
Female	229 (44.9)	852 (61.1)	247 (46.2)	
Male	280 (55.1)	542 (38.9)	288 (53.8)	
Age at entry (2011)				0
46 (born 1965)	271 (53.2)	816 (58.5)	304 (56.8)	
52 (born 1959)	238 (46.8)	578 (41.5)	231 (43.2)	
Partner status				7 (0.3)
Single	71 (13.9)	168 (12.1)	50 (9.4)	
Not single	438 (86.1)	1 221 (87.9)	483 (90.6)	
Work factors				
High physical demands	292 (58.5)	692 (50.6)	204 (38.7)	43 (1.8)
High quantitative demands	181 (36.2)	678 (49.5)	302 (57.1)	40 (1.6)
Low influence at work	240 (48.1)	593 (43.3)	129 (24.4)	41 (1.7)
Health				
Less-than-good (physical)	308 (61.7)	686 (50.3)	175 (33.2)	49 (2.0)
Less-than-good (mental)	248 (49.7)	652 (47.8)	249 (47.3)	49 (2.0)
Work ability				49 (2.0)
Low	193 (38.8)	429 (31.5)	117 (22.1)	
Labor force exit (2011–2017)				0
Disability pension	23 (4.3)	36 (2.6)	5 (0.9)	
Unemployment	19 (3.7)	34 (2.4)	7 (1.3)	
Unspecified	19 (3.7)	46 (3.3)	21 (3.9)	
Censored	448 (88.3)	1 275 (91.7)	502 (93.8)	

[a] Valid column percentages displayed.

Table 2. Main effects of socioeconomic status (SES), work factors, health, and work ability on the likelihood of early exit during a 6-year follow-up. Cox Proportional Hazard Regression: for each exit route, the independent variables were entered separately into the regression model; all models were adjusted for age, sex, partner status; statistically significant hazard ratios (HR) (P<0.05) with 95% confidence interval (CI) marked in bold; the proportional hazard assumption was fulfilled for all models.

	Disability pension	Unemployment	Labor market exit
	HR (95% CI)	HR (95% CI)	HR (95% CI)
SES (education) (N=2431)			
Low vs moderate [a]	**1.83 (1.08–3.13)**	1.69 (0.96–2.98)	1.15 (0.67–1.98)
Low vs high [b]	**4.62 (1.75–12.22)**	**2.85 (1.20–6.79)**	0.98 (0.52–1.80)
Work factors [c] (N=2387)			
Physical demands			
High	1.48 (0.87–2.53)	1.61 (0.92–2.84)	0.94 (0.61–1.46)
Quantitative demands			
High	0.97 (0.58–1.63)	1.57 (0.90–2.74)	1.06 (0.69–1.63)
Influence at work			
Low	1.03 (0.61–1.76)	0.70 (0.39–1.25)	0.86 (0.54–1.36)
Health (N=2383)			
Physical health			
Less than good	**1.90 (1.10–3.27)**	**2.79 (1.51–5.14)**	1.02 (0.66–1.57)
Mental health			
Less than good	**2.23 (1.29–3.87)**	1.51 (0.87–2.61)	1.09 (0.70–1.68)
Work & Worker (N=2383)			
Work ability			
Low	**4.44 (2.55–7.71)**	1.70 (0.99–2.94)	1.33 (0.85–2.08)

[a] Moderate education as reference, effect estimates for high vs moderate not displayed.
[b] High education as reference, effect estimates for moderate vs high not displayed.
[c] Variables from the work domain were mutually adjusted.

mial regression model was fitted for education conditional on the mediator(s) and the confounding variables. Second, the individual's IOW was calculated by taking the inverse of the predicted odds from the first step. The reference group (first the high educated, then the moderate educated) was assigned with a weight equal to 1. Third, the TE was estimated by using a cause-specific Cox regression model, regressing each exit route separately on education and the confounding variables. For this step, we declared the data to be survival-time data with Stata's "stset" command (37) without specifying a weight. Fourth, the NDE was estimated using the same model, but specifying the weights that were assigned to each subject in step 2. Lastly, the NIE was obtained by subtracting the NDE from the TE. We used bootstrapping with 1000 replications to derive the effect estimates and bias-corrected confidence intervals (CI) (41). Bias-corrected CI not including 1 indicate statistically significant effects and yield better coverage probabilities than normal approximation CI if the bootstrap distribution deviates from normal (41). A P<0.05 was considered statistically significant. Missing values of single variables did not exceed 5%. Hence, missing data were handled by listwise exclusion. The percentage of cases excluded did not exceed 2.4% in fully adjusted multi-mediator models. We calculated the proportion mediated (PM) using VanderWeele's (38) equation for ratio measures: $HR_{NDE}*(HR_{NIE}-1)/(HR_{NDE}*HR_{NIE}-1)$. In order to compute the NDE and NIE we assumed the absence of unobserved confounding for (i) the exposure-outcome relationship, (ii) for the mediator-outcome relationship and (iii) for the exposure-mediator relationship. Additionally, the absence of (iv) a mediator-outcome confounder that is an effect of the exposure was assumed (29). All analyses were conducted using Stata V15.1 (StataCorp LLC, College Station, TX, USA).

Sensitivity analysis

We conducted a competing risk regression using the Fine & Gray (42) model, estimating the main effects of education and the covariates on the competing exit routes
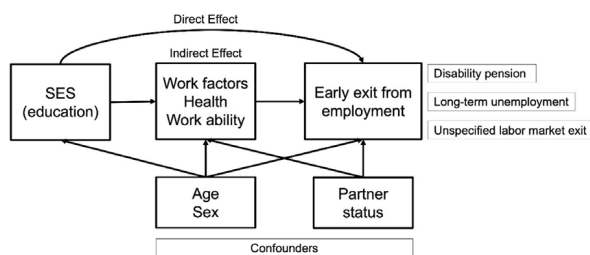

Figure 1. Hypothesized relationship between education, work factors, health, work ability and early exit from employment.

Table 3. Decomposition of the effect of socioeconomic status (SES) on disability pension into total effect (TE), natural direct effect (NDE) and natural indirect effect (NIE) using work factors, health, and work ability as mediators (N=2438). TE and significant NIE and respective proportion mediated (PM) marked in bold. Adjusted for age, sex, partner status. [BC=bias corrected; CI=confidence interval; HR=cause-specific hazard ratio.]

