Impacts of Different Measures of Health on Labor Market Exit

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Summary

Understanding how health affects labor market participation is essential for designing effective social security and pension policies in the context of an ageing workforce. While many studies document a strong link between poor health and labor market exit, much less is known about how this relationship varies depending on how health is measured. This study systematically examines the impact of different health measures based on administrative, survey, and biobank data on labor market exit in the Netherlands.

We combine data from 83,000 individuals aged 18–64 from the LifeLines Cohort Study, a large population-based study with rich self-reported and clinical health information, with administrative health and labor market records from Statistics Netherlands (CBS). We construct four commonly used health indices (probit, chronic disease, principal component, and frailty indices), using consistent sets of health indicators across multiple data sources: (1) administrative medication records, (2) survey-reported medication use, (3) medication plus self-reported disease data, and (4) broader health indicators including functional limitations and clinical measures. Labor market outcomes are defined as transitions from paid employment into disability benefits, unemployment, early retirement, or economic inactivity. We estimate subdistribution hazard models to account for competing risks, and conduct subgroup analyses by age, gender, and education.

Our results show that poor health is consistently associated with transitions out of paid employment, particularly into disability. Using CBS medication data only, a 10-percentile increase in the frailty index is associated with a 13% higher hazard of transitioning into disability and a 2% higher hazard of transitioning into unemployment. No associations were found for early retirement or economic inactivity. Other indices, such as the probit and PCA indices, produce similar results, while the chronic disease index (CDI) yields slightly weaker associations.

When additional disease information from LifeLines is added, including self-reported disease information, functional limitations and clinical measures, the estimated hazard of transitioning into disability and unemployment increases by 10 and 3 percentage points, rising to 23% and 5%, highlighting the added explanatory value of incorporating broader health information. Stratified analyses reveal that these differences are especially pronounced for individuals with lower education and for younger workers at risk of unemployment. The chronic disease index underperforms relative to other indices, likely due to its focus on mortality rather than work capacity.

Our findings underscore the importance of using comprehensive, multidimensional health measures to understand labor market risks, especially in policy domains such as disability insurance, retirement schemes, and pension forecasting. Relying solely on administrative medication data may lead to underestimation of labor market risk across socioeconomic

groups. Where survey data are unavailable, administrative data remain a valuable resource, though their limitations should be taken into account when interpreting results. Policy-makers and actuaries should consider integrating broader health indicators into pension and forecasting models to improve the targeting of interventions, risk assessment, and the design of equitable and sustainable labor market and retirement policies.

Samenvatting

Inzicht in de relatie tussen gezondheid en arbeidsmarktdeelname is essentieel voor het vormgeven van sociale zekerheid en pensioenbeleid in een vergrijzende samenleving. Hoewel veel studies aantonen dat slechte gezondheid samenhangt met uittreding uit de arbeidsmarkt, is er veel minder bekend over hoe deze relatie verschilt afhankelijk van hoe gezondheid wordt gemeten. In deze studie onderzoeken we systematisch hoe verschillende gezondheidsmaten, op basis van administratieve gegevens, cohort en biobank data, invloed hebben op uittreding uit de arbeidsmarkt in Nederland.

We combineren gegevens van 83.000 individuen in de leeftijd van 18 tot en met 64 jaar uit de LifeLines Cohortstudie, een grootschalig bevolkingsonderzoek met uitgebreide zelf-gerapporteerde en klinische gezondheidsinformatie, met administratieve gezondheids- en arbeidsmarktgegevens van het CBS. We construeren vier veel gebruikte gezondheidsindices (probit, principale componenten, frailty en chronische aandoeningen index), op basis van consistente sets gezondheidsindicatoren en vier datascenario's: (1) alleen medicatiegegevens uit CBS-registers, (2) medicatiegegevens uit LifeLines, (3) medicatiegegevens gecombineerd met zelfgerapporteerde aandoeningen, en (4) uitgebreidere gezondheidsmaten inclusief functionele beperkingen en klinische indicatoren. Arbeidsmarktuitkomsten worden gedefinieerd als transities vanuit betaald werk naar arbeidsongeschiktheid, werkloosheid, vervroegde uittreding of economische inactiviteit. We schatten subdistributie hazardmodellen waarbij rekening wordt gehouden met de keuze tussen alternatieve routes uit werk, en analyseren verschillen naar leeftijd, geslacht en opleidingsniveau.

Uit de resultaten blijkt dat slechte gezondheid consistent samenhangt met uittreding uit betaald werk, vooral richting arbeidsongeschiktheid. Bij gebruik van alleen CBS-medicatiegegevens leidt een stijging van 10 percentielpunten in de frailty index tot een 13% hoger risico op arbeidsongeschiktheid en een 2% hoger risico op werkloosheid. Voor vervroegde uittreding of economische inactiviteit vonden we geen verband. Andere indices zoals de probit- en PCA-index gaven vergelijkbare resultaten, terwijl de chronische aandoeningen-index iets zwakkere verbanden liet zien. Wanneer uitgebreidere gezondheidsmaten inclusief functionele beperkingen en klinische indicatoren worden toegevoegd, stijgt het geschatte risico op arbeidsongeschiktheid met 10 procentpunten naar 23%, wat de meerwaarde van bredere gezondheidsinformatie onderstreept. In subgroep analyses naar leeftijd en geslacht zien we dat verschillen bij het gebruik van CBS-medicatiegegevens of uitgebreidere gezondheidsgegevens verder worden uitvergroot.

Onze bevindingen benadrukken het belang van het gebruik van brede, multidimensionale gezondheidsmaten om arbeidsmarktrisico's goed in kaart te brengen, vooral bij beleid rond arbeidsongeschiktheid, vervroegde uittreding en pensioenen. Alleen vertrouwen op administratieve medicatiegegevens kan leiden tot onderschatting van risico's binnen bepaalde

sociaaleconomische groepen. Waar enquêtegegevens ontbreken, bieden administratieve gegevens een waardevol alternatief, mits hun beperkingen worden meegewogen. Beleidsmakers en actuarissen zouden bredere gezondheidsindicatoren moeten integreren in prognosemodellen om het gericht inzetten van interventies, risicobeoordeling en de ontwikkeling van duurzaam beleid voor arbeidsmarkt en pensioen te verbeteren.

1. Introduction

Understanding the relationship between health and labor market participation is essential for the development of policies to address the challenges of an ageing population. However, this relationship depends critically on how health is measured (e.g., Blundell et al., 2021; Currie & Madrian, 1999; Kalwij & Vermeulen, 2008; Pinna Pintor et al., 2024; van Rijn et al., 2014). Different data sources capture different dimensions of health, leading to varying conclusions about its relevance for labor market outcomes.

Administrative data are increasingly used to measure health through composite health indices (e.g., Danesh et al., 2024; van Ooijen et al., 2020; Kapteyn & Meijer, 2014). These data have gained popularity due to their population-wide coverage, minimal loss to follow-up, and ability for linkage to other data sources, and are often considered more objective than self-reported measures from survey data. Yet, administrative data often lacks the detail and breadth of health indicators available in surveys or biobanks. Despite the growing use of administrative data, comparative evidence on how different (more and less comprehensive) health measures and data sources affect findings on the health and labor market relationship remains limited.

This paper systematically examines how the relationship between health and labor market outcomes varies depending on the health indicators and data sources used. In particular, we compare health indices derived from administrative data with those based on survey and biobank data, focussing on differences across socioeconomic groups. First, we review and precisely document how previous studies have conceptualized and measured health in relation to labor market participation and transitions out of work, emphasizing the multidimensional nature of health and the variability of approaches to measuring health. While some studies examine how different health indicators shape this association, direct comparisons between administrative and survey-based data, which typically provides a more comprehensive range of health indicators, remain limited.

To guide our empirical analysis, we focus on four commonly used health indices: (1) an index based on an ordered probit model that predicts self-rated health (e.g., Jurges 2007; Lindeboom & Kerkhofs, 2009), (2) a principal component analysis (PCA) index (e.g., Poterba et. al., 2011), (3) a frailty index (e.g., Hosseini et al., 2022; Mitnitski et al., 2001), and (4) a chronic disease index (CDI) (Danesh et al., 2024). We then assess how these health indices, constructed from different health indicators and data sources, relate to labor market transitions.

Our empirical setting combines data from the LifeLines Cohort Study (Scholtens et al., 2015), a large-scale population study in the Netherlands with rich health information, and administrative labor market and medication records from Statistics Netherlands (CBS) (Bakker et al., 2014). We define five mutually exclusive labor market states based on CBS

records: paid employment, disability benefits, unemployment benefits, early retirement, and economic inactivity. We construct health indices under four data scenarios: (1) CBS medication data only, (2) LifeLines medication data only, (3) CBS medication data combined with self-reported diseases, and (4) LifeLines medication data combined with self-reported diseases. To estimate the relationship between health and labor market transitions, we apply Fine and Gray's proportional subdistribution hazard model (Fine & Gray, 1999). We further expand the indices by incorporating general health assessments, functional limitations, and clinical measures from LifeLines. Stratified analyses by age, gender, and education provide insight into heterogeneity in the estimated effects.

Our results show that health indices based solely on medication data yield similar findings across administrative and survey sources when capturing the same conditions. However, when broader health indicators, including self-reported disease information, general health assessments, functional limitations, and clinical measures, are incorporated, the associations between health and labor market outcomes become stronger. Indices that incorporated broader health dimensions from survey data showed approximately 10 percentage points stronger associations with transitioning into disability (hazard rates increasing from 1.13 to 1.23 related to a 10-percentile increase in the health (frailty) index) than those based solely on administrative medication data. In other words, relying exclusively on administrative medication data tends to underestimate the strength of this relationship, especially in subgroup analyses that indicate larger disparities across age and gender but less so across educational status, when more comprehensive health measures are used.

This study contributes in three important ways. First, we provide a systematic comparison of health indices derived from administrative and survey-based data, addressing an important gap in the literature, based on comprehensive review of literature on health and labor market outcomes and documentation of used indicators. Second, we offer insights into health index construction, comparing alternative methodologies and highlighting the value of incorporating diverse health indicators. Third, we show that the choice of health measure and data source significantly affects the estimated relationship between health and labor market participation. Our results underscore the importance of utilizing health indices based on comprehensive health indicators and indicate that relying solely on administrative medication data could underestimate the strength of this relationship. These findings have implications for both research methodology and public policy design aimed at reducing health-related labor market inequalities.

