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ORIGINAL ARTICLE

Interaction between education and income on the risk of all-cause mortality: prospective results from the MOLI-SANI study

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Abstract
Objectives To investigate the separate and inter-related associations of education and household income in relation to all-cause mortality.
Methods Prospective study on 16,247 men and women (≥35 years), a sub-sample of the MOLI-SANI cohort that had been randomly recruited within an Italian general population. Both education and income were used as categorical variables. Hazard ratios (HR) were calculated by Cox-proportional hazard models.
Results Over a median follow-up of 7.7 years (125,016 person-years), 694 deaths were ascertained. Either education (HR = 0.68; 95 % CI 0.51–0.91) or income (HR = 0.57; 0.42–0.77) was inversely associated with mortality. After simultaneous adjustment, the association of education appeared to be largely explained by income. A significant interaction between both variables was found ($p = 0.0078$). The inverse association with mortality was stronger when a higher income was combined with a higher educational level (HR = 0.59; 0.38–0.92 for the highest combination of the two indicators).
Conclusions Either education or income was the predictor of mortality in a large sample of the Italian population. The two variables significantly interacted and the inverse association of income with mortality tended to be stronger within higher education groups.

Keywords Education · Income · Interaction · Mortality

Introduction

A socioeconomic gradient in mortality is well established with higher death rates in lower socioeconomic groups (Pappas et al. 1993; Huisman et al. 2005). Socioeconomic status (SES) is a multidimensional construct comprising both cultural and material indicators (Braveman et al. 2005). Education and income are two primary indicators of SES reportedly associated with risk of illness and mortality (Huisman et al. 2005; Hajat et al. 2011; Martikainen et al. 2001) and in many studies are assumed to be interchangeable. Education, commonly used as a proxy for cultural resources, aims at capturing the knowledge -related assets of a person and is closely linked to the capacity of being more receptive to health education messages or more able to access appropriate health services (Galobardes et al. 2006a, b).

Income is the indicator that most directly measures the material resources component and can represent potential access to healthful lifestyles and a sense of security (Galobardes et al. 2006a, b; Backlund et al. 1999).

Both indicators have a well-established impact on a number of health outcomes but are often assumed as depicting a unique social dimension. Indeed, education and income measures emphasize different aspects of social stratification. In life-course perspectives, the education level represents an acquired knowledge and reflects the experiences of early life. Income represents material resources and mirrors experiences in adult life. However, previous studies have emphasized the need for addressing the interrelations between SES factors, since part of the effects of each socioeconomic indicator on health is either

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explained by or mediated through other socioeconomic indicators (Braveman et al. 2005; Lahelma et al. 2004; Geyer et al. 2006).

In spite of the awareness that the predictive value of SES indicators may relate to different causal processes (Geyer and Peter 2000; Andersen et al. 2005), much of the health-related research to date has mainly addressed the independent impact of a single SES factor on health while adjusting for one or more additional indicators (Lahelma et al. 2004). In addition, the actual interaction between SES indicators has been poorly investigated (Aitsi-Selmi et al. 2014; Gerber et al. 2008; Cundiff et al. 2015) and is even less explored with respect to mortality (Koch et al. 2010).

The purpose of the present study is threefold: first, we examine how education and income may mediate the effect of each other; second, we address a potential interaction between these two indicators on overall mortality in a large community sample of the Italian population; finally we assess the contribution of a large panel of material, behavioral, biomedical and psychosocial factors in explaining possible socioeconomic inequalities in mortality.

This study also investigates the socioeconomic gradient in health in Italy, a country where such data are scarce (Federico et al. 2013).

Methods

Study population

The MOLI-SANI study is a prospective cohort study of men and women, aged ≥35 years, randomly recruited from the general population of a Southern Italian region (Di Castelnuovo et al. 2013). From March 2005 to April 2010, 24,325 subjects were enrolled with a response rate of 70 % (di Giuseppe et al. 2012). Individuals refusing to declare data on income (31.9 %), those with missing information on educational level (0.2 %) or unreliable medical questionnaires (1 %), subjects lost to follow-up (1.4 %) or with incomplete personal data (0.2 %) were excluded from the present analyses. The final sample was of 16,247 individuals who were comparable with the excluded group in terms of death rate (4.3 vs 6.6 %; p value = 0.82 adjusted for age, sex and education) whereas the mean age of the study sample was slightly lower (54.8 ± 11 vs 57.9 ± 13) and had a higher number of men (50.4 vs 43.5 %) and of highly educated people (51.5 vs 36.2 %).

The cohort was followed-up for overall mortality for a median of 7.7 years.

All-cause death was assessed by linkage with Offices of vital statistics of the Molise region and follow-up was recorded until May 2015.

The MOLI-SANI study was approved by the Ethics Committee of the Catholic University of Rome, Italy. All participants signed an informed consent.

