



Mortality and risk of cardiovascular diseases by age at retirement in three Italian cohorts

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ABSTRACT

The relationship between age at retirement and subsequent physical health appears still contradictory in the literature, with more recent studies suggesting possible adverse health effects linked to employment at later ages. Aim of this study was to assess the long-term risk of overall mortality and incidence of cardiovascular diseases (CVDs) associated with age at retirement in three large Italian cohorts using both survey and administrative data.

The risk of mortality and CVDs associated with age at retirement, kept continuous, was assessed separately for gender using age-adjusted Cox models, further controlled for chronic morbidity, education, socioeconomic and previous working characteristics. In another analysis, age at retirement was examined treating it as a dichotomous variable, comparing, in a set of analyses with age at retirement from 52 to 65 years, the incidence of the health outcomes among subjects who retired after a certain age, compared to those who retired up to that age.

Higher age at retirement was associated with significantly higher mortality among men in the three cohorts, while among women the association was not significant, although in the same direction as for men. The risk of CVDs was also significantly associated with higher age at retirement in all the datasets among men, and in two of them among women. The set of the analyses on age at retirement dichotomized confirmed the results based on continuous age at retirement for both genders. Several robustness analyses, including IV Poisson instrumental variable, confirm the validity of results for men, whereas female results were less stable and robust.

Policy makers should be aware of the risk for public health of policies that increase retirement age.

1. Introduction

To balance the increase in life expectancy occurred in the last decades in most developed countries, many governments have increased the statutory pension age or have tightened the requisites for retirement [1]. However, there is concern that continue working at older ages may have health consequences, as aged workers may be more susceptible to exposure to adverse working conditions, involving exposure to physical and psychosocial factors in the workplace [2–5].

The relationship of age at retirement with subsequent mortality and physical health appears still contradictory in the literature. A recent meta-analysis concluded that the average effect of retirement on health is small, marginally beneficial and significant [6]. The study however

combines results based on physical, mental, objective, subjective and cognitive ability health outcomes; hence, there is the possibility that - if retirement has diverging effects depending on the outcome under scrutiny - these effects may be masked once pooled together. The most recent meta-analysis on mortality did not find a significant difference between early and on-time retirement but reported that the studies included showed significant heterogeneity [7]. Possible sources of such a variability may be the type of retirement, with involuntary retirement likely having more negative health effects than voluntary retirement [8, 9], as well as the type of job performed, given that workers employed in physically strenuous jobs may be relieved by retirement, whereas those employed in high-skilled white-collar occupations may miss stimulating work activities in a context of high decision latitude [10–13]. Another

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important source of inconsistency is related to the adjustment in the analyses for health problems before retirement, which may be confounders of the association between retirement and post-retirement health. In fact, pre-retirement health status may influence on one hand workers' decision to retire or not, and on the other hand the occurrence of health outcomes after retirement [14]. The importance of adjustment for health status has been shown by the meta-analysis by Sewdas et al. [7], in which no differences in mortality were found between on-time retirement and working beyond retirement age in studies with fully adjusted risk estimates, whereas a 50 % increase in mortality was computed in studies with insufficient adjustment [7]. Studies on the effect of retirement on the risk of cardiovascular disease (CVD) also show heterogeneous results that appear to be geographically clustered, with US studies finding no association and European studies finding a detrimental effect, apart from France [10] and Italy [15,16], where a reduced risk of CVD was found to be associated with retirement [17]. In Italy, another study found a null result, measuring however the CVD outcome on a short follow-up immediately after retirement [18]. Due to the endogeneity of the retirement choice, several studies have specifically investigated the association between age at retirement and subsequent physical health or mortality using quasi-experimental methods, although they also reported mixed findings [15,19–25].

This paper contributes to the ongoing debate about the potential unintended health consequences of reforms aimed at extending working lives. Our empirical analysis draws on three large datasets developed in Italy over the past two decades, a result of the collaborative efforts between the University of Turin and local and national institutions, aligning with the international consensus on the importance of studying the social determinants of health inequalities with reliable data. The three datasets combine census, survey, and social security data with health administrative registers, providing a comprehensive and unique picture of work and health biographies in Italy. We can therefore investigate the association between retirement age and the risk of mortality and cardiovascular diseases (CVDs), comparing three distinct and independent populations within Italy, using a consistent study design and relying on longitudinal, certified and reliable health outcome information.

We focus on retirements of the early 2000s, when statutory pension age was 65 years for men and 60 years for women. The age-range that we can consider however is much wider, since many workers used to retire earlier through seniority pensions, whose requisites in 2005 were 38 years of pension contribution, or 35 years of pension contribution plus 57 years of age, but even less stringent in 2000 (35 years of contribution and 55 years of age). Given that in Italy a substantial proportion of the subjects born in the 1940–50 s used to start working below 20 years of age, they reached the needed requisites during their fifties. The consequence of this was that in this generation about half women were already retired by age 55 and half men by age 60, with a bulk of subjects retiring exactly at these ages, suggesting that in our society at that time these were considered the normative retirement ages for men and women.

The objective of this study was to investigate whether individuals who retire at an earlier age exhibit differences in subsequent mortality and cardiovascular disease (CVD) incidence compared to those who retire later. The association between retirement age (treated as a continuous variable) and the risk of mortality and CVDs was assessed separately by gender using age-adjusted Cox models, which were further adjusted for chronic morbidity, education, socioeconomic status, and previous work characteristics. Although our primary analysis employed a longitudinal design, allowing us to track individuals over time and account for temporal relationships between retirement transition and health outcomes, we also controlled for a comprehensive set of baseline health variables to address potential concerns about reverse causality. To further mitigate concerns about endogeneity in the relationship between retirement age and health, we conducted several robustness checks, including an instrumental variable (IV) analysis on our largest

and most comprehensive cohort.

2. Material & methods

2.1. Data

The study used data from three large Italian cohorts that are part of the Italian mortality and morbidity surveillance system. One national cohort included participants in the National Health Survey (NHIS), while another national cohort was drawn from the administrative archives of the National Social Security Institute (WHIP-Health, Working Histories Italian Panel). The third cohort included all subjects resident in Turin from the censuses data of the TLS, the Turin Longitudinal Study. Individuals in the three cohorts were followed up for mortality and incidence of cardiovascular diseases by linking the records to the administrative archives of mortality and/or of hospital discharge records. The three datasets provide distinct perspectives and representativeness of the population. Notably, the WHIP administrative dataset is limited to formal private sector workers, whereas the NHIS survey and the TLS encompass a broader range of workers, including both formal and informal, and public and private sectors. Consequently, the NHIS and TLS offer a more comprehensive representation of the Italian labour force, albeit with smaller sample sizes. A more detailed description of the three studies is provided below.