The remainder of this paper is organized as follows. Section 2 reviews the literature. Section 3 describes the data and methods. Section 4 presents the results. Section 5 discusses the implications.

2. Literature Overview

This section documents findings from our literature review on how health is measured and how different health measures relate to labor market outcomes. We focus on studies using three main types of data sources: surveys, biobanks, and administrative records. Some studies combine multiple sources. A summary of key studies is presented in Table A1 in the Appendix.

Surveys typically rely on self-reported health assessments. These offer direct insights into individuals' physical and mental health and well-being, but have limitations, including smaller sample sizes, reporting bias, and attrition over time (van Ooijen et al., 2020). Biobanks extend survey data with biomarkers, providing more objective measures of health. However, they are less widely available due to high cost and restricted access. Administrative records, derived from interactions with healthcare or social security systems, include information such as prescription medication use and healthcare utilization (van Ooijen et al., 2020). These data facilitate large-scale, longitudinal analysis, but miss undiagnosed conditions or underrepresent populations with limited healthcare access (Van Mourik et al., 2015; Rahman et al., 2022). Moreover, data accuracy may vary: a Dutch registry study found accuracy rates between 88.2% and 100%, with discrepancies mainly in postoperative complications (Van der Werf et al., 2019).

Health Indicators

Health can be assessed using subjective, objective, or biomarker-based indicators (Brown, 2023). Subjective measures rely on self-reported health status. While highly correlated with objective health indicators (Kapteyn & Meijer, 2014), they are influenced by individual perceptions and potential justification bias; for example, individuals with disabilities may report worse health to rationalize their status (Bound 1991; Blundell et al., 2021). Several studies find cross-country and socioeconomic differences in self-rated health, even when objective health is similar (Meijer et al., 2011; Currie & Madrian, 1999). Objective measures, such as diagnosed conditions, offer a more standardized assessment of health, but may also be misreported in surveys. Blundell et al. (2021), however, show that structured self-reported indicators, such as disease prevalence, yield relatively robust estimates for labor market outcomes. Biomarkers, including blood tests, anthropometrics, and genetic markers, provide physiological bases health measures, but are costly and more invasive, limiting their use.

Health Dimensions

Studies relate labor market outcomes to various dimensions of health (see final column of Table A1).

- General health is often measured by self-rated health, which is widely used and correlates well with objective health.
- Physical health is assessed via diagnoses such as diabetes, cardiovascular disease, stroke, hypertension, chronic lung disease, and cancer.
- Mental health is typically assessed based on symptoms or diagnoses of anxiety and depression or broader psychological conditions.
- Cognitive health is measured using cognitive tests or diagnosis such as Parkinson's disease.
- Functional limitations are assessed via difficulties with activities of daily living (ADLs) and instrumental ADLs.
- Healthcare utilization includes indicators such as visits to general practitioners, hospital stays, home care use, and nursing home admissions.

Health Measurements

Common health measures include self-rated health, chronic diseases, presence or multi-morbidity, and composite indices (see the next to last column of Table A1). Self-rated health, based on the question "In general, would you say that your health is excellent, very good, good, fair, or poor" (Ware & Sherbourne, 1992), is simple to collect and correlates well with objective indicators (Kapteyn & Meijer, 2014). Chronic diseases or multimorbidity are captured using administrative or survey data on diagnosis and medication use (Danesh et al., 2024; Junna et al., 2022; Oude Hengel et al., 2021; Van de Ven et al., 2023; van Ooijen et al., 2020). Many studies use binary indicators for specific conditions or broader measures of multimorbidity (two or more chronic conditions). Others construct categorical variables based on the number of diseases present (Table A2 provides an overview of disease mapping via medication data).

A health index combines multiple health indicators into a single measure. Regression-based indices assign weights to predictors of self-rated health (García-Gómez et al., 2010; Jurges, 2007; Lindeboom & Kerkhofs, 2009; van Ooijen et al., 2020) or mortality risk in chronic disease indices (Danesh et al., 2024). These indices can flexibly account for age, gender, and other covariates. Alternatively, factor analysis or principal component analysis (PCA) identifies latent health dimensions and often incorporates self-rated health (Poterba et al., 2011). A frailty index sums the number of adverse health indicators and divides by the total number of indicators, giving equal weight to each (Mitnitski et al., 2001). While simple, the frailty index strongly predicts both health and economic outcomes (Hosseini et al., 2022) and benefits from established guidelines for indicator selection (Searle et al., 2008). Recent work also shows that clustering longitudinal frailty trajectories provides meaningful predictors of future frailty and mortality (Borella et al., 2024).

Impact of Health on Labor Market Outcomes

Research consistently shows that poor health is associated with early labor market exit (van Rijn et al., 2014). However, the magnitude of this relationship depends on how health is measured (Blundell et al., 2021; Currie & Madrian, 1999; Pinna Pintor et al., 2024; van Rijn et al., 2014). Self-rated health typically shows stronger associations with labor market participation than objective health indicators (Blundell et al., 2021; Kapteyn & Meijer, 2014; van Rijn et al., 2014). Notably, mental health appears more strongly linked to unemployment risk than general health measures (van Rijn et al., 2014). Co-occurring mental and physical health conditions have a more significant impact on labor market outcomes than either condition by itself (Gurgel do Amaral et al., 2022). Still, when multiple indicators are used, estimates from objective health measures align closely with those from self-rated health in the UK (Blundell et al., 2021). Similarly for several countries in the SHARE data set, adding objective health indicators does add to the relation between health status and labor force participation (Kalwij & Vermeulen, 2008). Kapteyn and Meijer (2014) conclude that the variety of health dimensions included in an index are more important to consider than the specific type of index employed.

3. Data and Empirical Method

This section describes the data, the construction of health indices, and the empirical strategy used to examine how different measures of health affect labor market outcomes.

Data

We use data from the LifeLines Cohort Study, linked to administrative data from Statistics Netherlands (CBS) (Bakker et al., 2014). LifeLines is a multidisciplinary, population-based, prospective cohort study of 167,729 persons living in the northern Netherlands (Scholtens et al., 2015). It uses a three-generation design and collects detailed biomedical, sociodemographic, behavioral, physical, and psychological information, with a focus on multimorbidity and complex genetics. Dutch-speaking adults were invited to participate via their general practitioners and could also self-register online. Family members of participants were also recruited. The first adult assessment wave was conducted between 2007 and 2014.

All participants provided written informed consent prior to enrolment. The study adheres to the Declaration of Helsinki and was approved by the Medical Ethics Committee of the University Medical Center Groningen (approval number: 2007/152).

For this analysis, we included individuals aged 18 to 64 who were employed at baseline and could be linked to CBS records. We excluded 17,978 individuals who did not meet the age requirement, 75 who could not be matched to CBS, and 39,793 who were not employed at baseline. This resulted in a base sample of 99,854 individuals. Of these, 17,061 were excluded due to missing data on health indicators, education, or marital status.

Labor Market Outcomes

Labor market status (exit routes from paid employment) was derived from CBS tax registry data, which includes monthly information on gross wages and social benefit receipt from 2007 up to 2022. We defined five mutually exclusive labor market outcomes: 1) paid employment, 2) disability benefits, 3) unemployment benefits, 4) early retirement, and 5) economic inactivity.

Individuals were classified based on the primary source of income sustained over at least three consecutive months. Disability benefit recipients received at least half of their income from disability insurance. Those classified as unemployed received unemployment or social assistance benefits. Early retirees were individuals below the statutory retirement age whose primary income was from private or occupational pensions. Economically inactive individuals had no recorded income or benefit receipt and included homemakers or early retirees without formal benefits. Only the first exit pathway from employment was used in the analysis.

Health Indices

We constructed four types of health indices: (1) Probit index, (2) Principal Component Analysis (PCA) index, (3) Frailty index, (4) Chronic Disease Index (CDI). To ensure comparability, we included the same set of health indicators in each index. The ten chronic conditions were selected based on the core list proposed by Ho et al. (2021), supplemented with migraines, Parkinson's disease, epilepsy, and osteoporosis. These conditions were included because they can be mapped to ATC medication codes, were available in the LifeLines dataset, and are relevant for the study's context, another important selection criterion according to Ho et al. (2021) (see Appendix Table A3).

For the probit index, we estimated an ordered probit model predicting self-rated health using the ten conditions. The estimated coefficients were used to generate index scores for the full sample. For the PCA index, we extracted the first principal component from the ten conditions. For the frailty index, we counted the number of conditions present and divided by the total, assigning equal weight. For the CDI, we estimated a linear regression of 5-year mortality among respondents aged 60–64 at baseline (n = 3,058), using the ten conditions as predictors.

Each index was constructed under four data scenarios providing 16 distinct health indices: (1) CBS medication data only, (2) LifeLines medication data only, (3) CBS medication data and/or LifeLines self-reported disease data, (4) LifeLines medication and/or self-reported disease data. We then constructed broader health indices (for the frailty index only) incorporating general health, functional limitations, and clinical biomarkers based on the procedure by Oude Voshaar et al. (2021) (Appendix Table A4). These included: 7 functional limitation items, 2 general health items, and 6 clinical measures. Each component was first added individually to the health index (based on LifeLines medication and self-reported data), then in pairs, and finally all together. This resulted in seven additional health indices. All index scores were converted to percentile scores for comparability.

Statistical Analysis

We estimated the associations between health and labor market outcomes using Fine and Gray's proportional subdistribution hazard model (Fine and Gray, 1999), which accounts for competing risks, i.e., the fact that one exit route (e.g., disability) precludes exiting to another (e.g., unemployment). Results are presented as subdistribution hazard ratios (SHRs) with 95% confidence intervals. All models were adjusted for age, gender, education, and marital status.

We also conducted stratified analyses by age, gender, and education. For these, we used two key indices: (1) the frailty index based solely on CBS medication data, and (2) the most comprehensive index constructed using LifeLines medication and self-reported data, func-

tional limitations, general health, and clinical indicators. All analyses were conducted using R version 4.4.0 (R Core Team, 2021).