	Low versus high SES [a]			Low versus moderate SES [a]		
	HR	BC CI [b]	PM [c] %	HR	BC CI [b]	PM [c] %
Analysis 1: Physical demands						
NIE	1.01	0.91–3.62	1	1.03	0.93–1.22	7
NDE	4.57	1.81–16.79		1.77	1.02–3.21	
Analysis 2: Quantitative demands						
NIE	0.88	0.73–1.06	–17	0.88	0.70–1.05	–30
NDE	5.25	2.18–23.36		2.08	0.99–3.59	
Analysis 3: Influence at work						
NIE	1.03	0.87–1.15	4	1.04	0.88–1.17	8
NDE	4.49	1.66–16.91		1.76	0.94–3.02	
Analysis 4: Physical health						
NIE	1.04	0.83–1.24	5	1.06	0.84–1.27	12
NDE	4.45	1.82–22.79		1.73	0.95–3.00	
Analysis 5: Mental health						
NIE	1.01	0.89–1.09	1	1.02	0.89–1.12	4
NDE	4.59	1.92–23.54		1.80	1.04–3.24	
Analysis 6: Work ability						
NIE	**1.22**	**1.07–3.99**	**23**	**1.21**	**1.06–1.50**	**38**
NDE	3.80	1.50–15.41		1.51	0.87–2.54	
Analysis 7: Health & work ability						
NIE	**1.27**	**1.06–1.76**	**27**	**1.27**	**1.03–1.64**	**47**
NDE	3.65	1.49–16.49		1.44	0.78–2.51	
Analysis 8: Health & work ability & work factors [d]						
NIE	1.12	0.87–4.18	14	1.11	0.86–1.76	22
NDE	4.13	1.64–24.01		1.65	0.79–3.01	
TE of SES [a]	**4.62**	**1.88–21.07**		**1.83**	**1.06–3.19**	

[a] Educational level.
[b] Obtained from bootstrapping (1000 reps)
[c] Proportion mediated = $HR_{NDE}*(HR_{NIE}-1)/(HR_{NDE}*HR_{NIE}-1)$
[d] 2.4% smaller sample size in fully adjusted multi-mediator model due to listwise exclusion of missing values (N=2 380)

to assess whether using this model would have changed the estimates compared to the Cox model.

Ethical approval

The Ethics Committee of the University of Wuppertal approved the protocol for the lidA Cohort study [5 December 2008 (Sch/Ei Hasselhorn) and 20 November 2017 (MS/BB 171025 Hasselhorn)]. All participants were informed about the aims and procedures of the study. In accordance with data protection requirements, verbal consent was required for participation at baseline and for each follow-up wave and written consent was required for data linkage.

Results

Main findings

We found a higher prevalence of high physical demands, low influence at work, less-than-good physical health and low work ability among subjects with low SES (table 1). High quantitative demands were more prevalent in groups with higher SES (table 1, see supplementary table S2 for the strength of these associations).

Furthermore, a larger proportion of subjects with low SES (4.3%) started to receive disability pension when compared to moderate (2.6%) or high (0.9%) SES groups. This similarly applied to becoming long-term unemployed during follow-up time, while no such social gradient was apparent with respect to unspecified premature labor market exits (table 1). In total, 11.7% exited employment early in the low SES group, 7.3% in the moderate SES group and 6.2% in the high SES group.

When compared to subjects with a high SES, employees with a low SES had a more than four-fold instantaneous rate of exiting into disability pension (HR 4.62, 95% CI 1.75–12.22) and an almost three-times higher rate of becoming long-term unemployed (HR 2.85, 95% CI 1.20–6.79) during the 6-year follow-up (table 2). Also, when compared to subjects with a moderate SES, those with a low SES had a significantly higher instantaneous rate of exiting into disability pension (HR 1.83, 95% CI 1.08–3.13) and a borderline significantly higher instantaneous rate of exiting into unemployment (HR 1.69, 95% 0.96–2.98) (table 2). Neither the SES nor any potential mediator exerted a statistically significant effect on unspecified labor market exit and hence mediation analysis was not conducted for this outcome. For all analysis models, the proportional hazard assumption was fulfilled (ph-test P-value >0.05).

Table 3 shows the effect decomposition of the TE of

Table 4. Decomposition of the effect of the socioeconomic status (SES) on unemployment into total effect (TE), natural direct effect (NDE) and natural indirect effect (NIE) using work factors, health, and work ability as mediators (N=2438). TE and significant NIE and respective proportion mediated (PM) marked in bold. Adjusted for age, sex, partner status. [BC=bias corrected; CI=confidence interval; HR=cause-specific hazard ratio.]

	Low versus high SES [a]			Low versus moderate SES [a]		
	HR	BC CI [b]	PM [c]%	HR	BC CI [b]	PM [c]%
Analysis 1: Physical demands						
NIE	1.29	0.99–1.59	35	**1.30**	**1.07–1.52**	**57**
NDE	2.20	0.79–6.92		1.30	0.64–2.55	
Analysis 2: Quantitative demands						
NIE	1.03	0.87–1.20	5	1.04	0.86–1.22	9
NDE	2.75	1.06–8.40		1.63	0.75–2.87	
Analysis 3: Influence at work						
NIE	**1.22**	**1.05–1.38**	**28**	**1.23**	**1.04–1.42**	**46**
NDE	2.34	0.89–6.90		1.37	0.64–2.65	
Analysis 4: Physical health						
NIE	**1.33**	**1.25–2.23**	**38**	**1.32**	**1.23–1.76**	**59**
NDE	2.15	0.80–5.95		1.28	0.58–2.47	
Analysis 5: Mental health						
NIE	**1.22**	**1.07–1.37**	**28**	**1.22**	**1.06–1.37**	**44**
NDE	2.34	0.96–6.59		1.39	0.69–2.56	
Analysis 6: Work ability						
NIE	**1.29**	**1.10–1.48**	**35**	**1.28**	**1.08–1.48**	**54**
NDE	2.21	0.92–7.13		1.32	0.63–2.56	
Analysis 7: Health & work ability						
NIE	**1.39**	**1.26–3.76**	**43**	**1.36**	**1.25–1.95**	**65**
NDE	2.05	0.85–7.75		1.24	0.58–2.47	
Analysis 8: Health & work ability & work factors [d]						
NIE	**1.28**	**1.08–2.12**	**34**	**1.28**	**1.09–2.13**	**54**
NDE	2.23	0.79–7.83		1.32	0.55–2.52	
TE of SES [a]	**2.85**	**1.38–12.99**		**1.69**	**1.14–3.49**	

[a] Educational level.
[b] Obtained from bootstrapping (1000 reps)
[c] Proportion mediated = $HR_{NDE}*(HR_{NIE}-1)/(HR_{NDE}*HR_{NIE}-1)$
[d] 2.4% smaller sample size in fully adjusted multi-mediator model due to listwise exclusion of missing values (N=2380)

the SES on disability pension into a NIE and NDE using work factors, health, and work ability as mediators. When comparing low versus high SES groups, 23% of the effect of the SES on disability pension was mediated by low work ability. Taking health and low work ability together, these factors explained 27% of the social inequalities in early exits into disability pension comparing low to high SES groups. Social inequalities between groups of low and moderate SES could be explained to an even higher degree by work ability (38%) and by health and work ability combined (47%).