Assessment of risk factors

History of cardiovascular disease at baseline included documented angina, myocardial infarction, revascularization procedures and stroke. History of cancer included self-reported diagnosis of cancer. Hypertension was defined as systolic blood pressure ≥140 mm Hg or diastolic blood pressure ≥90 mm Hg or treatment for hypertension. Hypercholesterolemia was defined if total cholesterol ≥240 mg/dL or by use of specific medication. Diabetes was defined as blood glucose ≥126 mg/dL or by use of specific pharmacological treatment.

Material, behavioral, biomedical and psychosocial factors

All socioeconomic information was self-reported and collected by a structured questionnaire administered by trained personnel. Education was based on the highest qualification attained and was categorized as none or primary education (approximately ≤5 years of study), middle school (5–8), secondary school (8–13) and university or higher (>13).

Household income (EUR/year) was a 4-level variable (<10,000; 10,000–25,000; 25,000–40,000 and >40,000).

Other SES factors were used as indicators of material resources. Occupation was assembled into five groups: non-manual, manual, other (unskilled workers, military careers, religious person, etc.), retired and housewife. Housing tenure was considered as rented, dwelling ownership and additional dwelling ownership (persons owning more than a dwelling). Socioeconomic condition during childhood was measured by a score based on the following items: ratio between the number of rooms and number of persons living in the household, family house ownership in childhood and availability of hot water (yes/no) at home in childhood. Room density >0.6 (median value in the whole population), dwelling ownership or availability of hot water were assigned 1 point. The SES in childhood score ranged from 0 to 3.

Food intake during the year before enrolment was assessed by the validated Italian EPIC food frequency questionnaire (Pala et al. 2003). Since a Mediterranean dietary pattern has been widely associated with reduced risk for a number of chronic diseases and health conditions (Trichopoulou et al. 2003), adherence to this pattern was used as marker of diet quality (Ruel 2003) and measured according to the Mediterranean Diet Score (Trichopoulou et al. 2003). The score ranged between 0 and 9, the latter reflecting maximal adherence, and was collapsed into a 4-category variable: poor (0–2), average (3–4), better than average (5–6) and very good adherence (≥7).

Sport activity was assessed by a structured questionnaire aiming at evaluating sport participation, expressed as hours of sport practiced during the week (h/week) and categorized as none, <2 or ≥2 h/week.

The ratio between waist and hip (WH ratio) circumferences was used to assess body weight distribution and expressed as quintiles. Subjects were classified as never-smokers, current smokers or ex-smokers (quitting from at least 1 year). Inflammation-related biomarkers such as leukocytes count ($10^9 \times$ L), the neutrophil (granulocytes)/leukocyte ratio and C-reactive protein (CRP; mg/L) were used as quintiles. Depression and marital status were used as indicators of psychosocial status. Marital status was considered as a measure of social support and networks (Khang et al. 2009) and classified as married/cohabiting, divorced/separated, single and widower. Depression (no/yes) was defined by the use of anti-depressive drugs.

Statistical analysis

Demographic, socioeconomic, material, behavioral, biomedical and psychosocial characteristics of the study population were presented as numbers and percentages, or mean values and standard deviation (age, SES in childhood, waist-hip ratio, Mediterranean diet score, C-reactive protein, leukocytes, granulocyte/lymphocyte ratio). Hazard ratios (HR) for risk of death and 95 % confidence intervals (95 % CI) were calculated using the Cox-proportional hazard models. An appropriate term for testing interaction between education and income was included in a multivariable model (controlled for presence of cardiovascular disease, cancer, diabetes and hypercholesterolemia at baseline), to test for a difference of effect of income in education strata. The association of a large panel of potential mediators (material, behavioral, biomedical and psychosocial factors) with income and education was assessed in Table 1 using age and sex adjusted general linear models (PROC GENMOD and PROC GLM in SAS for categorical and continuous variables, respectively). Potential mediators associated with mortality, income and education ($p < 0.20$) were included in the explanatory models shown in Table 3. To quantify the contribution of explanatory variables, we calculated the percentage change in hazard ratios by [(HR model 1) – (HR explanatory models)]/[(HR model 1) – 1]. To evaluate whether individuals likely to have poorer health, possibly leading to both higher mortality rates and altered income, would bias the results, calculations were repeated after excluding subjects with <1 year of follow-up.

Dummy variables for missing values of each variable of interest were created. The data analysis was generated using SAS/STAT software, Version 9.1.3 of the SAS System for Windows©2009. SAS Institute Inc. and SAS are registered trademarks of SAS Institute Inc., Cary, NC, USA.