4. Results

We begin by describing baseline characteristics of the sample, grouped by subsequent labor market outcomes: continued employment, or exit due to disability, unemployment, early retirement, or economic inactivity. Table 1 summarizes these characteristics. The mean age was 42.9 years (SD = 9.7); 56.3% were female, and 88.7% had a partner. Educational attainment was as follows: 34.9% had higher education, 41.7% had medium education, and 23.4% had lower education. Overall, 39.4% reported very good or excellent self-rated health, which was highest among those who remained employed and lowest among disability benefit recipients, 53.2% reported good self-rated health, and 7.4% reported mediocre or poor self-rated health.

Table 1: Background characteristics of the participants included in the analysis

	Continued employment (N=57447)	Unemployment (N=10170)	Disability benefits (N=3193)	Retired (N=6936)	Economic inactivity (N=5047)	Total (N=82793)
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Gender						
Male	26224 (45.6%)	4160 (40.9%)	1174 (36.8%)	3372 (48.6%)	1212 (24.0%)	36142 (43.7%)
Female	31223 (54.4%)	6010 (59.1%)	2019 (63.2%)	3564 (51.4%)	3835 (76.0%)	46651 (56.3%)
Partner status						
No partner	6177 (10.8%)	1609 (15.8%)	448 (14.0%)	612 (8.8%)	535 (10.6%)	9381 (11.3%)
Has a partner	51270 (89.2%)	8561 (84.2%)	2745 (86.0%)	6324 (91.2%)	4512 (89.4%)	73412 (88.7%)
Educational attainment						
Low	11478 (20.0%)	2884 (28.4%)	1000 (31.3%)	2516 (36.3%)	1508 (29.9%)	19386 (23.4%)
Middle	24786 (43.1%)	4208 (41.4%)	1367 (42.8%)	2128 (30.7%)	2055 (40.7%)	34544 (41.7%)
High	21183 (36.9%)	3078 (30.3%)	826 (25.9%)	2292 (33.0%)	1484 (29.4%)	28863 (34.9%)
Self-rated health						
Excellent	6358 (11.1%)	862 (8.5%)	177 (5.5%)	689 (9.9%)	485 (9.6%)	8571 (10.4%)
Very good	17663 (30.7%)	2649 (26.0%)	535 (16.8%)	1801 (26.0%)	1387 (27.5%)	24035 (29.0%)
Good	29961 (52.2%)	5647 (55.5%)	1750 (54.8%)	3968 (57.2%)	2741 (54.3%)	44067 (53.2%)
Mediocre	3360 (5.8%)	982 (9.7%)	664 (20.8%)	475 (6.8%)	418 (8.3%)	5899 (7.1%)
Poor	105 (0.2%)	30 (0.3%)	67 (2.1%)	3 (0.0%)	16 (0.3%)	221 (0.3%)
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Baseline age (years)	41.05 (8.28)	42.97 (9.68)	42.54 (10.30)	58.02 (4.68)	43.24 (11.68)	42.90 (9.74)

	Continued employment (N=57447)	Unemploy-ment (N=10170)	Disability benefits (N=3193)	Retired (N=6936)	Economic inactivity (N=5047)	Total (N=82793)
CBS medication indices						
Frailty index	0.04 (0.07)	0.05 (0.08)	0.09 (0.10)	0.07 (0.08)	0.05 (0.08)	0.05 (0.07)
Frailty index (percentile)	24.16 (33.90)	29.33 (36.00)	43.40 (39.28)	35.76 (37.38)	28.53 (35.98)	26.77 (35.14)
Probit index	0.18 (0.30)	0.23 (0.34)	0.40 (0.48)	0.29 (0.38)	0.22 (0.34)	0.21 (0.33)
Probit index (percentile)	26.92 (37.58)	32.63 (39.71)	47.58 (42.32)	39.92 (41.13)	31.67 (39.60)	29.80 (38.83)
PCA index	0.17 (0.27)	0.21 (0.31)	0.35 (0.41)	0.26 (0.33)	0.21 (0.30)	0.19 (0.29)
PCA index (percentile)	27.02 (37.53)	32.62 (39.51)	47.30 (41.95)	39.30 (40.45)	31.65 (39.41)	29.80 (38.66)
CDI index	0.00 (0.01)	0.00 (0.01)	0.01 (0.01)	0.01 (0.01)	0.00 (0.01)	0.00 (0.01)
CDI index (percentile)	27.25 (32.86)	32.34 (35.54)	42.59 (39.36)	40.21 (38.99)	31.27 (35.28)	29.80 (34.47)
LifeLines medication indices						
Frailty index	0.02 (0.05)	0.03 (0.06)	0.06 (0.08)	0.04 (0.07)	0.03 (0.06)	0.03 (0.05)
Frailty index (percentile)	16.44 (32.54)	20.60 (35.51)	33.86 (41.46)	30.28 (39.78)	20.36 (35.41)	19.02 (34.48)
Probit index	0.12 (0.27)	0.16 (0.32)	0.31 (0.46)	0.24 (0.37)	0.16 (0.32)	0.15 (0.30)
Probit index (percentile)	17.65 (34.92)	22.23 (38.24)	36.25 (44.20)	32.33 (42.35)	21.94 (38.08)	20.42 (36.97)
PCA index	0.08 (0.18)	0.10 (0.21)	0.20 (0.30)	0.16 (0.25)	0.10 (0.21)	0.09 (0.20)
PCA index (percentile)	17.64 (34.88)	22.16 (38.11)	36.06 (43.96)	32.69 (42.78)	21.88 (37.97)	20.42 (36.96)
CDI index	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)
CDI index (percentile)	18.29 (25.04)	21.74 (29.08)	28.60 (35.29)	31.61 (36.61)	21.49 (28.77)	20.42 (27.68)
CBS medication or self-reported diseases indices						
Frailty index	0.10 (0.10)	0.12 (0.11)	0.17 (0.14)	0.13 (0.11)	0.12 (0.11)	0.11 (0.11)
Frailty index (percentile)	33.35 (31.42)	40.38 (32.85)	52.77 (34.28)	42.85 (32.41)	40.08 (32.79)	36.17 (32.24)
Probit index	0.37 (0.43)	0.47 (0.48)	0.71 (0.62)	0.50 (0.49)	0.46 (0.47)	0.41 (0.46)
Probit index (percentile)	39.46 (34.83)	47.23 (35.50)	60.12 (35.20)	49.74 (34.51)	46.75 (35.41)	42.52 (35.32)
PCA index	0.37 (0.41)	0.47 (0.46)	0.68 (0.56)	0.49 (0.45)	0.46 (0.45)	0.41 (0.43)
PCA index (percentile)	39.47 (34.85)	47.25 (35.47)	59.80 (35.06)	49.73 (34.46)	46.78 (35.45)	42.52 (35.31)
CDI index	0.00 (0.01)	0.00 (0.01)	0.01 (0.01)	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)
CDI index (percentile)	40.39 (29.85)	44.62 (31.36)	51.63 (33.50)	51.65 (32.05)	44.13 (31.20)	42.52 (30.69)
LifeLines medication or self-reported diseases indices						
Frailty index	0.08 (0.09)	0.10 (0.11)	0.15 (0.13)	0.11 (0.11)	0.10 (0.10)	0.09 (0.10)
Frailty index (percentile)	31.42 (32.14)	38.31 (33.84)	50.02 (35.59)	41.82 (33.74)	38.45 (33.76)	34.29 (33.08)

	Continued employment (N=57447)	Unemploy-ment (N=10170)	Disability benefits (N=3193)	Retired (N=6936)	Economic inactivity (N=5047)	Total (N=82793)
Probit index	0.33 (0.42)	0.44 (0.49)	0.66 (0.64)	0.48 (0.50)	0.43 (0.48)	0.38 (0.46)
Probit index (percentile)	36.74 (35.99)	44.48 (37.14)	56.77 (37.48)	48.26 (36.47)	44.46 (36.93)	39.90 (36.67)
PCA index	0.30 (0.36)	0.38 (0.42)	0.56 (0.53)	0.42 (0.42)	0.38 (0.41)	0.33 (0.39)
PCA index (percentile)	36.72 (36.00)	44.52 (37.16)	56.49 (37.36)	48.35 (36.51)	44.60 (37.03)	39.90 (36.68)
CDI index	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)
CDI index (percentile)	38.14 (29.59)	42.10 (31.39)	46.55 (33.11)	46.79 (32.42)	41.76 (30.96)	39.90 (30.43)

Table 2: Association between different operationalizations of health and labor market outcomes (n = 82793)

	Unemployed SHR [95%CI]	Disability SHR [95%CI]	Retired SHR [95%CI]	Inactive SHR [95%CI]
Panel A - CBS medication				
CBS medication: Frailty index (percentile)	1.02 [1.01; 1.02]	1.13 [1.12; 1.14]	1.00 [0.99; 1.00]	1.00 [0.99; 1.01]
CBS medication: Probit index (percentile)	1.02 [1.01; 1.02]	1.12 [1.11; 1.13]	0.99 [0.99; 1.00]	1.00 [0.99; 1.01]
CBS medication: PCA index (percentile)	1.02 [1.01; 1.02]	1.12 [1.11; 1.13]	1.00 [0.99; 1.00]	1.00 [0.99; 1.01]
CBS medication: CDI index (percentile)	1.02 [1.01; 1.02]	1.10 [1.09; 1.11]	0.99 [0.98; 1.00]	1.00 [0.99; 1.01]
Panel B - LifeLines medication				
LifeLines medication: Frailty index (percentile)	1.01 [1.00; 1.02]	1.11 [1.10; 1.12]	0.99 [0.99; 1.00]	1.00 [0.99; 1.01]
LifeLines medication: Probit index (percentile)	1.01 [1.00; 1.02]	1.10 [1.10; 1.11]	0.99 [0.99; 1.00]	1.00 [0.99; 1.01]
LifeLines medication: PCA index (percentile)	1.01 [1.00; 1.01]	1.10 [1.09; 1.11]	1.00 [0.99; 1.00]	1.00 [0.99; 1.01]
LifeLines medication: CDI index (percentile)	1.01 [1.01; 1.02]	1.09 [1.08; 1.11]	0.99 [0.98; 1.00]	1.01 [1.00; 1.02]
Panel C - CBS or self-reported				
CBS disease: Frailty index (percentile)	1.04 [1.03; 1.04]	1.17 [1.16; 1.18]	1.00 [0.99; 1.00]	1.01 [1.00; 1.02]
CBS disease: Probit index (percentile)	1.04 [1.03; 1.04]	1.16 [1.15; 1.18]	0.99 [0.99; 1.00]	1.01 [1.00; 1.02]
CBS disease: PCA index (percentile)	1.04 [1.03; 1.04]	1.16 [1.15; 1.17]	1.00 [0.99; 1.00]	1.01 [1.00; 1.02]
CBS disease: CDI index (percentile)	1.02 [1.01; 1.03]	1.10 [1.09; 1.11]	1.00 [0.99; 1.01]	1.01 [1.00; 1.02]
Panel D - LifeLines or self-reported				
LifeLines disease: Frailty index (percentile)	1.03 [1.03; 1.04]	1.15 [1.14; 1.16]	0.99 [0.99; 1.00]	1.01 [1.00; 1.02]
LifeLines disease: Probit index (percentile)	1.03 [1.03; 1.04]	1.14 [1.13; 1.15]	0.99 [0.99; 1.00]	1.01 [1.00; 1.02]
LifeLines disease: PCA index (percentile)	1.03 [1.03; 1.04]	1.14 [1.12; 1.15]	0.99 [0.99; 1.00]	1.01 [1.00; 1.02]
LifeLines disease: CDI index (percentile)	1.02 [1.02; 1.03]	1.07 [1.06; 1.08]	1.00 [0.99; 1.01]	1.01 [1.00; 1.02]