When investigating unemployment as the outcome (table 4), (borderline) significant NIE were observed for all mediators except quantitative demands. We found that physical health mediated the largest proportion (38%) of the effect of the SES on this exit route when comparing low versus high SES groups, followed by work ability (35%), mental health and influence at work (each 28%). Estimating the mediation effects of health and work ability combined, the PM was 43%. The PM fell to 34% when work factors were added (table 4, analysis 8). A similar pattern was observed comparing low versus moderate SES groups: 59% of the effect of the SES on long-term unemployment was explained by physical health, followed by physical demands (57%),

work ability (54%), influence at work (46%) and mental health (44%). The combined mediation effect of health and work ability lead to a PM of 65%.

Sensitivity analysis

Using the Fine & Gray (F&G) competing risk regression to determine the main effects of education and the covariates on the probability of leaving employment through one of the competing exit routes did not reveal considerable differences compared to the Cox model (supplementary table S3). We note that the sub-distribution HR from the F&G model are not directly comparable to the HR as they are on a different scale.

Discussion

Main findings

Among older workers, those with a low SES (operationalized by education) had an increased risk of exiting employment early through disability pension and by entering long-term unemployment but not through an

unspecified premature labor market exit. The results suggest that for older workers in Germany, low work ability may be the most important pathway through which the SES exerts its effect on employment exits through disability pension, accounting for 23% of the social inequalities between low and high SES groups, and 38% between low and moderate SES groups.

With respect to becoming long-term unemployed, the effect of the SES on this exit route operates to a large extent through poor physical health, which accounts for 38% of social inequalities comparing low to high SES groups and 59% comparing low to moderate SES groups. The combined analyses of health and work ability consistently lead to the highest PM values. As much as 65% of the effect of the low versus moderate SES on long-term unemployment was mediated by the combination of health and work ability.

The study indicates that work factors, health, and work ability explain social inequalities in early exit from employment between low and moderate SES groups to a larger extent than the social inequalities between low and high SES groups.

Comparability with existing evidence

Our findings coincide with previous analyses by Robroek et al (11) and Schuring et al (8), who demonstrated that lower educated workers had an increased risk of leaving paid employment due to disability benefits and unemployment.

In our study, work ability turned out to be the main contributor to social inequalities in early exit through disability pension, while work factors and health played a minor role. Our findings thereby deviate from a similar study by Robroek et al (11), who found that self-perceived health mediated large parts of the effect of the SES on disability pension. Work ability was not investigated in that study. We assume two main causes of the predominant role of work ability and the minor role of health in our study. Firstly, continuing to work may be possible despite poor health, but difficult in the presence of low work ability. In a recent discussion paper (43), the authors stress that older workers with poor health may continue working if they have to for financial reasons, an argument applying specifically to those with low SES. Conversely, those experiencing low work ability may have no other option than to exit employment. This assumption is supported by existing evidence indicating a strong predictive value of low work ability for subsequent disability pension (18–20).

Secondly, in Germany, eligibility criteria for access to disability pension are formally based on the work ability of employees. Disability pension is not granted unless workers are incapable of working in any kind of job for more than three (full disability pension) or six hours per day (partial disability pension) (25).

When it comes to long-term unemployment, in our analysis health, work ability, and work factors significantly contributed to social inequalities in early exits. Physical health was the dominating mediator, with a proportion mediated of 38% between low and high SES groups. In a similar study (11), the mediating effect of self-perceived health on unemployment was smaller (9%). The differences between the studies may not only be explained by the different operationalization of health, but also by the age of the analysis samples. While Robroek et al (11) investigated workers aged 18–64 years, our sample consists of workers aged 46 and 52 years at baseline. The effect of poor health on exits into unemployment may be more pronounced for older workers, especially in the presence of unfavorable working conditions (44, 45).

Lastly, work factors, health, and work ability consistently explained social inequalities in early exits between low and moderate SES groups to a larger degree than inequalities between low and high SES groups. Comparable observations were made in a methodologically similar study investigating the outcome health among older workers (12). In our study, the set of investigated mediators mainly reflects aspects of the work and health domains. However, those with a high SES might differ from those with lower SES with respect to many further life aspects with potential influence on labor market participation. Eg, existing evidence suggests that those with higher SES also have a healthier lifestyle (11) and more stable employment relationships (46), both protective of early exit from employment.

Strengths and limitations

To our knowledge, this is the first study examining social inequalities in early exit from paid employment applying an IOW approach with discrete survival time data. An important strength of the IOW approach is that a causal interpretation of the effect estimates is possible irrespective of a potential exposure-mediator interaction (29).

A further strength of the study is the linkage between survey data and employment register data, whereby annual information on three early exit routes could be obtained. However, we would like to stress some limitations inherent with the longitudinal study design.

Compared to the initial lidA study sample, lower educated subjects (26% at wave 1) are slightly underrepresented in the current analysis sample (21%). The total effects of the SES on the three exit routes may therefore be underestimated, if lower educated are more likely to exit early, as similar studies indicate (11, 46). Additionally, a healthy worker effect may contribute to an underestimation of the mediation effects, especially of health variables.

We also note that for some analyses relatively few events per independent variable were observed. This mainly applies to the fully adjusted multi-mediator models, where less than the recommended ten events per independent variable for Cox regression models (47) were reached. Thus, the respective effect estimates need to be interpreted with caution.

A strength of this study is the focus on few age groups as the mechanisms leading to early exit and potentially to social differences in early exit may be assumed to be age related (3). This, however, limits the external validity of the results for other age groups (see above). Furthermore, the country-specific context regarding early exits may hamper the generalizability of our findings to non-German contexts (48).

Lastly, the causal interpretation of the NDE and NIE is based on the no-unmeasured confounding assumptions, which were formulated above. Leaving employment is a complex process (2). Although we adjusted for common outcome-mediator and mediator-outcome confounders, residual confounding cannot be ruled out. Concerning assumption 4, only the partner status is post-exposure and may violate the assumption. However, our analysis indicated that this mediator-outcome confounder is not statistically significantly associated with the exposure.

Implications

In times of extended working life policies, our findings highlight the necessity of investments into selective prevention of low work ability and poor physical health among (older) workers to forestall a widening of social inequalities in early exits through disability pension and long-term unemployment. So far, in many countries, extended working life policies do not sufficiently consider groups of workers with different needs and resources as well as cumulative (dis-)advantages over the life course (2).