Results

Over a median follow-up of 7.7 years (lower to higher quartile: 6.6–8.9 years; 125,016 person-years), 694 all-cause deaths were ascertained. The associations of household income and education with mortality are reported in Table 1. Higher income and education were inversely linked to mortality (Table 1, model 1). When these indicators were simultaneously included in the multivariable model, the protective effect of education did not hold, whereas the effect of income remained unaltered (Table 1, model 2). After excluding individuals with <1 year follow-up, results did not change (HR = 1.28; 1.04–1.58; HR = 0.93; 0.73–1.18; HR = 0.93; 0.66–1.32 from lowest to highest educational level groups as compared to the reference category and HR = 0.81; 0.66–1.00; HR = 0.61; 0.46–0.82 and HR = 0.56; 0.39–0.81 from lowest to highest household income strata as compared to the reference group).

Demographic characteristics, socioeconomic, material, behavioral, biomedical and psychosocial factors of the study population according to education or household income were reported in Table 1. Both highest income and education groups reported the highest score of SES in childhood and greater prevalence of additional dwelling ownership and of non-manual workers. Health-related behaviors and biomedical conditions were also socioeconomically patterned resulting more favorable at higher degrees of education and income (Table 1).

The whole set of material, behavioral, biomedical and psychosocial factors under study (with the exception of hypertension ($p = 0.54$) and occupation ($p = 0.069$) was associated with death (p values <0.05, hazard ratios not shown).

To better investigate the interrelationship between education and income, these two SES indicators were simultaneously included in a multivariable model including a term of interaction plus major chronic disease and health conditions; the p value for interaction was statistically significant ($p = 0.0078$), indicating a difference of effects of income in education strata (or vice versa). To highlight such interaction, we analyzed a 16-level combination of household income and education, using the lowest level for both indicators as the reference group. As shown in Table 2, an inverse association of higher levels of

Table 1 Main characteristics of the study population and risk of death by education and income (MOLI-SANI study, Italy, 2005–2010)

	Education				Household income (Euros/year)			
	None or primary	Middle school	Secondary school	University or higher	<10,000	10,000–25,000	25,000–40,000	>40,000
N of deaths/*n* of subjects	313/3329	170/4553	155/6128	56/2237	135/1377	356/7211	132/4839	71/2820
Risk of death[a] (hazard ratios; 95 % CI)	1	1.18 (0.96–1.43)	0.77 (0.63–0.95)	0.68 (0.51–0.91)	1	0.85 (0.69–1.04)	0.60 (0.47–0.78)	0.57 (0.42–0.77)
Risk of death[b] (hazard ratios; 95 % CI)	1	1.29 (1.05–1.58)	0.94 (0.75–1.19)	0.89 (0.63–1.24)	1	0.83 (0.67–1.02)	0.62 (0.47–0.82)	0.62 (0.44–0.88)
Characteristics of the sample								
Age	65.4 (9.2)	52.1 (10.0)	51.9 (10.0)	52.2 (10.2)	62.3 (12.6)	55.5 (11.7)	52.5 (10.2)	53.1 (9.3)
Sex (men)	1526 (45.8)	2400 (52.7)	3147 (51.4)	1118 (50.0)	533 (38.7)	3593 (49.8)	2533 (52.4)	1532 (54.3)
Education								
None or primary					810 (58.8)	2134 (29.6)	328 (6.8)	57 (2.0)
Middle school					381 (27.7)	2714 (37.6)	1194 (24.7)	264 (9.4)
Secondary school					170 (12.3)	2055 (28.5)	2535 (52.4)	1368 (48.5)
University or higher					16 (1.2)	308 (4.3)	782 (16.1)	1131 (40.1)
Household income								
<10,000	810 (24.3)	381 (8.4)	170 (2.8)	16 (0.7)				
10,000–25,000	2134 (64.1)	2714 (59.6)	2055 (33.5)	308 (13.8)				
25,000–40,000	328 (9.9)	1194 (26.2)	2535 (41.4)	782 (35.0)				
>40,000	57 (1.7)	264 (5.8)	1368 (22.3)	1131 (50.5)				
Material factors								
Occupation								
Non-manual	24 (0.7)	316 (6.9)	2254 (36.8)	1444 (64.5)	30 (2.2)	809 (11.2)	1669 (34.5)	1530 (54.3)
Manual	349 (10.5)	883 (19.4)	474 (7.7)	13 (0.6)	144 (10.5)	1051 (14.6)	451 (9.3)	73 (2.6)
Other	293 (8.8)	1345 (29.5)	1474 (24.1)	321 (14.3)	248 (18.0)	1502 (20.8)	1141 (23.6)	542 (19.2)
Retired	1795 (53.9)	872 (19.2)	1098 (17.9)	404 (18.1)	623 (45.2)	2109 (29.3)	962 (19.9)	475 (16.8)
Housewife	865 (26.0)	1134 (24.9)	825 (13.5)	55 (2.5)	331 (24.0)	1736 (24.1)	614 (12.7)	198 (7.0)
Housing tenure								
>1 dwelling ownership	219 (6.6)	323 (7.1)	766 (12.5)	428 (19.1)	38 (2.8)	490 (6.8)	584 (12.1)	624 (22.1)
SES in childhood	1.54 (1.60)	1.65 (1.56)	1.94 (1.41)	2.18 (1.30)	1.75 (1.84)	1.67 (1.48)	1.87 (1.43)	2.09 (1.48)
Health behaviors								
Sport activity (≥2 h/week)	60 (1.8)	256 (5.6)	517 (8.4)	219 (9.8)	35 (2.5)	346 (4.8)	374 (7.7)	297 (10.5)
Smokers	482 (14.5)	1262 (27.7)	1575 (25.7)	506 (22.6)	272 (19.8)	1663 (23.1)	1203 (24.9)	687 (24.4)
Waist-hip ratio	0.92 (0.08)	0.92 (0.07)	0.91 (0.08)	0.90 (0.08)	0.92 (0.08)	0.92 (0.08)	0.91 (0.07)	0.91 (0.07)
Mediterranean diet score	4.26 (1.60)	4.44 (1.63)	4.50 (1.63)	4.54 (1.70)	4.20 (1.62)	4.39 (1.62)	4.50 (1.63)	4.57 (1.70)