Associations Between Health and Labor Market Transitions

Table 2 reports subdistribution hazard ratios (SHRs) for different health indices across various labor market exit pathways. Panel A, based on CBS medication data only, shows that poorer health is generally associated with a higher risk of labor market exit, particularly into disability. For example, a 10-percentile increase in the frailty index was associated with a 2% higher hazard of transitioning into unemployment (SHR = 1.02, 95% CI: 1.01–1.02) and a 13% higher hazard of transitioning into disability (SHR = 1.13, 95% CI: 1.12–1.14). SHR estimates for early retirement and economic inactivity were closer to 1.00, indicating no associations. The other indices (probit and PCA) provided similar results, while CDI yielded slightly attenuated results (SHR = 1.10 for disability).

Panel B, using medication data from LifeLines only, showed somewhat weaker associations. The effect on unemployment became statistically insignificant, and the disability SHR was slightly lower. In Panels C and D, which incorporate both medication and self-reported disease data (from CBS and LifeLines, respectively), associations with both unemployment and disability strengthened. For example, in Panel C, a 10-percentile increase in the frailty index was associated with a 4% higher hazard of unemployment and a 17% higher hazard of disability. Definitions using CBS data yielded slightly stronger associations than those based solely on LifeLines data, although the differences were minor. Notably, when self-reported disease information was included, the CDI tended to underestimate the strength of association with disability transitions. This may reflect the weaker correlation between the CDI (constructed based on 5-year mortality predictions of those aged 60-64) and the other three indices (frailty, probit, and PCA), as shown in Table 3.

Table 3: Correlation between different indices

		Medication data only				Medication data or self-reported data			
CBS		Frailty	Probit	PCA	CDI	Frailty	Probit	PCA	CDI
	Frailty	-	0.97	0.98	0.49	-	0.96	0.98	0.32
	Probit	0.97	-	0.93	0.48	0.96	-	0.96	0.41
	PCA	0.98	0.93	-	0.58	0.98	0.96	-	0.36
	CDI	0.49	0.48	0.58	-	0.32	0.41	0.36	-
LifeLines		Frailty	Probit	PCA	CDI	Frailty	Probit	PCA	CDI
	Frailty	-	0.99	0.96	0.30	-	0.96	0.98	0.15
	Probit	0.99	-	0.97	0.33	0.96	-	0.96	0.23
	PCA	0.96	0.97	-	0.38	0.98	0.96	-	0.19
	CDI	0.30	0.33	0.38	-	0.15	0.23	0.19	-

Table 4 examines the effects of expanding the frailty index to include broader dimensions of health, using LifeLines data. Panel A, which includes only the 10 chronic conditions, replicates the baseline results from Table 2, Panel D. Panels B, C, and D successively add functional limitations, general health indicators, and clinical biomarkers in different combi-

nations. This resulted in small increases in the association with unemployment (e.g., SHRs rising from 1.03 to 1.04–1.05), and larger increases in the association with disability. For example, in Panel C, adding functional limitations and general health increased the SHR for disability to 1.23, meaning a 23% higher risk of disability per 10-percentile increase in the index. Including all health dimensions together (Panel D) slightly attenuated the association, yielding an SHR of 1.22 (95% CI: 1.20–1.24) for disability.

Table 4: Association between health and labor market outcomes (n = 82793)

	Unemployed SHR [95%CI]	Disability SHR [95%CI]	Retired SHR [95%CI]	Inactive SHR [95%CI]
Panel A - Diseases according to LifeLines medication data or self-reported (dx)				
Only disease	1.03 [1.03; 1.04]	1.15 [1.14; 1.16]	0.99 [0.99; 1.00]	1.01 [1.00; 1.02]
Panel B - Presence of disease + one other component				
Disease + functional limitations	1.04 [1.04; 1.05]	1.20 [1.19; 1.22]	0.99 [0.98; 1.00]	1.02 [1.01; 1.02]
Disease + clinical variables	1.04 [1.03; 1.05]	1.16 [1.15; 1.18]	0.99 [0.98; 1.00]	1.00 [0.99; 1.01]
Disease + self-rated health	1.04 [1.04; 1.05]	1.19 [1.18; 1.21]	0.99 [0.98; 1.00]	1.02 [1.01; 1.03]
Panel C - Diseases + two components				
Disease + functional limitations + clinical variables	1.05 [1.04; 1.05]	1.21 [1.19; 1.22]	0.99 [0.98; 1.00]	1.01 [1.00; 1.02]
Disease + clinical variables + self-rated	1.04 [1.04; 1.05]	1.19 [1.17; 1.20]	0.99 [0.98; 1.00]	1.00 [0.99; 1.01]
Disease + functional limitations + self-rated	1.05 [1.04; 1.06]	1.23 [1.21; 1.25]	0.99 [0.98; 1.00]	1.02 [1.01; 1.03]
Panel D - All components combined				
Disease + functional limitations + clinical variables + self-rated health	1.05 [1.04; 1.06]	1.22 [1.20; 1.24]	0.98 [0.97; 0.99]	1.01 [1.00; 1.02]

Stratified Analyses: Age, Gender, and Education

Tables 5-7 present subgroup analyses by age, gender, and education, using both the CBS-only frailty index and the most comprehensive LifeLines-based index, showing heterogeneous effects. For example, among individuals aged 55 and older, a 10-percentile increase in the frailty index based on comprehensive LifeLines data is associated with a 34% higher hazard of entering disability (SHR = 1.34), compared to 17% in the youngest age group (SHR = 1.17). Also, differences across gender are observed: for men, the SHR equals 1.28 with the broader health definition, compared to 1.20 for women. Among younger individuals (under 45), poor health is more strongly associated with unemployment (SHR = 1.06) than in older age groups, where the association with unemployment is weaker or not statistically significant. This suggests different pathways of labor market exit across the life cycle: health-related unemployment is more prevalent in early career stages, while health-related

disability becomes more prominent with age. Educational differences in the association between health and labor outcomes were also evident, though somewhat less pronounced. For individuals with low education, the SHR for transitioning into disability reached 1.26 with the broader LifeLines-based health index, compared to 1.23 for those with high education.

These subgroup analyses further suggest that using broader health definitions accentuates the association between poor health and transitions out of paid employment, particularly into disability benefits. This effect is especially pronounced for age and gender subgroups. For instance, the SHR for transitioning into disability among individuals aged 55 and older increases from 1.13 when using CBS medication data to 1.34 when using the full LifeLines-based frailty index. Similarly, for men, the SHR rises from 1.14 to 1.28 when broader health indicators are included. Among younger workers (<45), the broader index also strengthens the association with unemployment (from 1.02 to 1.06).

Stratification by Age

Table 5: Association between different operationalizations of health and labor market outcomes, stratified by age

	Unemployed SHR [95%CI]	Disability SHR [95%CI]	Retired SHR [95%CI]	Inactive SHR [95%CI]
Age: < 45 years (N= 45485)				
Frailty index: CBS medication	1.02 [1.01; 1.03]	1.11 [1.09; 1.13]	1.04 [0.99; 1.09]	1.00 [0.99; 1.01]
Frailty index: full LifeLines	1.06 [1.05; 1.07]	1.17 [1.15; 1.19]	1.01 [0.95; 1.08]	0.99 [0.98; 1.01]
Age: 45-54 years (N= 27967)				
Frailty index: CBS medication	1.01 [1.00; 1.02]	1.15 [1.13; 1.16]	1.01 [0.99; 1.03]	1.00 [0.98; 1.01]
Frailty index: full LifeLines	1.04 [1.03; 1.05]	1.25 [1.22; 1.28]	1.02 [1.00; 1.05]	1.02 [1.01; 1.04]
Age: >= 55 years (N= 9341)				
Frailty index: CBS medication	1.00 [0.99; 1.02]	1.13 [1.09; 1.16]	1.00 [0.99; 1.01]	0.99 [0.97; 1.00]
Frailty index: full LifeLines	1.02 [0.99; 1.04]	1.34 [1.26; 1.43]	1.00 [0.99; 1.01]	0.99 [0.97; 1.01]

Stratification by Gender

Table 6: Association between different operationalizations of health and labor market outcomes, stratified by gender

	Unemployed SHR [95%CI]	Disability SHR [95%CI]	Retired SHR [95%CI]	Inactive SHR [95%CI]
Males (N = 36142)				
Frailty index: CBS medication	1.02 [1.01; 1.03]	1.14 [1.12; 1.16]	0.99 [0.98; 1.01]	0.99 [0.97; 1.01]
Frailty index: full LifeLines	1.04 [1.03; 1.06]	1.28 [1.24; 1.32]	0.98 [0.96; 0.99]	0.98 [0.96; 1.00]
Females (N = 46651)				
Frailty index: CBS medication	1.01 [1.01; 1.02]	1.13 [1.11; 1.14]	0.99 [0.98; 1.00]	1.00 [0.99; 1.01]
Frailty index: full LifeLines	1.05 [1.04; 1.06]	1.20 [1.18; 1.22]	0.99 [0.97; 1.00]	1.02 [1.01; 1.03]