The findings further implicate that preventive measures targeting these intermediates may be more effective leveling inequalities between the low and moderate SES groups and – to a much lesser extent – those between low and high SES groups. Differences in employment participation between older workers with low and high SES may thus be explained to a larger extent by a conglomeration of further unobserved factors. Future studies should make use of the advantages of the IOW approach to examine an even broader selection of intermediates collectively, including health behavior and employment arrangements.

Concluding remarks

Our findings indicate low work ability and less-than-good physical health may propel social inequalities in early exit from paid employment through disability pension and long-term unemployment among older workers. Work factors contributed considerably to social inequalities in exits through unemployment but not through disability pension. Current extended working life policies should be accompanied by preventive measures addressing these factors to counteract the increase of social inequalities during the later career of older employees.

Competing interests

The authors declare no conflicts of interest.

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Appendix C: Study III

Rohrbacher, M., Hasselhorn, H. M., & Matilla-Santander, N. (2024). Associations between precarious employment trajectories and mental health among older workers in Germany: Vertical and horizontal inequalities. *Scandinavian Journal of Work, Environment & Health*, *50*(4), 290–299. https://doi.org/10.5271/sjweh.4160

Associations between precarious employment trajectories and mental health among older workers in Germany: Vertical and horizontal inequalities
by Rohrbacher M, Hasselhorn HM, Matilla-Santander N

To the knowledge of the authors, this is the first German study to assess the evolution of precarious employment (PE) conditions over time and their associations with mental health among older workers using a latent class modelling approach. Our results show that women are disadvantaged with respect to both exposure to and effects of PE, thereby highlighting intra-generational inequalities.

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Key terms: employment trajectory; Germany; group-based trajectory modelling; inequality; mental health; older employee; older worker; precarious employment; prospective cohort; trajectory

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Additional material
Please note that there is additional material available belonging to this article on the *Scandinavian Journal of Work, Environment & Health* -website.

Associations between precarious employment trajectories and mental health among older workers in Germany: Vertical and horizontal inequalities

by Max Rohrbacher, MSc,[1] Hans Martin Hasselhorn, MD,[1] Nuria Matilla-Santander, PhD [2]

Rohrbacher M, Hasselhorn HM, Matilla-Santander N. Associations between precarious employment trajectories and mental health among older workers in Germany:Vertical and horizontal inequalities. *Scand J Work Environ Health* 2024;50(4):290–299.

Objective The aim of the study was to investigate the longitudinal association between multi-dimensionally measured precarious employment (PE) trajectories and mental health among older employees in Germany.

Methods Current data from the German lidA study was used, including panel cases, who participated in all four survey waves (2011, 2014, 2018, 2022). The study comprised 1636 subjects, aged 46 and 52 years at baseline. Group-based trajectory modelling was used to model PE trajectories based on a score combining multiple items from the dimensions employment insecurity and income inadequacy. The association between PE trajectories (2011–2022) and mental health (2022) was tested using weighted logistic regression.

Results We identified a PE trajectory with upward movement that best described 13.6% of the study sample. Representation in this group was socially unequally distributed with noticeably larger shares of female, lower-educated and lower-skilled workers in PE. Women following this trajectory had increased odds [odds ratio (OR) 1.68–1.82] of reporting poor mental health in 2022 compared to their counterparts in constant non-PE. This was not the case for men (OR 0.37–0.51).

Conclusions Our findings highlight horizontal and vertical inequalities with respect to exposure to and consequences of PE. Future labor market reforms should improve protection of women, who will likely be disadvantaged by accumulating employment-related mental health risks over the course of their lives.

Key terms group-based trajectory modelling; older employee; prospective cohort.

Existing evidence clearly suggests adverse effects of precarious employment (PE) on mental health (1). There is growing agreement that PE is understood as an "accumulation of various unfavorable facets of employment quality" (2, p391), thus constituting a multi-dimensional construct regularly combining employment insecurity, income inadequacy and a lack of rights and protection (3).

During the past two decades, PE has received increased attention from both public and public health research. Different international research groups have laid important corner stones for future research on PE and its effects on health including: the conceptual model on the pathways between PE and health (4); Rönnblad et al's (1) review of the current evidence of the effect of PE on mental health, which demonstrated a scarcity of high-quality prospective studies; a review of commonly used dimensions and definitions of PE (3); and recent high-quality register-based cohort studies (5, 6).

So far, most high-quality studies on the association between PE and mental health have derived from Sweden (eg, 7, 8). Previously, authors have highlighted that the exposure to health-adverse employment conditions is unequally distributed along vertical (eg, education or occupation) and horizontal (eg, sex or migrant status) social positions (eg, 9–11). The magnitude of these vertical and horizontal inequalities likely varies between

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countries, given that welfare states act as "institutional filters" with respect to exposure and susceptibility to PE – this may limit the transferability of existing findings to other countries (4, 9, 12, 13).

Thus, evidence from outside Scandinavian countries would add to the existing knowledge. Only few studies succeeding Rönnblad et al's review (1) have used multi-dimensional measurements of PE. These stem from Scandinavia (5, 14) and also Germany (15–17). Based on data from the German Study on Mental Health at Work (S-MGA), Demiral et al (16) found that a cumulative PE exposure index combining multiple PE indicators was significantly associated with the development of depressive symptoms during the 5-year follow-up among men, but not women, aged 31–60 years (16). In Pförtner et al's study (15), which is based on data from the German Socio-Economic Panel, both prolonged PE and upward and downward mobility were associated with poor mental health [Short Form-12 Health Survey (SF-12)] over a 16-year follow-up among persons aged 18–67 years of both sexes (however, stronger among men) (15). To our knowledge, these are the only studies longitudinally investigating the effects of a multi-dimensionally measured PE on mental health among workers in Germany.

Still, there are two design features of these two German studies that may be regarded as limitations: first, the wide age range of included subjects and, second, the limited number of follow-ups. Exposure to and experience of PE likely varies between different age groups given the insider-outsider logic of the German labor market. Those who are already employed and established in the labor market are called 'insiders' (often mid-career and older male workers), while labor market entrants and those with interrupted, non-continuous careers (more often women) may be regarded as 'outsiders' (9, 18). Moreover, the consequences of PE might differ in dependence of the workers' proximity to retirement and their financial needs (19). Thus, even when statistical analyses are adjusted for age, the inclusion of multiple age groups might obscure the age- and context-dependent strength of the association between PE and mental health. Therefore, a narrower age range might be a strength when investigating PE conditions and their effects on health. Secondly, only Pförtner et al (15) measured exposure to PE at more than one time point – namely two. Given the time-varying nature of employment relations and its quality throughout the (late) career and the cumulative effect of different PE dimensions, the assessment of PE at more/multiple time points (trajectories) may help to prevent misclassification of the exposure (12, 20).