Table 1 continued

	Education				Household income (Euros/year)			
	None or primary	Middle school	Secondary school	University or higher	<10,000	10,000–25,000	25,000–40,000	>40,000
Biomedical factors and health conditions								
C-reactive protein (mg/L)[c]	1.68 (1.62–1.75)	1.59 (1.55–1.64)	1.41 (1.37–1.45)	1.25 (1.20–1.31)	1.62 (1.54–1.71)	1.55 (1.55–1.62)	1.43 (1.39–1.47)	1.31 (1.27–1.36)
Leukocytes ($10^9 \times$ L)	6.29 (1.88)	6.30 (1.78)	6.17 (1.65)	6.07 (1.50)	6.31 (1.71)	6.27 (1.75)	6.20 (1.71)	6.08 (1.65)
Granulocyte/lymphocyte	2.00 (0.83)	1.96 (0.78)	1.99 (1.36)	2.00 (0.93)	2.01 (0.82)	1.98 (0.80)	2.00 (1.21)	1.99 (0.90)
Cardiovascular disease	317 (9.5)	210 (4.6)	214 (3.5)	75 (3.5)	117 (8.5)	415 (5.8)	192 (4.0)	92 (3.3)
Cancer	139 (4.2)	104 (2.3)	180 (2.9)	77 (3.4)	55 (4.0)	209 (2.9)	150 (3.1)	86 (3.1)
Diabetes	518 (15.6)	395 (8.7)	441 (7.2)	124 (5.5)	194 (14.1)	733 (10.2)	355 (7.3)	196 (7.0)
Hypertension	2548 (76.5)	2358 (51.8)	3016 (49.2)	1006 (45.0)	938 (68.1)	4082 (56.6)	2472 (51.1)	1436 (50.9)
Hypercholesterolemia	1150 (34.5)	1278 (28.1)	1664 (27.2)	559 (25.0)	450 (32.7)	2088 (29.0)	1371 (28.3)	742 (26.3)
Psychosocial factors								
Marital status								
Married/cohabiting	2830 (85.0)	4175 (91.7)	5479 (89.4)	1919 (85.8)	923 (67.0)	6323 (87.7)	4458 (92.1)	2699 (95.7)
Separated/divorced	32 (1.0)	115 (2.5)	176 (2.9)	94 (4.2)	80 (5.8)	190 (2.6)	96 (2.0)	51 (1.8)
Single	56 (1.7)	133 (2.9)	301 (4.9)	178 (8.0)	93 (6.8)	341 (4.7)	186 (3.8)	48 (1.7)
Widowed	411 (12.4)	127 (2.8)	171 (2.8)	46 (2.0)	281 (20.4)	355 (4.9)	97 (2.0)	22 (0.8)
Depression	89 (2.7)	131 (2.9)	203 (3.3)	75 (3.4)	46 (3.3)	217 (3.0)	160 (3.3)	75 (2.7)

Categorical variables are presented as number and percentage; continuous variables (age, SES in childhood, waist-hip ratio, Mediterranean diet score, C-reactive protein, leukocytes, Granulocyte/lymphocyte ratio) as age/sex adjusted mean ± SD

[a] Model 1: Hazard ratios with 95 % confidence intervals (95 % CI) from a model adjusted for age, sex, cardiovascular disease, cancer and diabetes at baseline

[b] Model 2: Hazard ratios with 95 % confidence intervals (95 % CI) from a model adjusted for age, sex, cardiovascular disease, cancer and diabetes at baseline and including education and income simultaneously