The NHIS national cohort is based on a health survey representative of the Italian population, conducted approximately every 5 years by the National Institute of Statistics (ISTAT). The survey is characterized by a two-stage sampling design, with municipalities as primary sampling units and households as secondary units, and provides detailed information on health conditions, overweight and obesity, long-term chronic diseases, use of medications, disabilities, lifestyles and use of health services, as well as information on individual and household socioeconomic characteristics. The wave we analyse is the 2004–2005 NHIS, the only one with a specific question on the age of the retirement transition. The NHIS covered 50,474 families and 128,040 individuals, with a participation rate of 85.7 %. The NHIS data were linked by ISTAT to mortality and hospital discharge data through the individual tax code, which uniquely identifies each Italian citizen, to build the cohort, which has been named the Italian Longitudinal Study (ILS). Further details can be found in previous articles on this cohort [26,27] and in a published ISTAT report on the conduct of the follow-up [28].

The Italian Work History Panel (WHIP) is based on data from the Italian National Social Security Institute (INPS). It is a random sample of 7 % of private employees and self-employed persons insured with the INPS from 1985 to the present, linked to the hospital admissions of the National Archives from 2001 to 2014, thus forming the WHIP Health cohort. As part of its administrative tasks relating to the payment of pensions and benefits, the INPS itself records mortality data. It is the most complete and up-to-date source of statistical information for studying differences in mortality and hospitalisation between socioeconomic and occupational groups in Italy. It provides detailed information on working career, workers and firms characteristics, transition into retirement, together with information on all benefits and pensions paid to insured workers [29].

The Turin Longitudinal Study (TLS) urban cohort is an archival system that links data from the 1971, 1981, 1991 and 2001 censuses of the city of Turin to a wide range of health archives (mortality, hospitalization, drug prescriptions) through individual-level record-linkage procedures [30]. The 2001 census is the only one including information on the year of last job before retirement. Despite the limited local coverage, Turin is the fourth populous city in Italy, with almost 900,000 inhabitants and is the capital of the Piedmont region, which, with a GDP of 133 billion euros, contributes 7.7 % to the national GDP. Turin is historically an industrial city, known as the "Italian Capital of the Automobile", which in recent years has developed and acquired new production skills in strategic sectors linked to innovation and tourism.

Table 1
Descriptive results of the three cohorts.

	Italian Longitudinal Study (ILS)	Turin Longitudinal Study (TLS)	WHIP Health
Subjects (N)	3288	19,762	67,952
Women (%)	28	32	28
Age at baseline (mean, sd)	61.0 (4.3)	60.3 (3.8)	60.3 (3.9)
Age at retirement (mean, sd)	58.3 (4.0)	57.1 (3.6)	58.1 (3.8)
Education (%)			
University degree	8	11	Na
High school diploma	20	19	Na
Low secondary school	34	38	Na
Elementary or less	39	32	Na
Household composition (%)			
Couple with children	46	46	Na
Couple without children	34	32	Na
Single with children	5	6	Na
Single without children	11	15	Na
Cohabitation	4	1	Na
Occupational class			
Executives	3.8	5.04	3.03
Clerical workers	40.3	44.18	28.9
Blue collar workers	55.9	50.78	68.07
CMI (mean, sd)	4.75 (5.61)	0.44 (0.92)	0.36 (0.94)
(p5–95)	(0–25)	(0–2)	(0–2)
No. of new CVD (incident)	451	1876	6349
CVD (per 1000 person-years)	15.9	11.86	12.06
No. of Deaths	337	1553	4706
Mortality (per 1000 person-years)	11.1	9.41	10.23

Note: final study population, after selection rules outlined in paragraph §2.2. CMI, Chronic Morbidity Index.

2.2. Sample selection

To increase comparability and consistency between the results of the three studies, we have tried to use the same study design and sample selection rules in the three datasets as much as possible (see Appendix Table A1 for a synthesis). In all cohorts, the study population was restricted to subjects who worked as employees and retired between 50 and 65 years of age, no more than five years before baseline. Baseline year was the 2004–2005 for ILS and WHIP and the census of 2001 for TLS. Hence, individuals were selected if they retired in 2000–2005 for both ILS and WHIP and 1997–2001 for TLS. In TLS, information on the employment status as an employee was drawn from the closest previous census, i.e. the Turin 1991 census, restricting this way the analyses to those who were already resident at that occasion. In the ILS cohort it was based on self-reported information regarding the last job before retirement as reported in the 2004–2005 NHIS survey. Finally, in the WHIP-Health cohort, although we could have selected subjects who were predominantly employed in 2004–2005, as in the ILS study, we decided to make the most of the richness of the WHIP data and retrieve information on work status and main occupation using all data from the ten years prior to retirement transition.¹

After applying these selection rules, there were 3,283 participants in the ILS cohort, 19,766 in the TLS cohort, and 67,952 in the WHIP-Health cohort (Table 1). Subjects in the TLS cohort were followed for health outcome ascertainment from the beginning of 2002 until the end of 2010, those in the ILS cohort from the date of the baseline interview (2004–2005) until the end of 2014, and those in the WHIP-Health from the beginning of 2006 to the end of 2014 (Appendix Table A1).

2.3. Measures

2.3.1. Retirement age

Retirement age for the WHIP-Health cohort was assessed by the date

¹ In an earlier version of the manuscript, we adopted a more rigorous replication of the ILS design by adopting the exact time frame for identifying employment status in the WHIP data, and the results were very similar for both men and women (not shown here, but available on request).

of receipt of a state old-age or seniority pension, whereas for the other two cohorts, retirement age was self-reported and collected at baseline through questions on current employment status and, for retired persons, year of retirement.

2.3.2. Health outcomes

Two health outcomes were examined: all-cause mortality and incidence of cardiovascular disease, i.e. the rate of occurrence of new CVD cases. These outcomes are based on administrative records from local and national health authorities and therefore have high reliability and robustness to the typical problems of subjective measures, such as recall or social desirability bias. Cardiovascular disease incidence was constructed by death or hospitalisation for coronary heart disease or stroke, identified as ICD-9 codes 410–414 or ICD-10 codes I20-I25 (coronary heart disease) and ICD-9 codes 430–438 or ICD-10 codes I60-I69 (stroke) in SLT and SLI. In WHIP, data on mortality by cause of death is not available, hence the CVD outcome comprises only hospitalization for coronary heart disease or stroke, identified using the same ICD-9 codes, i.e. 410–414 (coronary heart disease) and 430–438 (stroke). Prevalent CVD cases, identified through self-report in ILS and through previous hospital admissions for CVD in TLS and in WHIP Health, were excluded from the analyses on CVD.

All-cause mortality was retrieved from official deaths registers linked to SLI and SLT data. In WHIP-Health, information on mortality is recovered by the archives on pensions, as for every pension termination due to death of the recipient, the information is promptly recorded by the INPS archives, given the need to stop paying for that pension. The mortality information available in WHIP has been already used and validated in previous studies, showing high reliability [31,32].