To the knowledge of the authors, there is no German study investigating the association between multi-dimensionally measured PE trajectories and mental health among older workers (from the German baby boom generations). Our aim is to fill this research gap.

Methods

This study is based on data from the German lidA study, a prospective cohort study on the topics age, health and labor participation (21). lidA includes a representative sample of socially insured employees (initially excluding self-employed and sworn civil servants) from the German baby boom generation born in either 1959 or 1965 (21), sampled from the official process data on employment histories of the German Institute for Employment Research. Response rates are reported in the lidA method reports (22–25) and are similar to those of other employee surveys, eg, the S-MGA (26). Our analysis used data from subjects born either 1959 or 1965, aged 52 and 46, respectively, at baseline and followed up for 11 years. Subjects who participated in all study waves (t0=2011, t1=2014, t2=2018, t3=2022/2023 [referred to as 2022]) were eligible to be included in this study (N=2291). We excluded subjects, whose employment status deviated from full-time (≥35 hours/week), part-time, or marginal, ie, long-term sick, 'other' [eg, on (parental) leave], those in a qualification measure or unemployed and pensioners, and those who were self-employed in any of the waves (figure 1). Lastly, cases with missing information on analysis variables were excluded.

Mental health (t₃)

Mental health was assessed at t_3 (outcome) and t_0 (adjustment) using the mental component of the SF-12. Following Nübling et al's procedure (27), we created a Mental Component Summary (MCS) score ranging from 0 (lowest) to 100 (highest). For our analysis, we chose three different cut-offs to determine poor mental health: The first cut-off was set at 47.0, which corresponds to the 25th percentile of the current sample at t_0. Subjects with values of ≤47.0 were regarded as poor mental health cases. The second cut-off was set at 45.6 (21st percentile), which Vilagut et al (28) suggested to be the optimal cut-off to detect 30-day depressive disorders in European samples. The third cut-off was set at 42.0 (14th percentile), which Ware et al (29) recommended to be indicative of a clinical depression based on a US sample.

Precarious employment trajectories (t₀–t₃)

We followed three steps when building the PE trajectories. First, we searched for the most suitable variables available at all four waves of the lidA survey data for a
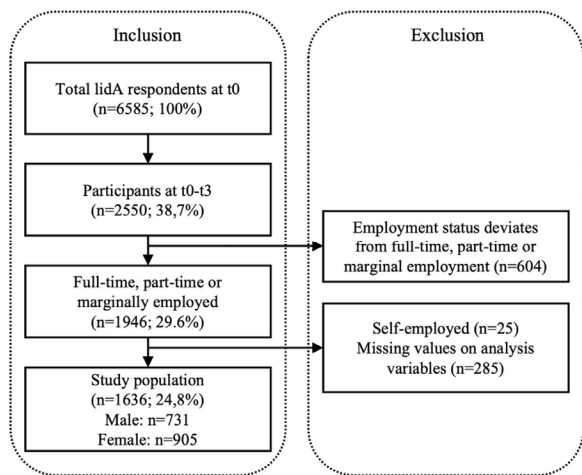
Figure 1. Flow chart of inclusion and exclusion criteria.

multi-dimensional measurement of PE. Our search was guided by Kreshpaj et al's article (3). From the three suggested dimensions – employment insecurity, income inadequacy and lack of rights and protection – only the first two could be operationalized with our data. Three items were used to cover the dimension employment insecurity, namely job threat (yes/no), temporary employment (yes/no) and multiple jobs (yes/no). To cover the dimension income inadequacy, we calculated a personal hourly net income based on information on monthly wage and the total amount of weekly working hours, following Demiral et al's descriptions (16). We then built five income groups (<60, 60–79, 80–99, 100–149, ≥150%) based on the median personal income in the study population. The calculation of the median and computation of income groups was done separately for each study wave to account for overall increases in income (eg, group <60% = income <€6.70/hour at t_0 and <€8.90/hour at t_3).

In a second step, we built a summative score following Jonsson et al (30). Job threat takes the values -2 (yes, job threat) and 0 (no job threat). Temporary employment takes the values -2 (temporary) and 0 (permanent). Multiple jobs take the values -1 (≥2 jobs) and 0 (1 job). The income level scores -2 (<60%), -1 (60–79%), 0 (80–99%), 1 (100–149%) and 2 (≥150%). The range of the resulting sum score of the four items was -7–2 (see supplementary material, www.sjweh.fi/article/4160, table S1).

In a third step, the PE trajectories were built by applying group-based trajectory modelling (GBTM) (31, 32). The model selection process was guided by several statistical criteria as well as subjective judgement/domain knowledge (cf, 32). We specified a censored normal distribution for the PE score. The number of

trajectory groups was determined based on the Bayesian Information Criterion (BIC) and Akaike Information Criterion (AIC) (see supplementary table S2). BIC and AIC closer to zero indicate a better model fit. We pre-determined a model choice set (cf, 32) of minimum three groups (PE, borderline PE, constant non-PE) and maximum six groups (constant PE, PE to non-PE, non-PE to PE, borderline PE, constant non-PE low, constant non-PE high). If only minor changes of BIC and AIC were observed between models, the most parsimonious model was selected (32). We chose a four-group option, since more groups lead to only marginal changes of the BIC and AIC and more groups in non-PE. Subsequently, the level of polynomials for each group trajectory was adjusted to achieve P<0.01 for the parameter estimate in the highest function (cf, 6). This resulted in a linear shape of all trajectories since P<0.01 could not be reached adding quadratic or cubic terms. The performance of the final model was assessed via the average posterior probability of assignment (≥0.7 for all groups), the odds of correct classification (>5.0 for all groups), the estimated group probabilities versus the proportion of the sample assigned to the group (close correspondence of both measures) and the 99% confidence intervals (CI) for group membership probability (reasonably narrow) (6, 32) (see supplementary table S3).

Covariates

Based on a directed acyclic graph (DAG) (supplementary figure S4), we chose the following minimal sufficient adjustment set for estimating the total effect of PE trajectories (t_0–t_3) on mental health (t_3): Age at baseline [46 (born 1965)/52 (born 1959)], sex (male/female), mental health (t_0), migrant status (non-migrant/ 1st and 2nd generation migrant), partner status (t_0) (partner / single), education (t_0) and occupation (t_0). The level of education was assessed with a score combining education and vocational training (33) and categorized into three classes of low, moderate, and high education (for more details see 33, p6). To measure a person's occupation, the German Blossfeld classification was used, consisting of 12 occupational categories based on KldB1988 (35). To reduce the number of categories, we classified these 12 occupations into manual and non-manual occupations and according to the degree of qualification following Götz et al (36), resulting in five groups (non-qualified manual, qualified manual; non-qualified non-manual; qualified non-manual, highly qualified non-manual).