[c] Geometric hs-CRP means with corresponding 95 % confidence intervals

Table 2 Combinations of household income and education on mortality in the study population and for men and women (MOLI-SANI study, Italy, 2005–2010)

P value for interaction = 0.0028	All (*n* = 16,247; deaths = 694)		Men (*n* = 8191; deaths = 481)		Women (*n* = 8056; deaths = 213)	
	N of deaths/*N* of subjects	Risk of death (HR; 95 % CI)[a]	*N* of deaths/*N* of subjects	Risk of death (HR; 95 % CI)[a]	*N* of deaths/*N* of subjects	Risk of death (HR; 95 % CI)[a]
Education						
None or primary and <10,000	104/810	–1–	53/307	–1–	51/503	–1–
None or primary and 10,000–25,000	179/2134	0.87 (0.68–1.11)	126/1030	0.93 (0.68–1.29)	53/1104	0.81 (0.55–1.19)
None or primary and 25,000–40,000	27/328	1.10 (0.71–1.68)	16/161	0.98 (0.56–1.73)	11/167	1.41 (0.73–2.72)
None or primary and >40,000	3/57	0.83 (0.26–2.63)	3/28	1.32 (0.41–4.25)	0/29	–
Middle school and <10,000	23/381	1.73 (1.09–2.73)	16/146	1.85 (1.05–3.25)	7/235	1.75 (0.78–3.89)
Middle school and 10,000–25,000	110/2714	1.20 (0.90–1.59)	83/1414	1.16 (0.81–1.65)	27/1300	1.58 (0.96–2.59)
Middle school and 25,000–40,000	20/1194	**0.49 (0.30–0.81)**	16/688	**0.48 (0.27–0.84)**	4/506	0.68 (0.24–1.92)
Middle school and >40,000	17/264	1.51 (0.89 –2.54)	15/152	1.76 (0.98–3.16)	2/112	0.76 (0.18–3.14)
Secondary school and <10,000	7/170	1.29 (0.60–2.78)	5/73	1.33 (0.53–3.35)	2/97	1.34 (0.32–5.54)
Secondary school and 10,000–25,000	62/2055	0.92 (0.67–1.28)	42/1018	0.89 (0.59–1.35)	20/1037	1.04 (0.61–1.75)
Secondary school and 25,000–40,000	61/2535	**0.68 (0.49–0.94)**	47/1325	0.68 (0.45–1.01)	14/1210	0.77 (0.42–1.41)
Secondary school and >40,000	25/1368	**0.46 (0.30–0.73)**	17/731	**0.40 (0.29–0.69)**	8/637	0.83 (0.39–1.81)
University or higher and <10,000	1/16	1.04 (0.15–7.45)	1/7	1.51 (0.21–10.92)	0/9	–
University or higher and 10,000–25,000	5/308	0.45 (0.18–1.11)	4/131	0.54 (0.20–1.50)	1/177	0.32 (0.04–2.34)
University or higher and 25,000–40,000	24/782	0.74 (0.48–1.16)	18/359	0.78 (0.45–1.33)	4/423	0.76 (0.32–1.78)
University or higher and >40,000	26/1131	**0.59 (0.38–0.92)**	18/621	**0.49 (0.29–0.85)**	8/510	1.35 (0.62–2.95)

Hazard ratios from a model adjusted for age and sex

Bold values indicate statistically significant results

HR; 95 % CI Hazard ratios with 95 % confidence intervals

household income against mortality was evident mainly in higher educational level groups. Separate analyses by sex confirmed similar results for men, although the number of deaths in women was too small to allow any meaningful consideration.

Hazard ratios for income categories stratified by educational level are depicted in Fig. 1, with the lowest income group being the reference category in each strata of education.

The independent and combined accounting of explanatory factors for the combinations of income and education is described in Table 3. For the four combinations of education and income that reported lower death risk (bold in Table 3), material factors, (occupation, housing tenure, SES in childhood) played a major role and explained 5.9, 18.8, 13.0 and 29.3 % of the protection against mortality as compared to the reference group, while all the explanatory factors accounted for 9.8–56.1 % of such differences.