2.3.3. Covariates

Information on sociodemographic characteristics (age, gender, etc.) was collected at baseline via interviews (for ILS) or questionnaires (for TLS), or administrative data (for WHIP-Health).

From both ILS and TLS, we derive variables on highest educational attainment, family composition and characteristics of current and previous employment status. In addition, ILS, being a survey designed to monitor health and health care use in Italy, also provides detailed information on health conditions, long-term chronic diseases, medication

use, disabilities, lifestyle and use of health services. In contrast, the WHIP, being an administrative dataset derived from social security records, has only basic socio-demographic information (no information on family, education or health behaviour), but is rich in information on work history, benefit receipt and certified information on disability and hospitalisation. These are all variables that are used as covariates in the main or extended analyses to increase the level of adjustment.

In addition, to adjust for baseline health status, we construct a measure of chronic comorbidity in all three cohorts. In ILS, a chronic morbidity index (CMI) was constructed, following d'Errico et al. [33], using the survey information on physicians' self-reported diagnoses of 22 chronic conditions (see Appendix Table A2, panel A). The index is constructed as a weighted sum of each condition where weights are determined by their influence (Odd Ratio) on self-perceived poor or very poor health. More details and previous validation of the index are described in d'Errico et al. [33].

In the Turin Longitudinal Study and WHIP, the CMI was constructed as Charlson Index [34], following adaptation proposed by of Quan et al. [35] and already validated with Piedmont register data by Silan et al. [36]. In TLS it is based on the combination of hospitalizations and prescription of drugs for 14 chronic pathologies that occurred in the period 1997–2001. For WHIP-Health, due to the lack of information on drugs, the index was constructed only from hospitalizations for the same 14 chronic pathologies during 2001–2005 (see Appendix Table A2, panel B). All indices increase with the number and severity of chronic conditions experienced by the person.

2.4. Main analysis

The incidence of mortality and cardiovascular diseases associated with age at retirement was assessed in all analyses using Cox proportional hazards models, excluding prevalent cases at baseline. The analysis was conducted in two steps: first, age at retirement was modelled as a continuous variable to estimate its association with health outcomes, as shown in Eq. (1):

$$H(t, X_i) = H_0(t) * \exp(\beta_1 \text{Retirement Age}_i + \beta_2 \text{Age}(t)_i + \beta_n W_i^n) \quad (1)$$

Where $H(t, X)$ is the hazard rate of CVD or mortality at time t , given the baseline hazard rate $H_0(t)$ and a vector X , which includes our key exposure variable, i.e. Retirement Age, time varying age, i.e. $\text{Age}(t)$, and a set of additional controls W_i^n that are specific for each study cohort. In ILS and TLS, the controls are: level of education (elementary or lower, middle school, diploma, university degree), type of household (couple with children, couple without children, single with children, single without children, other types), and chronic morbidity (CMI kept continuous) as recorded at baseline. In WHIP-Health, the covariates were constructed using information on the last 10 years of career as prevalent (weighted mode) occupational class (managerial, white-collar, blue-collar), logarithm of weekly wage (to normalise its distribution), economic activity (4 macroeconomic sectors). Moreover, we control for a binary variable for tagging those who ever received disability benefits and for a chronic morbidity index (continuous), consistently with the other two cohort studies.

Second, age at retirement was treated as a dichotomous variable ($I[\text{R.age} \geq a]$), and the incidence of the health outcomes was compared among subjects who retired after a certain age a (from 52 to 65) and those who retired at or before that age, as specified in Eq. (2):

$$H(t, X_i) = H_0(t) * \exp(\beta_1 I[\text{R.Age} \geq a]_i + \beta_2 \text{Age}(t)_i + \beta_n W_i^n) \quad (2)$$

For each value of a , we run a separate regression, using the corresponding dummy variable $I[\text{Retirement Age} \geq a]$ as main exposure variable. This would allow us to estimate the nonlinear effect of retiring at different ages on the hazard rate of mortality or CVD, while controlling for the same covariates W_i^n specified above. All analyses were both controlled or stratified by gender.

The Cox regression model has a key assumption. The assumption is related to proportional hazards. The proportional hazards assumption states that the hazard ratio is constant over time. The assumption of proportionality of the hazards in the Cox regression models was tested using the method of the scaled Schoenfeld residuals for the whole models (global test) and for each variable in the models. After exploratory analyses showing violations for several variables, we checked the robustness of our results replicating the main analysis by correcting for the variables that violate the proportional hazards assumptions of the Cox regression models by including them in the main model interacted with time (for continuous variables) and using them as stratum variables (for discrete variables). Correction was not made for discrete variables with more than two categories where only one category of the variable showed a violation (p -value < 0.05) and the global test did not (p -value > 0.05). We did run sensitivity analyses through the baseline main models to improve comparability of the analyses across the three cohorts, given that the variables violating the proportionality assumptions were different in the different cohorts, as well as to avoid that the interaction terms with time included in the corrected analyses could increase instability of the models.

2.5. Sensitivity analyses

2.5.1. Instrumental variable analysis

Endogeneity is a concern in our main analysis due to the lack of an experimental design and potential unobservable confounders. The risk of endogeneity primarily arises from the potential influence of poor health on retirement timing. Additionally, personal and family circumstances, such as the presence of dependent children in the household and caregiving obligations, may influence both retirement decisions and health outcomes. Working conditions, including the physical and psychosocial workload of a job, may also play a role. Previous studies have shown that these factors are associated with early retirement [37–38].

To address these concerns and ensure the robustness of our results to potential endogeneity issues, we conducted an instrumental variable (IV) analysis using changes in the statutory retirement age induced by the Italian pension reform as a source of exogenous variation in retirement age. Specifically, for the WHIP Health cohort, we repeated all the main analyses using an IV Poisson GMM regression, a model proposed by Windmeijer and Santos Silva [39] and described in Cameron and Trivedi [40] and Wooldridge [41]. This approach allows us to model the risk of mortality and CVD over time in an instrumental variable setting, while controlling for the duration of exposure.

The endogenous variable of interest, consistent with the main model, is age at retirement. To define our instrumental variables, we follow the approach of Fontana et al. [16], originally proposed by Angelini et al. [42] and Mazzonna and Peracchi [13], instrumenting retirement age with the number of years elapsed since eligibility for normal and early retirement. These instruments vary across individuals depending on their birth cohort and gender, reflecting changes in statutory pension eligibility ages over the study period. The control variables used are the same as those included in the main model.

The outcome variables in the regression are dichotomous and switch to 1 during the follow-up period in the year an individual experiences their first cardiovascular disease (CVD) event or dies. In this IV Poisson framework, the outcome is defined as the rate of incident CVD events (or mortality), with person-years used as the denominator to account for exposure time. Estimated coefficients are exponentiated and reported as Incidence Rate Ratios (IRR) [43]. All analyses are run separately for men and women.