Statistical analysis

We first showed the trajectory groups identified by GBTM. Secondly, the sample characteristics were displayed using the PE trajectories as column variables

and the socioeconomic variables as row variables. For all statistical analyses, the two constant non-PE groups were combined. For descriptive purposes, we displayed row percentages to highlight the relative fractions of socioeconomic groups within each PE group. Supplementary tables S5, S6 show these row percentages stratified by sex, supplementary table S7 shows column percentages, including the prevalence of poor mental health depending on cut-off. Next, we ran adjusted logistic regression analyses to obtain odds ratios (OR) and 95% CI for poor mental health in dependence of PE group membership. This was first done in the sample including women and men, adjusting for sex, then separately for women and men. We controlled for the minimal sufficient adjustment set. All main analyses were weighted by a longitudinal weight, which combines a post-stratification weight for t_0 and a stabilized inverse probability weight to account for selection into the current sample including age, sex, education, migrant status and occupation as predictors (mean weighting factors in the supplementary tables S8 and S9).

Sensitivity analysis

We conducted several additional and sensitivity analyses to check the robustness of our findings. First, we repeated the logistic regression analyses without using a sample weight. Second, we conducted ordinary least squares regression using SF-12 MCS as a continuous outcome, adjusting for the same set of covariates (including continuous instead of binary SF-12 MCS at t_0). Furthermore, we provided cross-tables to display the distribution of PE components by PE groups for each wave, separately for men and women. Next, we repeated the GBTM stratified by sex to check how it would alter the trajectory group compositions. Lastly, we repeated the model building and logistic regression allowing for up to two unemployment spells over the second (t_1) and third wave (t_2). We still required subjects to be employed in the first (t_0) and last (t_3) wave to avoid confounding by unemployment on the follow-up mental health.

Ethical approval

The Ethics Committee of the University of Wuppertal approved the protocol for the lidA Cohort study [5 December 2008 (Sch/Ei Hasselhorn) and 20 November 2017 (MS/BB 171025 Hasselhorn). All subjects included in the study provided verbal consent for their participation in waves 1–4 of the lidA cohort study.

Results

Figure 2 shows the trajectory groups with 95% CIs. The percentages describe the proportions by posterior probability-based classification. The two upper lines show the two constant non-precarious trajectories. The black line shows the trajectory for 10.4% of the sample with values close to the maximum of 2. A second non-PE trajectory with values close to 1 described 39.4% of subjects. Next, a constant borderline PE trajectory was identified (36.6%). Lastly, the grey dotted line shows a PE trajectory with upward movement. The trajectory starts below a PE-Score of -2 and shows a slight upward movement over time. This group best described 13.6% of the sample.

In table 1 the proportions within each category of the socioeconomic variables that are represented in the trajectory groups are shown. 20.2% of female workers and 5.5% of male workers were in the PE trajectory with upward movement. Furthermore, 17.7% of the low educated workers, 14.9% of the moderately educated and 7.8% of high educated workers followed this PE trajectory. Similarly, remarkably larger shares of non-qualified workers followed this PE trajectory. This was true for both manually (t_0: 18.9%; t_3: 16.7%) and non-manually (t_0: 33.6%; t_3: 31.0%) employed persons.

Table 2 displays the results from the logistic regression analyses. The first column shows the results from the unstratified sample (additionally adjusted for sex), the second and third column show the findings from the sex-stratified analyses. The results from the unstratified analysis indicate increased odds to report poor mental health at t_3 for the group of employees following the 'PE with upward movement' trajectory compared to those following a 'constant non-PE' trajectory. Regardless the
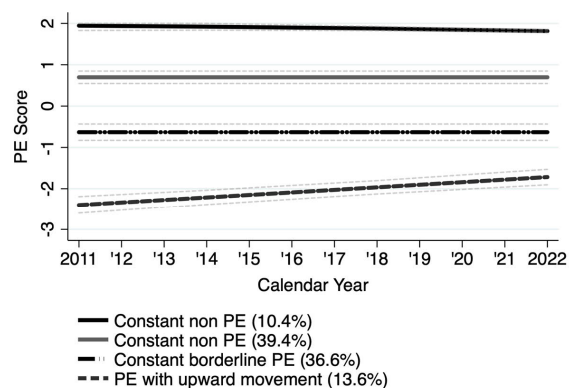

Figure 2. Trajectories of precarious and non-precarious employment (PE) (N=1636). An individual was regarded as precariously employed when the PE score was ≤-2 (%=proportion by posterior probability-based classification). Measurements took place in 2011, 2014, 2018, 2022.

selected cut-off this association was non-significant. Using the cut-off 47.0 for SF-12 MCS the OR was 1.22 (95% CI 0.80–1.86). Using the cut-offs 45.6 and 42.0, the OR were 1.37 (95% CI 0.90–2.09) and 1.47 (95% CI 0.92–2.34) respectively.

In the sex-stratified analysis (table 2), using the cut-off 47.0, we found that the OR of reporting poor mental health at t_3 was 1.68 (95% CI 1.06–2.66) for women following a PE trajectory with upward movement compared to women following a constant non-PE trajectory. Using cut-offs 45.6 and 42.0, the OR increased to 1.78 (95% CI 1.12–2.82) and 1.82 (95% CI 1.11–3.02) respectively. Among men the OR was 0.37 (95% CI 0.14–0.94) when using the cut-off 47.0. Using cut-offs 45.6 and 42.0 for SF-12 MCS, this association slightly increased to 0.43 (95% CI 0.16–1.11) and 0.51 (95% CI 0.18–1.44), respectively, and lost statistical significance. No statistically significant longitudinal association between the constant borderline PE trajectory and poor mental health was found.

Sensitivity analysis

Repeating the logistic regression without a sample weight (supplementary table S10) we found no statistically significant association in the unstratified sample and among men in the sex-stratified sample. Furthermore, weighted and unweighted linear regression (supplementary table S11) showed no statistically significant associations. Further descriptive statistics showed a general trend towards improving employment conditions among PE trajectory members (supplementary tables S12 and S13). This improvement was stronger among men, especially with respect to income. When GBTM was conducted stratified by sex (supplementary figures S14 and S15), we found very similar patterns.