Discussion

Results from the present study showed that income and education were predictors of mortality in a large community-based sample of the Italian population. The effect of education was largely mediated by income. Findings also

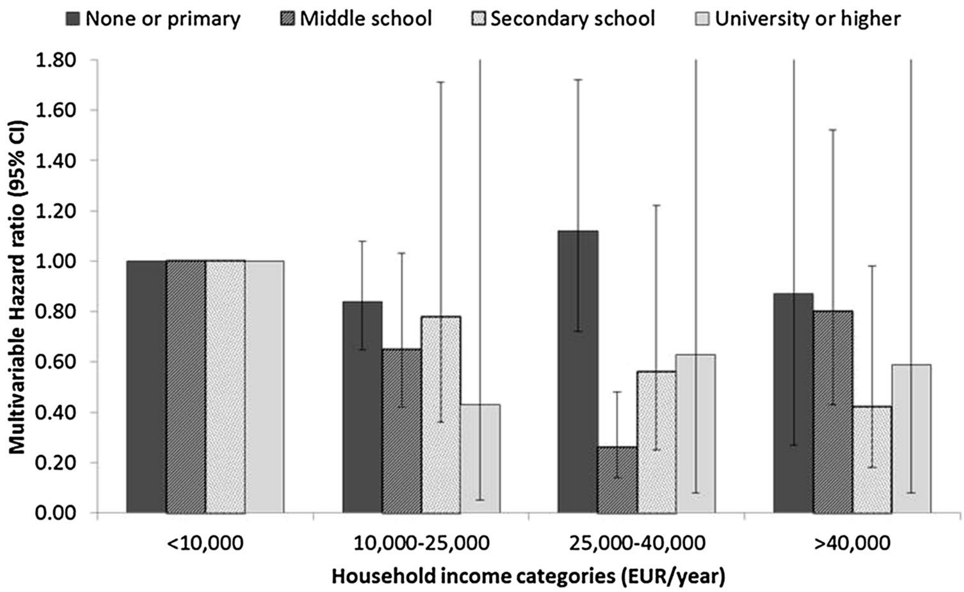

Fig. 1 Association of household income with mortality by educational level (MOLI-SANI study, Italy, 2005–2010)

showed a significant interaction between household income and education in relation to mortality: the inverse association of household income with all-cause death varied across educational level groups and was larger at higher levels of education. We may argue that education plays an important role in the way people spend their money in terms of pursuing healthy lifestyle; indeed, highly educated people are likely to make safer choices for their own health, such as following a healthful diet or engaging in sport activities. Additionally, having greater financial resources might not be enough for pursuing healthful behaviors in the absence of a good set of knowledge and skills likely linked to higher degrees of education.

It is noteworthy that education is an antecedent variable to income, behavioral lifestyle, risk factors, chronic disease and mortality, in such a way that it can be considered as a predictor rather than a mediator of the relationship of material conditions (including income levels) with total mortality (Koch et al. 2010). The importance of considering interrelationships between SES indicators when dealing with health outcomes has been repeatedly underlined (Braveman et al. 2005; Lahelma et al. 2004; Geyer et al. 2006) but to date, little attention has been paid not only to interdependencies but also to interactions among SES determinants in relation to health outcomes.

So far, different theoretical explanations of the pathways underlying health inequalities have been proposed; among them, the behavioral explanation argues that social inequalities in health are due to a higher distribution of unhealthy lifestyles in lower socioeconomic groups, whereas the biomedical approach provides explanation in terms of unequal prevalence of biological risk factors across different social groups (Skalická et al. 2009).

To better understand the pathways from which education and income differences originated in our population, we analyzed both the independent and the combined accounting of a large panel of modifiable risk/protective factors and found a dominant role of material circumstances over others (behavioral, biomedical and psychosocial). More specifically, housing tenure not only is a marker of additional material resources but is also related to some health promoting effects independently of income (Macintyre et al. 1998). Similarly, occupation encompasses material reward and job control but also social standing that a given occupation has in society (Galobardes et al. 2006a, b) with a consequent lower stress status and mortality (Nielsen et al. 2008).

Conversely, the four selected health-related behaviors only explained a small portion of the income differences in mortality in agreement with previous studies (Lantz et al. 1998, 2001).

Our results indicate that higher prevalence of health-risk behaviors among individuals with poor income is not the dominant mediating mechanism capable to explain income disparities in mortality, as already suggested (Lantz et al. 2001). Additionally, the relatively poor accounting of health-related behaviors may support the hypothesis that socioeconomic differences in mortality are likely to persist even with improved health behaviors (Lantz et al. 1998).

As well as for behavioral factors, biomedical and psychosocial indicators poorly contributed to the explanation of the education/income disparities in mortality.