To empirically estimate the IV Poisson regression, we first transformed the dataset into a person-year structure, treating only age and health outcomes as time-varying variables, while holding all other covariates constant at their baseline values, as specified in Eq. (3):

$$y_{it} = \exp(\beta_0 + \beta_1 \text{Retirement Age}_{it} + \beta_n W_{it}^n + \sigma_{it}^\beta) + \epsilon_{it} \quad (3)$$

Where Retirement Age_{it} is the endogenous variable, W_{it}^n represents the vector of n control variables with the same controls specified above for Eq. (1), and o_j^β is the offset variable (logarithm of person years); ϵ_{it} represents the additive unit-mean errors. Given the error function $u(y_{it}, Retirement\ Age_{it}, W_{it}, \beta_1, \beta_2)$ and the set of instrumental variables $DistN_i$ and $DistE_i$ (years elapsed since eligibility for normal and early retirement), the population-moment conditions for GMM estimation are:

$$E\{\tilde{z}_i u(y_{it}, DistR_{it}, W_{it}, \beta_1, \beta_2)\} = 0 \quad (4)$$

Where the vector \tilde{z}_i is partitioned as $(DistN_i, DistE_i, W_{it}^n)$.

As the model is over-identified—with one endogenous regressor (age at retirement) and two instruments (years elapsed since eligibility for early and normal retirement)—we are able to test, albeit imperfectly, the validity of the exogeneity assumption. In the context of IV-GMM, this assumption is typically assessed using the Sargan-Hansen J-test for overidentifying restrictions (Arellano, [44]). Additionally, we evaluate instrument relevance through the first-stage linear regression F-statistic from a two-stage least squares (TSLS) estimation, consistent with prior literature applying the IV-Poisson GMM approach (e.g.; [45–46,43,16]).

2.5.2. Other robustness analyses

Furthermore, additional sensitivity analyses were performed to evaluate the robustness of the results to other possible issues and residual confounding:

- An analysis with 5-year lag between year of retirement and start of follow-up, to reduce the possible effect of health selection into retirement on the association between age at retirement and the health outcomes; in such a way, we keep constant across individuals the time frame, increasing comparability across retirees of different cohorts and giving higher weight to mid- to long-term effects of retirement age, rather than to short-term ones (model 1, appendix tables A5 and A6).
- Analyses with different ways of controlling for age, to check for possible residual confounding under this dimension too (linear, quadratic, fixed effects) (model 2 and 3, appendix tables A5 and A6).
- An analysis with additional adjustment for more detailed demographics, health and working conditions for ILS and WHIP cohorts. In particular, we added controls for macro-area of residence (north-west, north-east, centre, south and islands), as well as for lifestyles (smoking, BMI, leisure time physical activity) and biological factors (hypertension, diabetes), limited to the ILS cohort, where this information was present, to reduce potential residual confounding by health, as these factors may have not had a relevant impact on health yet, due to the relatively young age of the study population (model 4, ILS, appendix tables A5 and A6).
- Within the WHIP cohort, we could in turn expand the adjustment for retrospective career histories, running an analysis with additional adjustment for years of work in the last 10 years before retirement, macro area of birth, and in relation to the last job before retirement: time schedule (part time vs full time) and firm size (log of employees). Moreover, we added amount of first pension benefit (in log, 2005 prices), years of contributions accrued during the entire career and an indicator variable identifying retirees who transited within 2 years from last job to retirement, to reduce potential residual confounding by socioeconomic position; in fact, especially in the generation investigated, subjects with a shorter pension contribution are more likely to have worked in the informal economy during their first years of employment, which is more typical or more disadvantaged social groups (model 4, WHIP, appendix tables A5 and A6).
- An analysis, limited to the ILS cohort, was conducted as this dataset uniquely provided information on the job code (Italian professional code based on CP 2001 classification) for the last job held before retirement. This analysis included an additional adjustment for an

index of occupational physical activity (OPA), based on a job-exposure matrix (JEM) constructed from 17 physical factors present in the Italian ONET database (www.onetcenter.org), which accounted for potential exposure to high physical workload. The adjustment for the OPA index was meant to reduce potential confounding by working conditions on the relationship between age at retirement and the outcomes examined, driven for example by the possible gender segregation of workers in different occupations. Further details on the Italian ONET database, the JEM, the construction of the OPA index, and its assignment to members of the ILS cohort can be found in previous studies [47,48]; (Model 5, ILS, Appendix Tables A5 and A6).²

- To further assess the external validity of our findings, we conducted a supplementary analysis focusing on public sector employees within the ILS and TLS cohorts. This allowed us to examine whether the relationship between age at retirement and health outcomes differed for these subpopulations compared to the main analysis (model 6, ILS and TLS, appendix tables A5 and A6).
- We also performed an additional analysis using the WHIP cohort to evaluate the external validity of our results across different cohorts of workers. Specifically, we investigated the impact of retirement age on later health outcomes for retirees who retired between 50–65 years old during the period 1997–2001, utilizing a sampling strategy similar to that of the TLS cohort, which was based on the previous quinquennium of pension inflows (model 7, WHIP, appendix tables A5 and A6).
- Finally, we run a full set of interactions and stratified analyses to evaluate effect modification of the association of the health outcomes with age at retirement by socioeconomic position (high school diploma or university degree vs. elementary or low secondary in ILS and TLS; white collars vs. blue collars in all cohorts).

3. Results

3.1. Descriptive statistics

Table 1 provides descriptive statistics for the main variables of interest in the final study population across our three cohorts. Average retirement age was 58.3 years in ILS, 57.1 years in TLS and 58.1 years in WHIP-Health. The average age at retirement in the national cohorts is consistent with the age at retirement observed among male pension claimers retired with old age and seniority pension in Italy (58.3 years) in the same years (1995–2002) [15]. The lower retirement age in the Turin cohort, compared to the two national cohorts is likely attributable to the fact that Turin has an industrial economy with higher employment levels than average in Italy. Hence, residents in Turin are more likely to have continuous working careers with a higher number of contributions years paid and consequently they are more likely to have a higher share of persons who retired earlier via the seniority retirement option, which can be claimed at younger age.

Age at baseline was almost one year greater in the ILS cohort than in the TLS and in the WHIP-Health cohort. The proportion of women was highest in TLS (32 %), followed by ILS (28 %) and WHIP-Health (24 %). Both the proportion of subjects who died during follow-up and that of those who had a cardiovascular outcome were slightly higher in the ILS cohort (10 % and 13 %, respectively), likely because of their older age, compared to TLS and WHIP-Health. Information using the ATECO (Attività Economiche) classification developed by the Italian National Institute of Statistics (ISTAT). Specifically, we controlled for 1-digit (1-letter) sector fixed effects and included a full set of interactions between

² To further refine our control for job types and reduce potential confounding by working conditions, career fragmentation, gender segregation, we conducted an additional check also in the WHIP cohort by incorporating more detailed sectoral

1-digit sectors and occupation (manual job). We also examined the impact of maternity and paternity leave on our results, modelling these variables as both a flag and cumulative weeks of leave taken between 1991 and 2000. The results, presented in Appendix Table 7, demonstrate minimal differences in point estimates, providing reassurance that job characteristics are well-accounted for in our models.