Table 1. Sample characteristics. [PE=precarious employment.]

	PE with upward movement (N=223)	Borderline PE (N=599)	Non-PE (N=814)
	N (%)	N (%)	N (%)
Age in years (t_0)			
46 (born 1965)	137 (13.3)	374 (36.4)	516 (50.2)
52 (born 1959)	86 (14.1)	225 (36.9)	298 (48.9)
Sex			
Male	40 (5.5)	208 (28.5)	483 (66.1)
Female	183 (20.2)	391 (43.2)	331 (36.6)
Migrant			
Non migrant	188 (13.3)	532 (37.6)	695 (49.1)
Migrant	35 (15.8)	67 (30.3)	119 (53.8)
Educational level			
Low	51 (17.7)	133 (46.2)	104 (36.1)
Moderate	140 (14.9)	378 (40.3)	419 (44.7)
High	32 (7.8)	88 (21.4)	291 (70.8)
Occupation (t_0)			
Non-qualified manual	21 (18.9)	51 (45.9)	39 (35.1)
Qualified manual	24 (9.1)	90 (34.1)	150 (56.8)
Non-qualified non-manual	81 (33.6)	120 (49.8)	40 (16.6)
Qualified non-manual	88 (11.5)	306 (40.1)	369 (48.4)
Highly qualified non-manual	9 (3.5)	32 (12.5)	216 (84.0)
Occupation (t_3)			
Non-qualified manual	17 (16.7)	46 (45.1)	39 (38.2)
Qualified manual	24 (9.3)	87 (33.9)	146 (56.8)
Non-qualified non-manual	80 (31.0)	130 (50.4)	48 (18.6)
Qualified non-manual	96 (12.2)	308 (39.3)	380 (48.5)
Highly qualified non-manual	6 (2.6)	28 (11.9)	201 (85.5)

Table 2. Longitudinal association between precarious employment (PE) trajectories and poor mental health [(SF-12 mental component summary (MSC)]. Regression results are weighted by a longitudinal weight accounting for selective dropout (post-stratification weight*inverse probability weight for selection into analysis sample including education, age, sex, migrant status and occupation as predictors); P< 0.05 was regarded as statistically significant **Bold signifies statistical significance.** [OR=odds ratio; CI=confidence interval.]

	Unstratified sample [a] (N=1636)				Women [b] (N=905)				Men [b] (N=731)			
	Total N	Cases t_0 N	Cases t_3 N	OR (95% CI)	Total N	Cases t_0 N	Cases t_3 N	OR (95% CI)	Total N	Cases t_0 N	Cases t_3 N	OR (95% CI)
MCS cut-off at 47.0 [c] (at t_0 25% of sample below)												
Constant non-PE (reference)	814	201	245	1	331	93	109	1	483	108	136	1
Constant borderline PE	599	136	195	1.00 (0.74–1.35)	391	98	143	1.21 (0.84–1.75)	208	38	52	0.87 (0.53–1.43)
PE with upward movement	223	62	87	1.22 (0.80–1.86)	183	54	79	**1.68 (1.06–2.66)**	40	8	8	**0.37 (0.14–0.94)**
Pseudo R^2				0.079				0.093				0.105
MCS cut-off at 45.6 [c] (at t_0 21% of sample below)												
Constant non-PE (reference)	814	166	216	1	331	76	97	1	483	90	119	1
Constant borderline PE	599	121	173	1.04 (0.77–1.40)	391	91	128	1.17 (0.81–1.69)	208	30	45	0.97 (0.59–1.60)
PE with upward movement	223	55	81	1.37 (0.90–2.09)	183	47	73	**1.78 (1.12–2.82)**	40	8	8	0.43 (0.16–1.11)
Pseudo R^2				0.080				0.077				0.111
MCS cut-off at 42.0 [c] (at t_0 14% of sample below)												
Constant non-PE (reference)	814	107	151	1	331	52	69	1	483	55	82	1
Constant borderline PE	599	90	120	0.97 (0.69–1.36)	391	68	92	1.10 (0.74–1.65)	208	22	28	0.80 (0.43–1.50)
PE with upward movement	223	36	59	1.47 (0.92–2.34)	183	31	53	**1.82 (1.11–3.02)**	40	5	6	0.51 (0.18–1.44)
Pseudo R^2				0.079				0.057				0.145

[a] Adjusted for sex, age, education, migrant status, partner status, occupation, and mental health status at baseline (t0).
[b] Adjusted for age, education, migrant status, partner status, occupation, and mental health status at baseline (t0).
[c] Values of equal or below indicate poor mental health.

Allowing for up to two unemployment spells (supplementary material S16-S21) resulted in similarly shaped trajectories, with the 4-group option with linear terms as the only one fulfilling all the selection criteria described in the method section. In the logistic regression in the unstratified sample, PE with upward movement was associated with increased but non-significant OR to report poor mental health at t_3. In the analyses stratified by sex, OR was significant among women (1.65–2.04). Among men, PE with upward movement was associated with lower odds to report poor mental health at t_3. This was significant using the cut-offs 47.1 (25% percentile) and 45.6 but not with the cut-off 42.0.

Discussion

The aim of the present study was to investigate the longitudinal association between trajectories of PE and mental health. We identified a PE trajectory with upward movement that best described 13.6% of the study sample. Representation in this group was socially unequally distributed with noticeably larger shares of female, lower-educated and lower-skilled workers in PE.

In the non-stratified analyses, the group of persons following the PE with upward movement trajectory (versus constant non-PE) showed increased odds to report poor mental health at t_3. This association was non-significant. In the sex-stratified analyses, among women, those following the PE trajectory with upward movement had significantly increased odds to report poor mental health at the last survey (t_3) (OR1.68–1.82 depending on cut-off level). Among men those following the PE trajectory with upward movement had reduced odds to report poor mental health at t_3 using the cut-off 47.0 (OR 0.37, 95% CI 0.14–0.94). The association was statistically non-significant when outcome cut-offs were lowered to 45.6 and 42.0 to define more severe mental health cases.