Altogether, the explanatory factors accounted for up to a half of the association of different combinations of income and education with mortality. Of notice, our results are in agreement with data from a large sample of Norwegian men from the Hunt study (Skalická et al. 2009) in which

Table 3 Combinations of household income and education on mortality and role of material, behavioral, biomedical and psychosocial factors (MOLI-SANI study, Italy, 2005–2010)

	Model 1 (HR; 95 % CI)	Model 1 + material factors (HR; 95 % CI)	Model 1 + health behaviors (HR; 95 % CI)	Model 1 + biomedical factors (HR; 95 % CI)	Model 1 + psychosocial factors (HR; 95 % CI)	Model 1 + all factors[a] (HR; 95 % CI)
Education						
None or primary and <10,000	–1–	–1–	–1–	–1–	–1–	–1–
None or primary and 10,000–25,000	0.87 (0.68–1.11)	0.89 (0.70–1.14)	0.87 (0.68–1.11)	0.86 (0.67–1.10)	0.90 (0.70–1.15)	0.93 (0.72–1.20)
		−15.4	*0.0*	*+7.7*	*−23.1*	*−46.2*
None or primary and 25,000–40,000	1.10 (0.71–1.68)	1.16 (0.76–1.78)	1.09 (0.71–1.68)	1.07 (0.69–1.64)	1.15 (0.75–1.76)	1.18 (0.76–1.84)
		+60.0	*−10.0*	*−30.0*	*+50.0*	*+80.0*
None or primary and >40,000	0.83 (0.26–2.63)	0.87 (0.28–2.76)	0.87 (0.28–2.74)	0.85 (0.27–2.68)	0.87 (0.28–2.76)	0.96 (0.30–3.05)
		−23.5	*−23.5*	*−11.8*	*−23.5*	*−76.5*
Middle school and <10,000	1.73 (1.09–0.73)	1.69 (1.07–2.67)	1.72 (1.09–2.72)	1.69 (1.07–2.68)	1.65 (1.05–2.61)	1.61 (1.01–2.58)
		−5.5	*1.4*	*−5.5*	*−11.0*	*−16.4*
Middle school and 10,000–25,000	1.20 (0.90–1.59)	1.22 (0.92–1.62)	1.20 (0.90–1.59)	1.17 (0.88−1.55)	1.24 (0.93–1.65)	1.25 (0.93–1.67)
		+10.0	*0.0*	*−15.0*	*+20.0*	*+25.0*
Middle school and 25,000–40,000	**0.49 (0.30–0.81)**	**0.52 (0.32–0.85)**	**0.49 (0.30–0.80)**	**0.50 (0.30–0.81)**	**0.51 (0.31–0.83)**	**0.54 (0.33–0.88)**
		−5.9	*0.0*	*−2.0*	*−3.9*	*−9.8*
Middle school and >40,000	1.51 (0.89–2.54)	1.66 (0.98–2.80)	1.64 (0.97–2.76)	1.47 (0.87–2.48)	1.57 (0.93–2.66)	1.81 (1.05–3.09)
		+29.4	*+25.5*	*−7.8*	*+11.8*	*+58.8*
Secondary school and <10,000	1.29 (0.60–2.78)	1.32 (0.61–2.85)	1.27 (0.59–2.75)	1.36 (0.63–2.94)	1.19 (0.55–2.57)	1.32 (0.60–2.89)
		+10.3	*−6.9*	*+24.1*	*−34.5*	*+10.3*
Secondary school and 10,000–25,000	0.92 (0.67–1.28)	0.97 (0.70–1.35)	0.90 (0.65–1.25)	0.93 (0.67–1.29)	0.90 (0.65–1.25)	0.95 (0.68–1.32)
		−62.5	*+25.0*	*−12.5*	*+25.0*	*−37.5*
Secondary school and 25,000–40,000	**0.68 (0.49–0.94)**	**0.74 (0.53–1.03)**	**0.69 (0.50–0.97)**	**0.66 (0.48–0.92)**	**0.70 (0.50–0.97)**	**0.77 (0.55–1.09)**
		−18.8	*−3.1*	*+6.3*	*+6.2*	*−28.1*
Secondary school and >40,000	**0.46 (0.30–0.73)**	**0.53 (0.33–0.84)**	**0.49 (0.31–0.77)**	**0.51 (0.32–0.80)**	**0.48 (0.31–0.75)**	**0.61 (0.38–0.97)**
		−13.0	*−5.6*	*−9.3*	*−3.7*	*−27.8*
University or higher and <10,000	1.04 (0.15–7.45)	0.96 (0.13–6.88)	1.10 (0.15–7.93)	0.85 (0.11–6.36)	0.89 (0.12–6.43)	0.86 (0.12–6.41)
		−200.0	*+150.0*	*−475.0*	*−375.0*	*−450.0*
University or higher and 10,000–25,000	0.45 (0.18–1.11)	0.49 (0.20–1.22)	0.47 (0.19–1.15)	0.50 (0.20–1.23)	0.38 (0.15–0.95)	0.50 (0.20–1.24)
		−7.3	*−3.6*	*−9.1*	*+12.7*	*−9.1*
University or higher and 25,000–40,000	0.74 (0.48–1.16)	0.81 (0.51–1.28)	0.75 (0.48–1.18)	0.71 (0.45–1.12)	0.73 (0.47–1.15)	0.77 (0.48–1.22)
		−26.9	*−3.8*	*+11.5*	*+3.8*	*−11.5*