Stratification by Education

Table 7: Association between different operationalizations of health and labor market outcomes, stratified by education

	Unemployed SHR [95%CI]	Disability SHR [95%CI]	Retired SHR [95%CI]	Inactive SHR [95%CI]
Low education (N = 19386)				
Frailty index: CBS medication	1.02 [1.01; 1.03]	1.16 [1.14; 1.18]	0.99 [0.98; 1.01]	0.99 [0.98; 1.01]
Frailty index: full LifeLines	1.04 [1.02; 1.05]	1.26 [1.22; 1.30]	0.98 [0.97; 1.00]	1.01 [0.99; 1.02]
Middle education (N = 34544)				
Frailty index: CBS medication	1.02 [1.01; 1.03]	1.12 [1.10; 1.14]	0.99 [0.98; 1.01]	1.01 [1.00; 1.02]
Frailty index: full LifeLines	1.06 [1.05; 1.07]	1.20 [1.17; 1.22]	0.98 [0.96; 1.00]	1.02 [1.01; 1.04]
High education (N = 28863)				
Frailty index: CBS medication	1.01 [1.00; 1.02]	1.12 [1.10; 1.14]	1.00 [0.99; 1.01]	0.99 [0.97; 1.01]
Frailty index: full LifeLines	1.04 [1.03; 1.06]	1.23 [1.20; 1.26]	0.99 [0.97; 1.01]	0.99 [0.98; 1.01]

5. Discussion

To better understand the relationship between health and labor market outcomes, and to develop and evaluate pension and social security policy, we systematically assessed the impact of different health measurements using rich data from the LifeLines Cohort Study linked to administrative health and labor market records from CBS. Across all data sources and methods to construct health indices, our findings confirm that poor health is strongly associated with labor market exit, particularly into disability. The findings also underscore the value of using comprehensive, multidimensional health measures to fully capture the risks of labor market transitions.

All health indices, regardless of construction method or data source show that poor health increases the risk of transitioning into disability and, to a lesser extent, into unemployment, but not into inactivity or early retirement. These findings are consistent with studies in the Netherlands (Ots et al., 2020; Oude Hengel et al., 2019; Robroek et al., 2015). However, an earlier study by Kerkhofs & Lindeboom (2009) reports larger effects of health on inflows into unemployment. Indices that incorporated broader health dimensions from survey data showed approximately 10 percentage points stronger associations with transitioning into disability (increasing from 1.13 to 1.23) than those based solely on administrative medication data. This suggests that while medication-based health measures are valuable, they do not fully capture the complexity of health.

Incorporating additional domains, such as functional limitations, general health, and clinical indicators, revealed stronger associations with adverse labor market outcomes. These findings emphasize the importance of using multidimensional health assessments, especially when evaluating risks across population subgroups. Using multidimensional measures of health appears particularly important when evaluating risks in different sub-populations. In our stratified analyses, differences between demographic groups (age and gender) were notably smaller when health was measured based on an index using only CBS administrative medication data compared to a comprehensive LifeLines-based index.

There are also limitations to relying solely on administrative medication data. First, these data may lead to misclassification, as many medications are prescribed for multiple conditions. For example, antidepressants are commonly used to treat both mental health conditions and chronic pain (NHS, 2015). Second, some conditions may be missed entirely due to gaps in ATC code mappings or the level of aggregation in available data. For instance, CBS only reports the first four characters of ATC codes. A drug like G03XC01 (used as a proxy for osteoporosis) would appear as G03X, a broader category not specific to osteoporosis. Such limitations should be carefully considered when interpreting findings based on medication data.

Another notable finding is that the different index construction methods (probit, PCA, frailty, chronic disease index) produced similar results when based on the same data source, aligning with Kapteyn and Meijer (2014). This pattern also held across different data sources. However, the chronic disease index tended to underestimate associations with labor market outcomes, especially disability. This likely reflects its focus on mortality risk, which may be less relevant for the working-age population. By prioritizing mortality in older adults, the chronic disease index may fail to capture health conditions related to work disability that are highly relevant earlier in the life course.

From a policy perspective, our findings have important implications for labor market, social security, and pension planning. Policies aimed at extending working lives should prioritize health interventions, particularly for individuals with chronic conditions or functional limitations. Early identification and targeted support for these individuals may help reduce transitions into unemployment or disability. Our findings are especially relevant for actuarial models, which forecast disability claims and pension liabilities based on assumptions about morbidity, mortality, and labor market behavior.

Narrow health measures, such as those based solely on administrative medication data, may underestimate risks in certain subpopulations. Integrating more comprehensive health indices can improve the accuracy of actuarial models, particularly for occupations with high physical or mental demands, thereby improving the accuracy of reserve calculations, premium setting, and risk classification. This could also inform more effective policies around early retirement, job transitions, or vocational rehabilitation. Still, in contexts where survey data are unavailable, administrative data remain a practical and scalable alternative that captures the general direction of effects.

In conclusion, our findings show that while results from administrative medication data only are broadly aligned with those from survey-based measures, comprehensive health assessments provide a more nuanced understanding of labor market risks and age and gender related inequalities. By incorporating diverse health indicators and considering demographic differences, policymakers can develop more targeted and equitable strategies to promote sustained labor market participation and improve retirement outcomes.

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Supplementary Material

Supplementary Table A1: Overview of the health measures used in key studies that assess the association between (different measures of) health and labor market outcomes

Author (year)	Data sources	Years of data collection	Population	Analysis	Labor market outcome	Measure of health used	Types of indicators included
Linde-boom and Kerkhofs (2009)	University Center for Research on Retirement and Aging (CERRA) panel survey	Waves 1993-1995	Households of which the head was between 43 and 63 years of age in the first wave	(joint) Multi-nomial logit model	Employed, Unemployed, Disabled, Early retirement scheme	Self-rated work related health: Index constructed from various objective measures (Bound, 1991)	Hopkins Symptoms Checklist Score (HSCS) and demographics, socioeconomics and work history.
Kapteyn and Meijer (2014)	Survey of Health, Ageing and Retirement in Europe (SHARE):	Waves 1 (2004-2005) and 2 (2006-2007)	Adults 50 years or older and working during wave 1	Linear probability models	Retiring versus working	Subjective: Self-rated health	General health
					Becoming disabled versus working	Subjective and objective: Index constructed with various measures (Meijer et al., 2011)	General health; mobility, fine motor, and functional limitations; difficulties with activities of daily living (ADL); difficulties with instrumental activities of daily living (IADL); biomarkers; demographics and socioeconomics
						Subjective and objective: Index constructed with various measures (Poterba et al., 2011)	General health; mobility, fine motor, and functional limitations; ADL; self-reported physical health (heart problems, hyperten-sion, stroke, diabetes, chronic lung disease, arthritis, cancer, and pain in back, knees, hips, or joint); self-reported mental health (psychological problems); health care utilization; biomarkers; demographics and socioeconomics
						Objective: Index constructed from various objective measures (Jurges, 2007)	Self-reported physical health (heart prob-lems; hypertension; high blood cholesterol; stroke; diabetes; chronic lung disease; asthma; arthritis; osteoporosis; cancer; stomach or duodenal ulcer, peptic ulcer; cataracts; hip fracture or femoral fracture; other conditions); self-reported cognitive health (Parkinson's); self-reported mental health (psychological problems); biomarkers

Author (year)	Data sources	Years of data collection	Population	Analysis	Labor market outcome	Measure of health used	Types of indicators included
Blundell et al. (2021)	Health and Retirement Study (HRS) English Longitudinal Study of Ageing (ELSA)	HRS: waves 3-11 (1996-2012) ELSA: waves 1-6 (2002-2012)	Adults aged 50-70 years	Linear probability model	Employment (binary indicator)	Subjective health: three separate items and an index based on the three items	General health (self-rated health); health limits activities; health limits work
						Subjective health and cognition	Same subjective measures mentioned above, plus four cognitive measures (2 from IADL + 2 recall items)
						Objective measures: various separate measures	Self-reported physical health (cancer, diabetes, sight, hearing, blood pressure, arthritis, lung disease, stroke, heart attack) and self-reported mental health (psychiatric problems)
						Subjective measures adjusted for reporting bias using objective health measures	Same indicators mentioned above
Hosseini et al. (2022)	Panel Study of Income Dynamics (PSID)	2002-2016 (8 waves)	Adults aged 25-64 years	Dynamic panel data approach to estimate the marginal effects of changes in frailty on earnings, hours worked, and wages	Earnings, hours worked, and wages	Objective: Frailty index (Mitnitski et al., 2001)	ADL; IADL; mental and cognitive impairments; medical diagnosis and measurements (e.g. hypertension, diabetes, and obesity).
García-Gómez et al. (2010)	British Household Panel Survey (BHPS)	Waves 1-12 (1991-2002)	Individuals aged 16 years or older	Discrete time duration models	Employment entries and exits (modelled separately using 1 sample only of people working during wave 1 and another sample only of people not working during wave 1)	Subjective and objective: Index constructed by predicting self-rated health using various objective measures of health (Bound, 1991)	General health; self-reported physical health (problems with arms, legs or hands, sight, hearing, skin conditions or allergies, chest/breathing, heart/blood pressure, stomach or digestion, diabetes, epilepsy or migraine, or other physical health issues); self-reported mental health (anxiety or depression, alcohol or drugs, or other mental health issues)
						Objective: ADL	ADL (1 item "Does your health in any way limit your daily activities compared to most people of your age?")
						Objective: Index created using the General Health Questionnaire (Goldberg, 1972)	Mental health (12 items: concentration, sleep loss due to worry, perception of role, capability in decision making, whether constantly under strain, perception of problems in overcoming difficulties, enjoyment of day-to-day activities, ability to face problems, loss of confidence, self-worth, general happiness, and whether suffering depression or unhappiness)