The Turin cohort was more educated, displaying a higher share of individuals with tertiary education and a lower share with at most primary school than the ILS cohort. Accordingly, TLS showed also a lower proportion of blue-collar workers, compared to ILS, whereas WHIP-Health, which includes only workers from the private sector, showed the highest proportion of manual workers. Household composition was similar in the two cohorts, with about 46 % of individuals living in couples with children and 30 % in couples without children. In contrast, cohabitation was 4 times more likely in the ILS cohort than in the city of Turin, coherently with enlarged family type structures being less common in urban contexts. Associations of continuous age at retirement with mortality and CVD incidence

3.2. Main analyses

Table 2 presents the HRs for all-cause mortality and CVD incidence estimated through Cox regression models adjusted for potential confounders (age, education, household composition, and health status assessed by means of the comorbidity index in ILS and TLS; age, occupational class, weekly salary, sector of activity, disability benefits and health status, also assessed by means of the comorbidity index, in WHIP-Health).

In all cohorts, higher age at retirement was associated to an increased risk of mortality in the full sample, with a one-year delay in retirement associated to an increased Hazard Ratio of mortality by 8 % in ILS, 4 % in TLS and 5 % in WHIP-Health. Stratifying by gender we find in all studies a null effect (or only marginally significant) of retirement age on women's mortality, but a highly significant increased risk for every additional year at retirement among men (9 % in ILS, 5 % in TLS and 5 % in WHIP-Health).

Regarding CVD, in the analysis including both genders the hazard rate of CVD incidence was increased by 4 % for every additional year of age at retirement in the TLS study, by 5 % in the WHIP-Health study, whereas the association was in the same direction but only marginally significant in the ILS study (4 % for each year). Among men, in the ILS and the WHIP-Health studies the risk of CVD associated with every additional year of age at retirement was increased by 5 %, and in the TLS study by 3 %, whereas among women results were conflicting across the three cohorts: while in the TLS and in the WHIP-Health cohorts there was a significantly increased risk of cardiovascular disease (HR=1.08, 95 % CI: 1.02–1.15, and HR=1.06, 95 % CI: 1.02–1.10, respectively), in the ILS cohort the association was null.

The results of the proportionality of hazards tests, shown in

Appendix Tables A3, show that a few variables violated the proportionality assumption, including chronic morbidity in TLS for mortality and CVD in both sexes, and age at retirement and chronic morbidity in WHIP-Health for mortality, also in both sexes, with a significant violation of the global test for mortality in TLS and WHIP-Health in both sexes. In the corrected models, only a violation of borderline significance remained in TLS and WHIP-Health for the interaction between chronic morbidity and time on mortality risk (p-value: 0.04), with the global test suggesting no violation. The comparison of hazard ratios between the main and corrected models showed very similar results for both TLS and WHIP-Health, indicating that our main results are robust to possible biases introduced by this type of violation (Appendix Table A4). In contrast, in ILS the violations concerned only one category of the included variables (a category of household typology for both mortality and CVD in men, and a category of education level for CVD in women), without significant violations of the global tests, so the main models were not corrected for the analysis of this cohort.

3.3. Sensitivity analyses

The different sensitivity analyses strongly confirmed the results of the main analysis for men in all the three cohorts for both mortality and CVD incidence (Appendix Table A5 and A6, models 1–5), showing estimates of similar direction, magnitude and significance using different specifications for age, adjusting for behavioural and biological factors in ILS, adjusting for an index of occupational physical activity in the same cohort, adjusting for years of work, and for different types of transitions from work to retirement in WHIP-Health, or allowing the time at risk for each retiree to start 5 years after the personal retirement date, i.e. giving more weight to long-term effect of retirement age. Given the observational nature of the study and the potential presence of unobserved confounders, endogeneity remains a key concern. Our primary strategy to mitigate endogeneity relies on the longitudinal design of the datasets and the inclusion of a comprehensive set of pre-retirement health covariates, which help to reduce bias arising from reverse causality and selection effects.

As an additional robustness check, we employed an instrumental variables (IV) approach to explicitly account for the potential endogeneity of retirement age. Specifically, we estimated an IV Poisson Generalized Method of Moments (IV-Poisson GMM) model [39,40,49], which fully corroborated our main findings—namely, that a higher retirement age is associated with an increased risk of both mortality (Appendix Table A5, Model 5) and cardiovascular disease (Appendix Table A6, Model 5) among men. The diagnostic statistics further support the validity of the instruments used: they appear plausibly exogenous, as indicated by J-test p-values above 0.05, and strongly relevant, with first-stage F-statistics well exceeding the conventional threshold of 10. On the contrary, the results for women appeared to be quite sensitive to changes in the main specification and regression models, with some of

Table 2
Hazard ratios (HR) of MORTALITY and CVD incidence associated with continuous age at retirement in the three cohorts.

Age at retirement	Italian Longitudinal Study (ILS) HR (95 % CI)	Turin Longitudinal Study (TLS) HR (95 % CI)	WHIP-Health Study HR (95 % CI)
MORTALITY			
All	1.08*** (1.03–1.13)	1.04*** (1.02–1.07)	1.05*** (1.03–1.06)
Men	1.09*** (1.03–1.14)	1.05*** (1.02–1.08)	1.05*** (1.03–1.06)
Women	1.04 (0.91–1.19)	1.03 (0.97–1.08)	1.04** (1.00–1.08)
CVD INCIDENCE			
All	1.04* (1.00–1.09)	1.04*** (1.02–1.06)	1.05*** (1.04–1.06)
Men	1.05** (1.00–1.10)	1.03*** (1.01–1.05)	1.05*** (1.04–1.06)
Women	0.99 (0.85–1.14)	1.08*** (1.02–1.15)	1.06*** (1.02–1.10)

Notes: Final sample of analysis described in Table 1. ILS and TLS estimates are adjusted for time-varying age (cont.), education (4 cat.), household type (5 cat.), chronic morbidity index (cont.) and sex dummy (only in the models for “All”). WHIP estimates are adjusted for time-varying age (cont.), prevalent occupational class, sector of activity (4 cat.) and weekly wage (log, 2005 prices) in the previous 10-years; ever received a disability benefit; CMI (cont.) and sex dummy (only in the models for “All”). Legend. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

the estimated null effects becoming significant in some specifications (such as the estimates for CVD in the TLS) or vice versa, showing that the increased risk of mortality and CVD associated with higher retirement ages (as for the result found in the WHIP data) was not robust and only persisted in very few tests (Appendix Tables A5, A6, model m1).