Comparability with existing evidence

In line with previous studies on the risk of PE for mental health (5, 7, 8, 15, 16, 37), our study finds evidence for the longitudinal association between trajectories in PE and mental health. Rönnblad et al's systematic review and meta-analysis (1) contained five studies using a multidimensional PE measurement, of which two may be comparable to our study with respect to exposure measurement (7, 37). Canivet et al (7) found an incidence ratio of 1.4 (95% CI 1.1–2.0) for poor mental health using exposure data combining unemployment, temporary versus permanent employment and job insecurity. Virtanen et al (37) found an OR of up to 1.67 (95% CI

0.78–3.58) adjusting for unemployment and up to 2.33 (95% CI 0.99–5.51) not adjusting for unemployment for suboptimal mental health combining job insecurity and temporary employment as the exposure. These findings approximate those from our unstratified analyses using the outcome cut-off 42.0. However, both studies investigated a younger sample (mean age at baseline was 27 or 30 years, respectively) and did not provide a sex-stratified analysis. Burr (38) very recently provided an overview over longitudinal studies on the topic and constitutes that most sex-stratified analyses found stronger associations in men compared to women. In our study women in PE with upward movement were more likely and men were less likely to report poor mental health than their counterparts following a non-PE trajectory. We found four plausible explanations for our findings and the differences and similarities to existing studies.

Firstly, within-group differences: The multitude of (sensitivity) analyses revealed that men assigned to the PE-group were less precariously employed than women and most of them may likely experience a maximum of two indicators simultaneously by the end of the observation time. Results from Burr (38) suggest that for single men exposed to only one PE indicator rather than multiple adverse employment conditions, the association between PE and depressive symptoms may be negative (OR 0.50, 95% CI 0.06–4,29) (38). Our sensitivity analyses showed that single men had higher chances than those with a partner to be represented in the PE-group (supplementary table S6), hence our results may point to a comparable phenomenon. Our additional analyses showed that among both sexes the prevalence of many of the PE indicators decreased over time while the share of workers with multiple jobs remained stable (supplementary tables S12 and S13). Previous results from Jonsson et al (5) suggest that multiple job holdings may be mentally hazardous for women but not men. Our additional analysis furthermore showed that employment conditions improved more among men with respect to income (supplementary tables S12 and S13). Previous findings point at this PE component to be a particular risk factor for mental health (16, 38). Reduced odds for men following the PE trajectory compared to men following constant non-PE might be a result of the combination of few adverse employment conditions for men in PE, and assumably higher prevalence of other mental health risk factors in the constant non-PE group (see supplementary table S13).

The second explanation is that the experience of PE depends on context. A recent qualitative study by Lain et al (39) indicated that especially older women reported a heightened perception of precarity due to the interaction of PE conditions, financial insecurities due to repeated absences from the labor market and a resulting lack of choice with regard to the timing of retirement (39). This

may also apply to Germany, where women are more likely to be unable to amass sufficient financial resources to have adequate control over their working life due to highly gendered unpaid care duties (9, 40, 41) and the associated higher risk of discontinuous and PE patterns (42). The concomitant mental health consequences may be more evident in women approaching retirement. This may explain the differences in findings compared to studies including younger employees.

A third explanation for the differences in study findings could be that due to the unobserved third dimension of PE, namely "lack of rights and protection" (see 3), some cases within the PE with upward movement trajectory could be misclassified.

The fourth explanation is that an unequal selection into the study sample, resulting in a healthier, less precariously employed population may have shaped the upward movement of the PE trajectory and biased the findings.

Implications

We infer that – when it comes to older workers – the institutional context in Germany allows for a very selective distribution of labor market risks to the disadvantage of female and lower educated workers and those in non-qualified manual and non-manual occupations. These intra-generational horizontal (by sex) and vertical (by qualification) inequalities regarding the exposure to PE should be reduced. Moreover, we assume that especially among older female workers, the constant exposure to employment insecurity and income inadequacy adds to further mental health risks, such as combining work and family/care duties and fragmented employment biographies, which may aggravate financial insecurities when approaching retirement age (43). This may be very specific to the German contribution-based social security system which heavily links current income and non-employment to (future) welfare support (43, 44). These horizontal (by sex) inequalities regarding the vulnerability to PE should be reduced, eg, by alleviating the impact of temporary work and spells of low earnings on pension eligibility and replacement rates.

Strengths and limitations

Our study is one of the first German studies to multidimensionally measure PE and to our knowledge, the first German study to use a latent class modelling approach to assess the evolution of PE conditions over time. For our literature search, we applied the same search string used in Rönnblad et al's review (1) to search for all articles published since 4 September 2017, ie, the date of the last search for their review, until 7 February 2023. Our findings were to some extent surprising as we had expected

stronger negative associations between PE and mental health among men based on existing evidence. Potential bias associated with selection effects and the trajectory model selection need to be noted.

Selection effects. First, we did not exclude subjects with existing poor mental health prior to the outcome assessment to keep sample size large enough to conduct sex stratified analyses. There is a possibility that those with poor health at baseline may select into more PE relations (45). To account for this, we adjusted for the baseline mental health status. Secondly, the prospective design of our study is prone to selection bias, caused by selective unit and item non-response as well as inclusion/exclusion criteria. Initially, we excluded unemployed since we could not separate long- from short-term unemployed. However, previous analyses suggest that short-term spells of unemployment may be indicative for PE (eg 38,). In a sensitivity analysis we therefore allowed for a maximum of two unemployment spells between the first and last waves, which resulted in similar findings. We therefore infer that selective unit non-response (probability of being a panel case) rather than our additional exclusion criteria may bias the findings and contribute to the upward trend of the PE trajectory. The application of a sample-weight does not account for all selection effects but for unequal selection probability by design, unequal participation probability at baseline and for unequal selection into the analysis sample by age, sex, education, migrant status and occupation.

Model building: One of our major concerns is that we could not operationalize the third PE dimension "lack of rights and protection" which was suggested by Kreshpaj et al (3). Therefore, we possibly underestimated the association between PE and mental health and/or misclassified some workers. Furthermore, a major pitfall of GBTM is that within-class variance is not accounted for (31). In our case, this may have resulted in a PE group that contains few cases driving the upward movement among both sexes. Consequently, the association between PE and mental health might be underestimated, given that membership in this group may be accompanied by both the adverse consequences of PE and the likely positive consequences of improving PE-components over time. However, the four-group option with linear trajectory shapes was the only model to fulfill all selection criteria.

Concluding remarks

We found that 13.6% of our sample may be best described as precariously employed with upward movement. Representation in this trajectory group was socially unequally distributed by sex, education and occupation.

Very few men followed this trajectory (5.5%) compared to women (20.2%). Women in PE from 2011 to 2022 were much more likely (OR 1.68–1.82) than women in constant non-PE to report poor mental health in 2022. To reduce inequalities in adequate employment conditions, political actions are needed to reduce both, exposure to PE and the vulnerability of those exposed.

Conflicts of interest

The authors have no conflicts of interest to declare.

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Appendix D: Acknowledgement (Danksagung)

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Max Josef Rohrbacher, August 2024

Appendix E: CV/ Lebenslauf

Der Lebenslauf ist in der Online-Version aus Gründen des Datenschutzes nicht enthalten.