Author (year)	Data sources	Years of data collection	Population	Analysis	Labor market outcome	Measure of health used	Types of indicators included
Danesh et al. (2024)	Statistics Netherlands (CBS) data	2003-2021 (medication data only from 2006)	Entire Dutch population	Linear regression	5-year mortality	Objective: index created by first identifying chronic diseases with medication data, then weighting these conditions based on their ability to predict 5-year mortality in 70-year-olds	Physical health (acid-related disorders, bone diseases, cancer, heart disease, diabetes, epilepsy, glaucoma, gout, HIV, hyperlipidaemia, intestinal inflammatory diseases, iron deficiency anaemia, migraines, pain, respiratory illness, rheumatological conditions, thyroid disorders, and tuberculosis) Cognitive health (dementia and Parkinson's) Mental health (psychological disorders and psychoses)
Borella et al. (2024)	HRS	Waves 3-14 (1996-2018)	Individuals aged 52 and older	Linear and logistic regression	Future mortality and frailty(after period of clustering)	Objective: The longitudinal data on the frailty index (Mitnitski et al., 2001) was clustered to identify patterns over time (n = 5)	ADLs; IADLs; other functional limitations; self-reported physical health (high blood pressure, diabetes, cancer, lung disease, heart condition, stroke, BMI > 30, and arthritis); self-reported mental health (psychological or psychiatric problems); health care utilization; ever smoked
van Ooijen et al. (2020)	Longitudinal Internet Study in the Social Sciences (LISS) linked to CBS data	Participated at least once in LISS between 2008-2011	Individuals aged 16 and older	Transition probabilities derived from the health measurement model	Evolution of health (transitions between health status)	Objective: index constructed using various objective measures of health taken from medication, hospital discharge, and long-term care use registers	Physical health (peptic ulcer, diabetes, cardiovascular disease, hypertension, high blood cholesterol, pain, rheumatism, chronic lung disease, and cancer), mental health (anxiety and depression), and health care utilization (home care, hospital stay, and length of stay)
van Rijn et al. (2014)	Systematic review	-	Non-patient populations	-	Exit from paid employment (receiving disability pension, unemployment or early retirement)	Subjective: Self-rated health Objective: Mental health Objective: Chronic conditions	General health Mental health Physical conditions generally, and specific focus on musculoskeletal disorders and respiratory illness
Schuring et al. (2013)	Permanent Survey on Living Conditions (POLS) combined with data from Sociaal Statistisch Bestand (SSB) of CBS	1999-2002	Individuals aged between 18–64 years who were in paid employment for >12 hours per week in the Netherlands at the time of the health survey	Cox proportional hazards analysis	Labor force exit (modeled separately for unemployment, early retirement, disability pension, and economic inactivity) and return to work (becoming employed for >3 months after a period of non-employment of >1 month)	Subjective: Self-rated health	General health

Author (year)	Data sources	Years of data collection	Population	Analysis	Labor market outcome	Measure of health used	Types of indicators included
Robroek et al. (2015)	POLS linked with data from SSB	1999-2008	Selection included individuals aged between 18–64 years who were in paid employment for at least 12 hours per week in the Netherlands at the time of the health survey and who filled out questions on health, lifestyle, and work	Competing risks analysis	Exit from paid employment (disability benefits, unemployment, early retirement, and economically inactive)	Subjective: Self-rated health	General health
Leijten et al. (2015)	Study on Transitions in Employment, Ability and Motivation (STREAM)	2010–2013	Employees aged 45-64 years	Competing risks analysis	Exit from paid employment (disability benefits, unemployment, or early retirement)	Objective: various separate measures, which were also combined into any disease that is present	Self-reported physical health (severe headache or migraine, diabetes mellitus, musculoskeletal, cardiovascular disease, respiratory, and digestive) and self-reported mental health (psychological health problems)
Oude Hengel et al. (2019)	STREAM combined with CBS data	2010-2017	Employees aged 45-64 years	Competing risks analysis	Exit from paid employment (disability benefits, unemployment, early retirement, or economically inactive)	Objective: various separate measures, which were also combined into no disease, one disease, or two or more diseases	Self-reported physical health (diabetes mellitus, musculoskeletal, cardiovascular disease, respiratory, and digestive) and self-reported mental health (psychological health problems)
Gurgel do Amaral et al. (2022)	LifeLines combined with CBS data	2006-2013 (LifeLines baseline) + 11 years follow-up from CBS	Employees aged 18-64 years	Cox-proportional hazards analysis	Exit from paid employment (first occurrence of either disability benefits, unemployment, early retirement, or economically inactive)	Objective: multimorbidity (defined using clinical measures, self-reported conditions, and medication use)	Physical health (diabetes mellitus, cardiovascular disease, chronic obstructive pulmonary disease, rheumatoid arthritis) and mental health (depression). All conditions measured using a combination of clinical measures, self-reports and medication use data.

Author (year)	Data sources	Years of data collection	Population	Analysis	Labor market outcome	Measure of health used	Types of indicators included
Oude Hengel et al. (2021)	CBS data		Individuals in paid employment who were born six months before (control group) and six months after (intervention group) January 1, 1950. Individuals were followed from age 60-65 years	Regression discontinuity design combined with restricted mean survival time analysis	Monthly employment status was defined based on the most important source of income and categorized into paid employment, disability benefits, unemployment benefits, early retirement benefits, and economically inactive.	Objective: chronic diseases (ordinal variable 0, 1, 2+ diseases defined with medication use data)	Physical health (cardiovascular, respiratory . and inflammatory diseases, and diabetes) and mental health (depression, anxiety and sleep disorders, and psychotic disorders)
Schram et al. (2022)	STREAM combined with CBS data	STREAM 2010/2015 + CBS data (2010-2018)	Employees aged 50-66 years (excluding self-employed individuals)	Multistate model	Working life expectancy (WLE) and working years lost (WYL) derived from time spent in paid employment, involuntary exit (disability benefits, unemployment), and voluntary exit (economic inactivity, early retirement)	Objective: Chronic disease present (binary indicator)	Self-reported physical health (diabetes mellitus, musculoskeletal, cardiovascular disease, respiratory, and digestive) and self-reported mental health (psychological health problems)
van Zon et al. (2020)	HRS	1992-2014	Participants aged 50–64 years at baseline who worked full time at their first measurement wave	Competing risks analysis	Exit from paid employment (unemployment, disability, economic inactivity, and full retirement)	Objective: self-reported chronic disease (no disease, one disease, or multimorbidity)	Self-reported physical health (hypertension, diabetes, cancer, chronic lung disease, cardiovascular disease, cerebrovascular disease, or arthritis) and self-reported mental health (emotional, nervous, or psychiatric problems)
Schram et al. (2019)	EU Statistics on Income and Living Conditions	2005-2014 (repeated cross-sectional data)	Individuals aged 30–59 years	Linear regression and Cox-proportional hazards analysis	Employed or outside paid employment (unemployed, economically inactive, retired, disabled, and other)	Objective: presence of chronic illness (binary indicator)	Unclear which domains are included, but the item is self-reported "Do you have any longstanding illness or health problem?"
van de Ven et al. (2023)	CBS data	2011-2020	Unemployed persons aged 18- 64 years	Restricted mean survival time analyses (RMSTs)	Entering paid employment with a permanent contract	Objective: six different chronic conditions assessed with medication data	Physical health (cardiovascular diseases, inflammatory conditions, diabetes, and respiratory illness) and mental health (common mental disorders and psychotic disorders)

Author (year)	Data sources	Years of data collection	Population	Analysis	Labor market outcome	Measure of health used	Types of indicators included
Reeuwijk et al. (2017)	SHARE	2004-2012 (waves 1-4)	Employed individuals aged 50 or older (excluding those above retirement age)	Competing risks analysis	Exit from paid employment (unemployment, disability, economic inactivity, and early retirement)	Subjective: Self-rated health	General health
van den Berg et al. (2010)	SHARE	2004-2006 (waves 1-2)	Employed individuals aged 50-63 years	Multinomial logistic regression	Employment status (employed, retired, unemployed and disabled)	Subjective: Self-rated health	General health
						Objective measures: chronic disease (binary indicator)	Self-reported physical health conditions (heart disease, stroke, diabetes, lung disease, asthma, arthritis or rheumatism, and osteoporosis)
						Objective: mobility problems	Self-reported functional limitations (limitations with mobility, arm or fine motor functions presence of at least 1 of 10 items)
						Objective: IADL	Self-reported functional limitations (presence of at least 1 of 13 items about IADL)
Sewdas et al. (2020)	Danish National Working Environment Survey combined with Danish register data	Survey data from 2008–2009 + 4 years of follow-up from register	Workers aged 56–64 years who participated in a voluntary early retirement scheme, with and without a chronic disease	Cox regression analyses	Timing of retirement	Subjective: Self-rated health	General health
						Objective: continuous depression variable measured using the Major Depression Inventory Scale (MDI)(Bech et al., 2001)	Mental health
Junna et al. (2022)	Finnish registry data	2009-2020	Finnish residents aged 30-60 with a period of unemployment between 2009-2018	Cox regression analyses	Finding any employment, stable employment (still employed at the end of the calendar year), or unstable employment (no longer employed at the end of the calendar year)	Objective: various indicators of health taken from hospitalizations and prescription registers	Physical health (cancer, diabetes, heart disease, and injuries), mental health (depression, anxiety, substance use, self-harm), and cognitive health

Author (year)	Data sources	Years of data collection	Population	Analysis	Labor market outcome	Measure of health used	Types of indicators included
Norrbäck et al. (2019)	Two samples: National Survey of Living Conditions (ULF/SILC) Stockholm Public Health Surveys (SPHS) Employment data from: Longitudinal Integration Database for Health Insurance and Labor Market Studies (LISA)	ULF/SILC: 1996-2011 SPHS: 2002-2006 LISA: 1997-2012	Samples from two separate populations including people of working age (ages 19–64) were included.	Cox regression analyses	Any unemployment (≥1 day) and long-term unemployment (≥90 days during two consecutive years)	Objective: self-reported measures of health	Physical health (overweight/obesity) and disability (mobility disability)