Moreover, relatively small differences with the main analysis were observed among both genders for both mortality and CVD incidence when the analyses were restricted to public employees in the ILS and TLS cohorts. Notably, the point estimates of the HRs remained relatively stable, but often became non-significant due to the increased uncertainty associated with the larger confidence intervals. This loss of significance was largely driven by the substantial reduction in sample size, which resulted in wider confidence intervals and reduced statistical power (Appendix Tables A5, A6, model m6).

In addition to the main analysis, we conducted a further robustness check to assess the external validity of our findings and explore how the results might vary when different populations are analyzed. To this end, we utilized the WHIP-Health cohort and focused on older cohorts of retirees, specifically those who retired in the previous quinquennium. This exercise revealed remarkably stable results for men, with minimal changes in the hazard ratios (HRs). In contrast, among women, the HRs decreased in both magnitude and significance. This finding suggests that, in periods with low female participation in the labor market, women employees may have been more positively selected [50], enjoying better health and working conditions, which could have mitigated the potential detrimental effects of postponing labor market exit (Appendix Tables A5, A6, model m7).

Finally, the results of the analyses stratified by socioeconomic position, available in all cohorts, showed that the hazard ratios for mortality did not differ significantly between strata for both men and women, except for educational level in TLS for men, with a significantly higher HR for subjects with low education, and for occupational class in WHIP-Health, also for men, with a significantly lower risk for manual workers. In addition, for CVD there was a significantly higher risk for men with low education in TLS and a significantly higher risk for women employed as manual workers in ILS, whereas no significant modifying effect of occupational class was found in WHIP-Health for either men or women.³

3.4. Non-linearities in the effect of retirement age on health

In this section we show how the risk of mortality and CVD associated to age at retirement depends on the level of age at retirement. To do so, we run a set of separate fully adjusted Cox regression models where retirement age R is replaced by a dummy variable $I[R.age \geq a]$ that takes the value of one if the individual retirement age is greater or equal age a , for a in the range 50–65, and 0 otherwise. The set of figures below, report the estimated HR and 95 % C.I. relative to this indicator variable, separately for gender, health outcome and study population. Only coefficients starting from age 53 onward are reported, as coefficients relative to $a = 51, 52$ generate extremely large confidence intervals centred on 1, due to highly unbalanced samples sizes (for example for $a = 51$, retirees who retired at age ≥ 51 vs retirees who retired at 50).

Fig. 1 displays results for men. In ILS and TLS, we notice that the risk of mortality induced by retiring at older age (age $\geq a$) is flat up to age $a = 57$, showing no significant difference among those who retire before/after ages up to 57. Starting from 58 the HR starts increasing, to reach the maximum hazard rate at the age of 62, and then declines again after. In the Turin study, the risk of dying for those who retired at age ≥ 62 is about 1.4 times greater than that of those who retired earlier, i.e., from 50 to 61. In the ILS cohort, for those who retired at age ≥ 62 the risk of dying is 2.3 times greater than that of those who retired earlier. In the WHIP-Health cohort a significant increase in mortality is observed

already among those who retire after 56 years, with risks similar to those found in TLS.

For CVD, the pattern is generally similar, although in the Turin cohort the maximum hazard rate is found in correspondence of a retirement age higher than 62 years, while in the Italian study the peak is reached at the age of >60 years. In WHIP-Health, an increased risk of CVD is present already for men who retired beyond 52 years of age, with a peak after age 59.

In Fig. 2 results are displayed for women. In ILS, estimated HRs fluctuate mainly around one, indicating that, coherently with the main Cox regression analyses, there is no significant excess risk of mortality or CVD associated to higher age at retirement in the Italian study. For TLS, the only significant pattern emerges for the CVD outcome, where we spot two peaks at ages 55 and 60, with significantly higher CVD risk for retiring beyond 54, 58 and 59 years. In WHIP-Health, women show a significantly higher risk of mortality for retiring beyond 56 and 60, and of CVD beyond the ages of 53–60.

The fact that the estimated dummy coefficients from these separate regressions do not linearly increase with age, indirectly provides support to the underlying assumption that age is properly controlled for.⁴

4. Discussion

4.1. Main findings

In the present study on three Italian cohorts, among men an increased risk of mortality and CVD incidence was found consistently associated with higher age at retirement, in the range of 5–9 % increase per one-year increase in retirement age, treating this variable as continuous, whereas among women we observed only a significant positive association with CVD risk in the TLS cohort. The set of the analyses on age at retirement dichotomized confirmed the results based on continuous age at retirement, revealing among men a higher risk of mortality for retiring above 57 years in ILS, 58 years in TLS, and 56 years in WHIP-Health, and of CVD incidence for retiring after 59 years in ILS, after 56 in TLS and after 52 for WHIP-Health. In these analyses, after a retirement age of 61–62, both mortality and CVD incidence started to decrease, likely because of health selection into retirement, leaving at work subjects healthier than those who retired earlier. Among women, a higher risk of mortality was present for retiring after 56 years in the WHIP-Health cohort, and of CVD for retiring after 54 years in the TLS cohort and after 53 years in the WHIP-Health cohort, which also confirm the results of the previous analysis.

The results were highly consistent across cohorts, at least among men, in spite of differences by type of employment and source from which data were drawn. In fact, the WHIP-Health data include only employees of the private sector and are based on social security administrative data, implying that all workers in this dataset have a formal work contract, whereas the ILS and the TLS cohort include also employees of the public sector (around 22 % in ILS and 28 % in TLS) and a share of informal workers, which in Italy was estimated to be around 15 % at the end of last century, with a lower proportion in the North and a higher one in the South of Italy (ISTAT, 2005) [51].

The results were robust to several sensitivity analyses, including the use of an instrumental variable model, which allows correction for the potential bias associated with endogeneity, in particular reverse

⁴ Consider in fact that the comparison is always done between a younger subsample of retirees versus an older one. For example, among men in the TLS cohort, when $a = 53$, the exposed group (those who retired at ages ≥ 53) has on average 60.5 years at baseline (s.d. 3.7), while the unexposed group (those who retired at ages <53) has on average 53.7 years (s.d. 1.3); when $a = 65$, the exposed group (those who retired at ages ≥ 65) has on average 67.9 years at baseline (s.d. 1.4), while the unexposed group (those who retired at ages <65) has on average 60.12 years (s.d. 3.6).

³ Heterogeneity analysis results are available upon request.