Supplementary Table A2: Overview of previous mapping of ATC codes to diseases

Disease	Available in LifeLines	Danesh et al. (2024)	Huber et al. (2013)	van Ooijen et al. (2020)	Lamers and van Vliet (2004)	Chini et al. (2011)	Vivas et al. (2011)	Pratt et al. (2018)	Lujic et al. (2017)	Jegou et al. (2018)	Halfon et al. (2013)
Digestive disorders											
Acid- related disorders	Stomach ulcer / could you indicate which of the following disorders you have (had)?	A02	A02		A02A; A02B		A02A; A02B				
Gastro-esophagal reflux disease	No							A02BA01– A02BX05			
Irritable bowel syndrome	Yes							A07EC01– A07EC04; A07EA01– A07EA02; A07EA06; L04AA33			
Intestinal (inflam-matory) diseases	LifeLines has some data on digestive diseases, but not sure which ones fall under this group:	A07E	A07EA; A07EC								
Crohn's and ulcerative colitis	Yes				A07EC (excluding A07EC01)	A07EA; A07EC	A07EC (excluding A07EC01)				A07EA; A07EC
Peptic ulcer	No, LifeLines has data on stomach ulcer but this is a different form of ulcer			A02B							
Mental health and substance use											
Alcohol dependency	Only during 3A							N07BB01- N07BB99			
Psycholog-ical disorders	LifeLines has several rele-vant items, but need to see which ones are considered psycholog-ical disorders	N06A	N06A			N05AA; N05AB; N05AC; N05AD; N05AF; N05AG; N05AH; N05AL; N05AN; N05AX; N05BA; N05AA; N06AB; N06AX					N06A; N06C; N05AN except N06AX01 and N06AX02" Mood disorders

Disease	Available in LifeLines	Danesh et al. (2024)	Huber et al. (2013)	van Ooijen et al. (2020)	Lamers and van Vliet (2004)	Chini et al. (2011)	Vivas et al. (2011)	Pratt et al. (2018)	Lujic et al. (2017)	Jegou et al. (2018)	Halfon et al. (2013)
Anxiety	Yes			N05B	N05B		N05B	N05BA01–N05BA12; N05BE01			
Depression	Yes			N06A	N06AA; N06AB; N06AE; N06AF; N06AG; N06AX		N06AA; N06AB; N06AE; N06AF; N06AG; N06AX	N06AA01–N06AG02; N06AX03–N06AX11; N06AX13–N06AX18; N06AX21–N06AX26	N06AB03; N06AB04; N06AB05; N06AB06; N06AB08; N06AB10; N06AF03; N06AF04; N06AG02; N06AX03; N06AX11; N06AX16; N06AX18; N06AX21		
Psychoses	Only measured during wave 3A. Schizo-phrenia, which can lead to psychoses, was assessed during 1A	N05A	N05A		N05A		N05A	N05AN01: Bipolar disorder N05AA01–N05AB02; N05AB06–N05AL07; N05AX07–N05AX13: psychotic illness			
Musculoskeletal											
Bone diseases (osteoporosis)	Yes	M05	M05	M05; G03X		H05AA02; H05AA03; H05BA; M05BA; M05BB; G03XC01; M05BX; A12AA; A12AX		M05BA01–M05BB05; M05BX03; M05BX04; G03XC01; H05AA02			H05; M05BA; M05BB
Gout	No	M04	M04	M04	M04A		M04A	M04AA01–M04AC01			
Rheuma-tological conditions	Several musculo-skeletal conditions recorded, but need to see which fall under this category.	L04A	M01; M02; L04AA; L04AB	M01	H02; M01CB; M01CC01; P01BA02; L01BA01; A07EC01	M01AB; M01AC; M01AE; M01AG; M01AH; M01AX; M01CB; M01CC; P01BA	H02; M01CB; M01CC01; P01BA02; L01BA01; A07EC01				
Rheumatoid arthritis											
Urological conditions											
Incontinence	Yes							G04BD01–G04BD99			
Benign prostatic hyperplasia	No							G04CA01–G04CA99; G04CB01; G04CB02*			G04BD; G04C

Disease	Available in LifeLines	Danesh et al. (2024)	Huber et al. (2013)	van Ooijen et al. (2020)	Lamers and van Vliet (2004)	Chini et al. (2011)	Vivas et al. (2011)	Pratt et al. (2018)	Lujic et al. (2017)	Jegou et al. (2018)	Halfon et al. (2013)
Endocrinological disorders											
Diabetes	Yes	A10A; A10B; A10X	A10A; A10B; A10X	A10	A10A; A10B	A10AB; A10AC; A10AD; A10AE; A10BA; A10BB; A10BD; A10BG; A10BX	A10A; A10B	A10AA01–A10BX99	A10AB01; A10AB02; A10AB04; A10AB05; A10AB06; A10AC01; A10AC02; A10AD; A10AD01; A10AD04; A10AE04; A10AE05; A10B; A10BA02; A10BB01; A10BB07; A10BB09; A10BB12; A10BD02; A10BD03; A10BF01; A10BG02; A10BG03; A10BH01	A10	A10
Thyroid disorders	No	H03	H03		H03A; H03B	H03AA; H03BB; H03BC	H03A; H03B	H03BA02; H03BB01-Hyperthy-roidism H03AA01–H03AA02-Hypothy-roidism			H03
Liver diseases											
Chronic hepatitis	Yes					L03AB					
Cirrhosis	Yes					B05AA; B02BA					
Liver failure	No							A06AD11; A07AA11			
Respiratory diseases											
Respiratory disease	Yes, COPD and asthma	R03	R03	R03; R05C	R03	R03AC; R03AK; R03BA; R03BB; R03BC; R03CC; R03DA; R03DC	R03	R03AC02–R03DC03; R03DX05	R03AC02; R03AC03; R03AC12; R03AC13; R03AK06; R03BA01; R03BA02; R03BA05; R03BB01; R03BC01; R03BC03; R03CC02; R03CC03; R03DA04; R03DC03: Asthma	R03	R03

Disease	Available in LifeLines	Danesh et al. (2024)	Huber et al. (2013)	van Ooijen et al. (2020)	Lamers and van Vliet (2004)	Chini et al. (2011)	Vivas et al. (2011)	Pratt et al. (2018)	Lujic et al. (2017)	Jegou et al. (2018)	Halfon et al. (2013)
Tuberculosis	No	J04A	J04A		J04A	J04AB; J04AC; J04AK; J04AM	J04A	J04AC01–J04AC51; J04AM01–J04AM99			
COPD											
Cystic fibrosis	No				A09AA02		A09AA02				
Neurological diseases											
Dementia	Yes, but not in our data	N06D	N06D					N06DA02–N06DA04; N06DX01			
Epilepsy	Yes	N03	N03			N03AA; N03AB; N03AD; N03AE; N03AF; N03AG; N03AX	N03A (excluding N03Ae01)	N03AA01–N03AX99			
Alzheimer's	Yes, but only in very small sample					N06DA; N06DX		J05AF08; J05AF10; J05AF11 – Hepatitis B J05AB54; L03AB10; L03AB11; L03AB60; L03AB61; J05AE14; J05AE11–J05AE12; J05AX14; J05AX15; J05AX65; J05AB04-Hepatitis C			N06D not N06DX02
Parkinson's disease	Yes	N04; N05B; N05C	N04; N05B; N05C		N04B	N04AA; N04AB; N04BA; N04BC; N04BX	N04B	N04AA01–N04BX02	N04AA01; N04AA02; N04AC01; N04BA02; N04BA03; N04BB01; N04BC01; N04BC02; N04BC05; N04BC06; N04BD01; N04BX02		
Migraines	Yes	N02C	N02C			N02CA; N02CC; N02CX		N02CA01–N02CX01			

Cardiovascular disease

Disease	Available in LifeLines	Danesh et al. (2024)	Huber et al. (2013)	van Ooijen et al. (2020)	Lamers and van Vliet (2004)	Chini et al. (2011)	Vivas et al. (2011)	Pratt et al. (2018)	Lujic et al. (2017)	Jegou et al. (2018)	Halfon et al. (2013)
Hyperlipid-emia	Yes	C10	C10	C10	C10A		C10A	A10BH03‡; C10AA01–C10BX09			C10
Hypertension	Yes			C02; C03A; C03B; C03E; C07; C08; C09	C02; C03A; C03EA01; C07; C08; C09A; C09B		C02; C03A; C03EA01; C07; C08; C09A; C09B	C03AA01–C03BA11; C03DB01; C03DB99; C03EA01; C09BA02–C09BA09; C09DA02–C09DA08; C02AB01–C02AC05; C02DB02–C02DB99 (C03CA01–C03CCO1 or C09CA01–C09CX99) C02KX01–C02KX05; PBS item code 9547L; 9605M – pulmonary hypertension	C02AB01; C02AB02; C02AC01; C02AC05; C02DB02; C02DC01; C02KX01; C02KX02; C02KX03; C03AA03; C03BA04; C03BA11; C03DA01; C03DA04; C03DB01; C03EA01; C09BA02; C09BA04; C09BA06; C09BA09; C09BB02; C09BB05; C09BB10; C09DA02; C09DA04; C09DA06; C09DA07; C09DA08		C02;C03 except C03C; C04AB; C07; C08; C09
Cardiovas-cular disease in general		B01A; C01; C04A; C02; C07; C08; C09 (includes hyper-tension)	B01AA; B01AC; C01; C04A; C02; C07; C08; C09 (includes hyper-tension)			C01AA; C01BA; C01BB; C01BC; C01BD; C01DA; C02AB; C02AC; C02CA; C03AA; C03BA; C03CA; C03CX; C03DA; C03EA; C03EB; C07AA; C07AB;		B01AA03–B01AB06; B01AE07; B01AF01; B01AF02; B01AX05 – Anticoagu-lants B01AC04–B01AC30 – Antiplatelets		C01; C02; C03; C04; C07; C08; C09; B01 (excl. B01AB) (includes hyperten-sion)	

Disease	Available in LifeLines	Danesh et al. (2024)	Huber et al. (2013)	van Ooijen et al. (2020)	Lamers and van Vliet (2004)	Chini et al. (2011)	Vivas et al. (2011)	Pratt et al. (2018)	Lujic et al. (2017)	Jegou et al. (2018)	Halfon et al. (2013)
Coronary and peripheral vascular disease	Yes			B01 (coronary disease)	B01A; C04AD03		B01A; C04AD03	C07AA01– C07AA06; C07AA08– C07AB01; C07AB02— if PBS item code is not 8732N; 8733P; 8734Q; 8735R; C07AG01; C08CA01– C08DB01; C09DB01– C09DB04; C09DX01; C09BB02– C09BB10; C07AB03; C09DX03; C10BX03Å˜ coronary artery disease C01DA02– C01DA14; C01DX16; C08EX02- Ischaemic heart disease: angina			
Cardiac disease	Yes			C01; C03C; C03D – cardiac disease	C01; C03C; C03EB01 – Cardiac disease/ ASCVD/ CHF		C01; C03C; C03EB01 – Cardiac disease/ ASCVD/ CHF	C03DA02– C03DA99; C07AB02— if PBS item code is 8732N; 8733P; 8734Q; 8735R; C07AB07; C07AG02; C07AB12; C03DA04 (C03CA01– C03CC01 and C09AA01– C09AX99; C09CA01– C09CX99)† - Congestive heart failure C01AA05; C01BA01– C01BD01; C07AA07- Arrhythmia	C01DA02; C01DA08; C01DA14; C07AA02; C07AA03; C07AA05; C07AB02; C07AB03; C07AB07; C07AB12; C07AG01; C07AG02; C08CA01; C08CA02; C08CA05; C08CA13; C08DA01; C08DB01_ heart disease		C01CA04; C01CA07; C01CE; C01CX; C03C: heart failure C01A; C01B; C01CA02; C01EB10: conduction disorders and cardiac arrhythmia