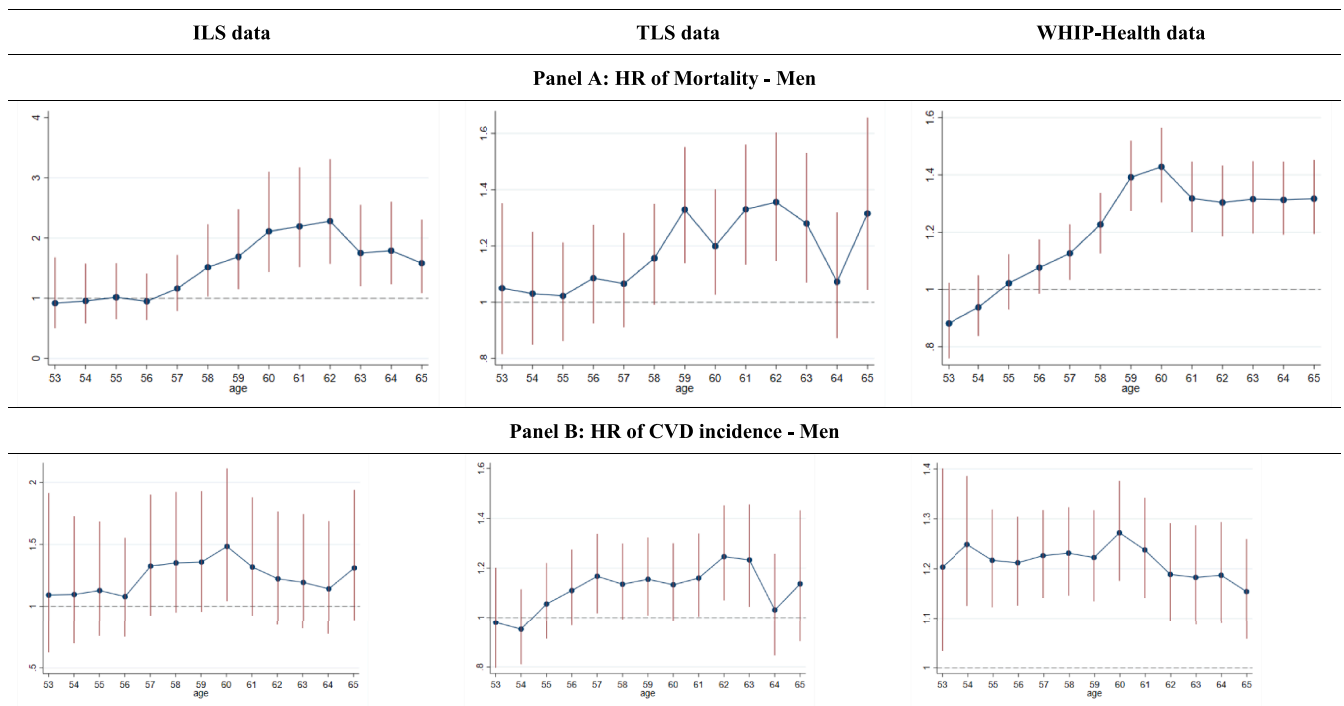


Fig. 1. Men - HR of mortality and CVD incidence for different age at retirement $I[R.Age \geq a]$ in fully adjusted models, with each HR corresponding to a separate model. Age 50–65 years
 Note: Final sample of analysis described in Table 1.

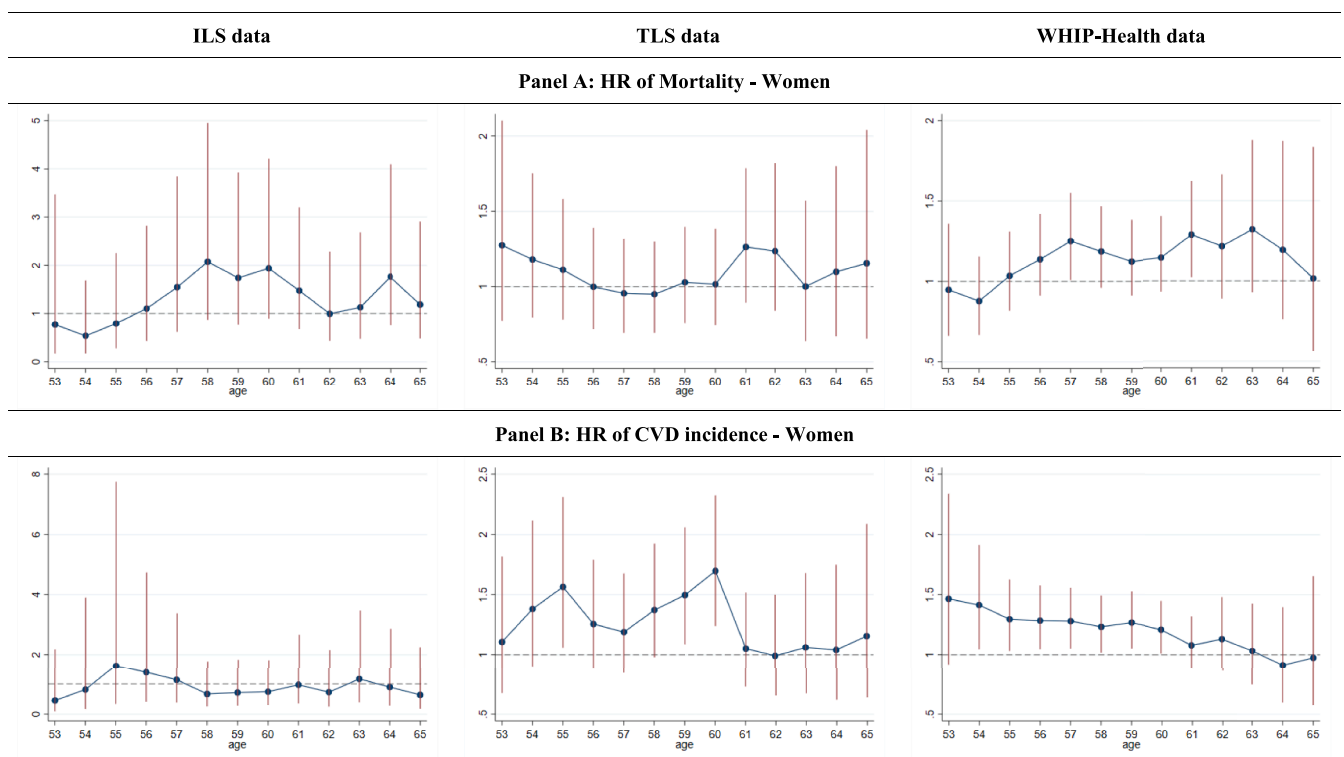


Fig. 2. Women - HR of mortality and CVD incidence for different age at retirement $I[R.Age \geq a]$ in fully adjusted models, with each HR corresponding to a separate model. Age 50–65 years
 Note: Final sample of analysis described in Table 1.

causality between health and retirement age. In a wide range of robustness tests, we confirm that the results were also highly robust to adjusting for different measures of age, for biological and lifestyle

factors, for a rich set of working conditions, job type, career and personal life events in the last 10 years before retirement, pension benefit and eligibility characteristics, as well as to the inclusion of a lag in the

follow-up to allow for more long-term effects on health. Furthermore, the similarity of the results of the OPA-adjusted analysis to those of the main analysis, even taking into account the uncertainty of the hazard ratios, suggests that confounding by working conditions is an unlikely explanation for the positive association between age at retirement and the health outcomes examined. The results are also robust to possible violations of the proportional hazards assumption. Furthermore, the results showed only little, although significant, heterogeneity by socioeconomic position, which was nonetheless inconsistent across cohorts and genders.