Disease	Available in LifeLines	Danesh et al. (2024)	Huber et al. (2013)	van Ooijen et al. (2020)	Lamers and van Vliet (2004)	Chini et al. (2011)	Vivas et al. (2011)	Pratt et al. (2018)	Lujic et al. (2017)	Jegou et al. (2018)	Halfon et al. (2013)
Stroke	Yes								B01AA03; B01AB01; B01AB04; B01AC04; B01AC05; B01AC06; B01AC07; B01AC30		
Other diseases											
Cancer	Yes	L01	L01	L01. L02B; L03A	L01 (excluding L01BA01); L03AA02/ 03/ 10; A04AA	A04AA; H01CB; L01AA; L01AB; L01AX; L01BA; L01BB; L01BC; L01DB; L01XB; L01XX; L02AB; L02AE; L02BA; L02BB; L02BG; L03AA; L03AX; R05DA; R05DB27	L01 (excluding L01BA01); L03AA02/ 03/ 10; A04AA	L01AA01– L01XX41	L01AA01; L01AA02; L01AA03; L01AA06; L01AB01; L01AX03; L01BA01; L01BA03; L01BA04; L01BB02; L01BB03; L01BB04; L01BC01; L01BC02; L01BC05; L01BC06; L01CA01; L01CA02; L01CA04; L01CB01; L01CD01; L01CD02; L01DB01; L01DB07; L01DC01; L01XA01; L01XA02; L01XC02; L01XC03; L01XE01; L01XE06; L01XE07; L01XX05; L01XX19; L01XX32		
Glaucoma	Not part of general assessment	S01E	S01E		S01E	S01EA; S01EB; S01EC; S01ED; S01EE; S01EX	S01E	S01EA01– S01EB03; S01EC03– S01EX99			S01E
HIV	No	J05A	J05AE; J05AG. J05AR		J05AB06; J05AD01; J05AE; J05AF	J05AB; J05AD; J05AF		J05AE01– J05AE10; J05AF12– J05AG05; J05AR01– J05AR99; J05AX07– J05AX09; J05AX12; J05AF01– J05AF07; J05AF09			J05AE; J05AF; J05AG; J05AR; J05AX07– J05AX09 except J05AF08

Disease	Available in LifeLines	Danesh et al. (2024)	Huber et al. (2013)	van Ooijen et al. (2020)	Lamers and van Vliet (2004)	Chini et al. (2011)	Vivas et al. (2011)	Pratt et al. (2018)	Lujic et al. (2017)	Jegou et al. (2018)	Halfon et al. (2013)
Pain	No direct mapping. Closest is probably "How much bodily pain have you experienced during the past 4 weeks?" (Likert scale)	N02A; N02B	N02A; N02B	N02A; N02C	M01A – Pain and inflammation N02A		M01A – Pain and inflammation N02A	M01AB01–M01AH06 – Inflammation/pain N02AA01–N02AX02; N02AX06; N02AX52; N02BE51			
Transplantations	Yes, specifically kidney/heart transplant				L04AA01/ 5/ 06; L04AX01		L04AA01/ 5/ 06; L04AX01	L04AA06; L04AA10; L04AA18; L04AD01; L04AD02			L04AA02-10; L04AX01; L04AC01; L04AC02; L04AD01; L04AD02
Allergies	Yes							R01AC01–R01AD60; R06AD02–R06AX27; R06AB04			
Steroid-responsive disease								H02AB01–H02AB10			
Renal disease	Various renal diseases, not sure which ones would be treated with these medications:				B03XA01; V03AE01	V03AE; B03XA	B03XA01; V03AE01	B03XA01–B03XA03; A11CC01–A11CC04; V03AE02; V03AE03; V03AE05		A11CC vitamin D and analogues B03XA other anti-anemic preparations V03AE drug for treatment of hyperkalemia and hyperphosphatemia	
Anemia	Yes, but not in our data	B03A	B03AA; B03AB; B03AC								
Psoriasis	Yes					D05AX; D05BB		D05AA01–D05AA99; D05BB01 D05BB02; D05AX02; D05AC01–D05AC51; D05AX52			

Supplementary Table A3: Overview of chronic diseases considered for inclusion in this study, based on list by Ho et al. (2021)

Core conditions with high disability-adjusted life-years or high years of life lost	ATC codes from previous studies	Available in LifeLines	Decision to include in the study
1. Cancer	L01*	Yes	No, due to most cases not being captured by medication data recorded in CBS
2. Coronary heart disease 3. Stroke 4. Heart failure	Cardiovascular disease: B01A; C01; C04A; C07; C08; C09	Several items about cardiovascular disease including heart attack, stroke, aortic aneurysm, balloon angioplasty, heart failure, and atrial fibrillation	Yes, as a single item called cardiovascular disease
5. Diabetes	A10	Yes	Yes
6. Dementia	N06D	Yes, but not available in our dataset	No, due to missing self-reported data
7. Depression	N06A	Yes	Yes
8. Schizophrenia		Yes	No, due to lacking ATC mapping
9. Anxiety	N05B	Yes	Yes
10. Alcohol use disorders	N07BB	Not present during baseline assessment	No, ATC code is too specific, and self-reported data also not available
11. Drug use disorders	-	No, but data on drug use are available	No, missing ATC code and self-reported data
12. Chronic liver disease	Chronic hepatitis: L03AB Cirrhosis: B05AA; B02BA Liver failure: A06AD11; A07AA11	Hepatitis and cirrhosis are reported in LifeLines	No, ATC codes are too specific
13. Chronic renal disease	Renal disease: V03AE; B03XA	Several specific renal conditions assessed, such as narrowing of the renal artery, contracted kidney, kidney transplant, and hydronephrosis	No, ATC codes are too specific, and it is not clear how well they map to specific conditions that LifeLines assessed
14. COPD 15. Asthma	Respiratory diseases: R03	Yes, COPD and asthma are assessed	Yes, COPD and asthma are grouped together as respiratory diseases since the ATC code cannot distinguish the two
16. Vision impairment	Glaucoma: S01E	Items on general vision impairment and cataracts assessed during baseline, but glaucoma not assessed during baseline visit	No, missing LifeLines data on glaucoma
17. Musculoskeletal impairment due to injury	-	Various conditions assessed, but mostly not specifically caused by injury	No, ATC mapping and self-reported data not available
18. Osteoarthritis	Rheumatological conditions: M01; L04A	Yes, rheumatoid arthritis and osteoarthritis are assessed	Yes, included as more generic rheumatological conditions since ATC codes cannot make distinction
19. Chronic pain	N02A; N02B	Question about severity of pain in past 4 weeks	Yes, severity of pain variable dichotomized into chronic pain present ("very severe", "severe", "quite a bit") and not present (light", "very light", "none").
20. Gynaecological disorders	-	Limited items about surgeries, use of contraceptives, and pregnancy outcomes are available in full cohort. Some subsamples have additional questions about menopausal or other issues pertaining to reproductive health.	No, ATC mapping is not available
Additional considerations for work outcomes with available ATC mappings:			
21. Migraines	N02C	Yes	Yes
22. Parkinson's disease	N04	Yes	Yes
23. Epilepsy	N03	Yes	Yes
24. Osteoporosis	M05	Yes	Yes

*Medications identified using the L01 classification are used to treat cancer. However, our data are derived from medications dispensed by pharmacies. Also, in the Netherlands, most cancer treatments are not provided through this channel. According to Danesh et al. (2024), this method accounts for only around 5% of all cancer treatments. Therefore, given the nature of our data source, cancer cases are not comprehensively mapped. Nonetheless, this code may still be relevant when analyzing other sources of medication data.

Supplementary Table A4: Additional components of health included in the frailty index derived from Oude Voshaar et al. (2021)

Health deficits	Cut-off values and/or scoring rules
General health (n = 2)	
Self-rated health	Excellent = 0; very good = 0.25; good = 0.50; fair = 0.75; poor = 1
I am as healthy as anybody I know	Definitely true = 0; mostly true = 0.25; don't know = 0.5; mostly false = 0.75; definitively false = 1
Clinical data (n = 6)	
Body mass index (kg/m2)	18.5-25 = 0; 25.1-30 = 0.5; <18.5 = 1; >30 = 1
Waist circumference (cm)	<88 (men) and <102 (women) = 0; ≥88 (men) and ≥102 (women) = 1
Systolic blood pressure (mmHg)	90-140 = 0; 140-160 = 0.5; <90 = 0.5; >160 = 1
Glucose (mmol/L)	7.8 - 11.0 = 0; <7.8 = 1; >11.0 =1
HDL cholesterol (mmol/L)	≥1.55 = 0; <1.55 = 1
LDL cholesterol (mmol/L)	< 2.59 = 0; 2.59 – 3.34 = 0.5 ; >3.34 = 1
Functional limitations (n = 7)	
Limitation climbing one flight of stairs	Not limited = 0; yes, a little bit limited = 0.50; yes, severely limited = 1
Limitation in lifting/carrying	Not limited = 0; yes, a little bit limited = 0.50; yes, severely limited = 1
Limitation in moderate activities	Not limited = 0; yes, a little bit limited = 0.50; yes, severely limited = 1
Limitation in vigorous activities	Not limited = 0; yes, a little bit limited = 0.50; yes, severely limited = 1
Limitation in walking 100 meters	Not limited = 0; yes, a little bit limited = 0.50; yes, severely limited = 1
Limitation in walking >1 kilometer	Not limited = 0; yes, a little bit limited = 0.50; yes, severely limited = 1
Are you limited by your hearing in daily life?	No = 0; yes, a little bit = 0.50; yes, a lot = 1