Therefore, our results indicate that retirement at older ages may have detrimental effects on mortality and cardiovascular health, at least among men. It is worth considering that the positive association of age at retirement with mortality and CVD in men cannot be explained by residual confounding by health status, as it would bias the results in the opposite direction, given that subjects affected by chronic conditions are expected to retire on average earlier than healthy ones and to be at higher risk of mortality or CVD.

The association between our health outcomes and the age at which women retire appears to be less consistent and robust across studies, as already noted in previous studies based on Italy [16], and also highlighted in the meta-analysis by Sewdas et al. [7], where the risk of mortality associated with early retirement was about 40 % lower for women than for men. A possible explanation, at least for the generation investigated, is that this is attributable to a healthy worker effect of employed women in midlife, as evidenced by the low proportion of women in all cohorts, which may have selected out of the workforce women with health problems already at age 50, leaving a population of women in the workforce less susceptible to the effect of delayed retirement. This interpretation is supported by the robustness test conducted on older cohorts in the WHIP study, where the effect on women disappeared. Specifically, it is possible that older cohorts of women are subject to an even stronger positive selection (Olivetti and Petrongolo [50]), resulting in a workforce that is particularly healthy and resilient, and therefore less affected by the potential negative health consequences of delayed retirement.

4.2. Comparison with previous research

Regarding mortality, results in the literature appear mixed, but, although earlier age at retirement was associated with increased mortality in several observational studies with a non-causal design, as reported by different reviews [52,53], most studies which used a causal design, such as instrumental variable (IV), difference-in-difference, or regression discontinuity design, found a reduced mortality associated with earlier retirement age [22,24] or no effect [20,21,25,54,55]. A Scandinavian study did not find an association with mortality using a regression discontinuity design but observed a decrease in the hospitalizations for any cause after retirement [54]. In contrast, an Austrian study performed using instrumental variable analysis found a 13 % increase in mortality for those who retired before 67 years among men, but no difference among women [23].

Regarding CVD, our findings are consistent with those by Ardito et al., who used an IV strategy and found an increased risk of CVD hospitalization among men delaying retirement in Italy [15]. Furthermore, a Finnish study, also using an IV design, based on a sample of almost 100,000 individuals, found a decreased CVD incidence associated with earlier retirement [56], while another recent study, also based on an IV design and exploiting differences in SPA among 35 countries, found a decreased risk of heart disease associated with retirement [57]. However, other studies with a causal design focusing on CVD did not find any significant association between early retirement and CVD hospitalisation [18,58], CVD mortality [59], or myocardial infarction [60]. Another study found a higher risk of CVD among retirees when a matching estimator was used, but the association disappeared when the IV strategy was employed [19]; furthermore, newly diagnosed CVD were

self-reported, leaving open the possibility that retired individuals could have over-reported such conditions. Another recent US study based on a difference-in-difference analysis found increased mortality associated with retirement, especially due to cardiovascular causes of death, although together with an improvement in self-reported health and activity limitations [61].

4.3. Strengths & limitations

A main strength of the study is the use of different cohorts, which gave the possibility to compare the results across them and evaluate consistency of their results, despite differences in the available information on covariates and in territorial and temporal coverage. Furthermore, two of the cohorts were quite large, with TLS including almost 20,000 subjects and WHIP-Health almost 70,000, hence providing large statistical power for the analyses.

Another strength is that information on CVD occurrence and mortality, and in WHIP-Health also that on timing of retirement, relied on administrative data and not on self-report, excluding the possibility of differential misclassification of the outcome between subjects who retired earlier or later.

The most important limitation appears the lack of information on potential confounders in TLS and WHIP-Health, where only few individual covariates were available for adjusting the analyses. However, adjustment for lifestyles and biological factors in ILS practically did not change the results, so we don't expect that confounding by these covariates could have strongly biased the associations in the other two cohorts.

Another possible limitation is that in both ILS and TLS information on age at retirement was self-reported at baseline, and in theory could have been affected by the health status of the individuals, but this possibility appears unlikely. The exact question people answered was about the year they withdrew from the labour market, so it could refer to the year when workers stopped working, but also to the year they left their perceived job as a "life's work". The age at retirement is subject to recall bias, but it is estimated that this type of error is limited, since we restricted to subjects who retired within 5 years before the interview.

5. Conclusions

This study found that, at least among men, higher age at retirement was consistently associated with an increased risk of mortality and CVD, suggesting that national policies that tighten pension eligibility conditions should take into account the possible increased burden on population health. Also, from a cost-benefit perspective, the increased sustainability of the pension system should be weighed against the negative impact on health care expenditure.

Our results were very consistent for men across all cohorts and methodological designs considered, but less so for women, for whom this issue deserves further investigation. One possible interpretation is related to the lower labour market participation of women in the cohorts studied. On the one hand, this leads to a lower sample size and statistical power for women. On the other hand, the external validity of our result may be limited by the different composition of the female labour force that characterises these cohorts.

Another finding that deserves further investigation is that we did not find heterogeneities by socioeconomic position, which is contrary to the prevailing evidence reported in the general literature on the relationship between critical career stages and health outcomes. Again, sample size may be an issue. Other possible explanations for the null result are the fact that we consider both acute health outcomes and a limited time follow-up; and the fact that we measure economic position at the individual level, whereas a more relevant measure would be equalised household income. From a policy relevance point of view, this is a matter of the utmost importance, as the possibility of differentiating pension schemes according to the socioeconomic position of individuals

is currently a highly debated issue.

Our contribution also points to a possible avenue of shedding light on the two issues for which our results are inconclusive, namely the existence of gender and socioeconomic differentials in the impact of reforms. We have used cohorts that are different in terms of the reference population (local versus national; public versus private sector employment) and based on different integrated data sources. It is clear that each of these has relative advantages and disadvantages, but still provided highly consistent results on our main research question.

The continued development of study cohorts that integrate survey and administrative sources, improve the level of detail provided, and possibly expand the accessibility of population versus sample data to researchers, is crucial to informing policy makers on how to manage population ageing, taking into account both the socioeconomic and health biographies of individuals.

CRedit authorship contribution statement

Chiara Ardito: Writing – review & editing, Writing – original draft, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Roberto Leombruni:** Writing – review & editing, Data curation, Conceptualization. **Giuseppe Costa:** Writing – review & editing, Funding acquisition. **Angelo d’Errico:** Writing – review & editing, Writing – original draft, Project administration, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Angelo d’Errico, Giuseppe Costa reports financial support was provided by Italian Ministry of Health. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.bdr.2025.100543](https://doi.org/10.1016/j.bdr.2025.100543).

Data availability

The authors do not have permission to share data.

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