Table 3 continued

	Model 1 (HR; 95 % CI)	Model 1 + material factors (HR; 95 % CI)	Model 1 + health behaviors (HR; 95 % CI)	Model 1 + biomedical factors (HR; 95 % CI)	Model 1 + psychosocial factors (HR; 95 % CI)	Model 1 + all factors[a] (HR; 95 % CI)
University or higher and >40,000	**0.59 (0.38–0.92)**	**0.71 (0.45–1.13)**	**0.64 (0.41–1.01)**	**0.64 (0.41–0.99)**	**0.61 (0.39–0.96)**	**0.82 (0.51–1.33)**
		−29.3	*−12.2*	*−12.2*	*−4.9*	*−56.1*

Model 1 adjusted for age and sex

Material factors: occupation (non-manual, manual, other, retired, housewife), housing tenure (rented, dwelling ownership, additional dwelling ownership), SES in childhood (score)

Health behaviors: smoking (no, current, former), sport activity (none, <2 h/week or ≥2 h/week), waist to hip ratio (quintiles) and Mediterranean diet score (4-levels: poor, average, better than average and very good adherence)

Biomedical factors: C-reactive protein (quintiles), leukocyte count (quintiles), cardiovascular disease, cancer and diabetes at baseline

Psychosocial factors: marital status (married/cohabiting, divorced/separated, single and widower)

Percentage (%) change in hazard ratios obtained by [(HR model 1) − (HR explanatory models)]/[(HR model 1) − 1]

HR; 95 % CI hazard ratios with 95 % confidence intervals

Italics indicate the percentage change in hazard ratios

[a] Hazard ratios from Model 1 + material factors + health behaviors + biomedical factors + psychosocial factors

additional material resources contributed to the income gradient more than behavioral and biomedical indicators, the latter explaining to a greater extent the observed educational disparities. Yet, all pathways under analysis are probably interrelated, indicating that some mechanisms work through others rather than independently from each other (van Oort et al. 2005; Dunn 2010). Other possible explanations for the socioeconomic gradient in mortality may be that less advantaged groups are less prone to monitoring their own health status independently of any health-awareness. This can be of crucial importance especially at a time of economic crisis (Bonaccio et al. 2014).

Strengths and limitation of this study

Major strengths of the present study are represented by the large number of subjects involved, the explanatory factors considered and its prospective design.

A major limitation is the exclusion of individuals with missing data on income who represent about 30 % of the population originally enrolled. Yet, such a large non-respondent group is quite common in this type of investigation, since income is a sensitive issue and people are often reluctant to provide such information. Other individuals do not even know exactly their household income (Galobardes et al. 2006a, b; Bonaccio et al. 2012). Generally, individuals with missing income information do not represent a random sample of the population (Kim et al. 2007) and many (Kim et al. 2007; Potter et al. 2005; Winkleby and Cubbin 2003) but not all (Turrell 2000) agree that this sample is likely to represent the most vulnerable socioeconomic group. The potential bias of excluding participants with missing incomes may lead to under-over estimation of a number of characteristics of the population under study (Kim et al. 2007).

However, the study sample and the subgroup who refused to give information on income, shared similar prevalence of major chronic diseases at baseline (CVD: 5.0 vs 6.2 %, cancer: 3.1 vs 3.5 % respectively with age/sex adjusted p values >0.05) but differed for some health conditions (diabetes: 9.1 vs 10.8 %; hypercholesterolemia: 28.6 vs 36.2 % respectively with age/sex adjusted p value <0.0001). Additionally, those not declaring income were more likely to be less educated but reported no differences in SES in childhood ($p > 0.05$). Moreover, underreporting of income information cannot be entirely excluded.

Another limitation of this study relies in the unaddressed accounting of other explanatory factors which have been proven to play a substantial role in accounting for social inequalities, e.g. stress status (Dunn 2010; Rod et al. 2009) or adverse life events (Rosengren et al. 1993). Also, it might be that the psychological dimension has been underestimated since marital status and depression were used as the sole markers of it.

A further limitation of our approach is the one-time measures of behavioral and biomedical factors that are unlikely to fully capture exposure over the life course (Lantz et al. 2001; Stringhini et al. 2010).

On the other side, we are confident in excluding, or at least minimizing, possible disparities in access to health-care or medication, since the Italian National Health Service is completely free of charge for everyone.

Conclusions

Our findings highlight the complexity of the interrelatedness of education and income as health determinants thus suggesting a careful accounting of both variables when dealing with the association between SES and health outcomes. Moreover, our data support the view that the predictive power of socioeconomic indicators on health run the risk of being fruitless, if interrelations between various indicators are neglected (Geyer et al. 2006).

We found that material resources, such as income, are inversely associated with all-cause mortality when combined with a higher educational level, a proxy of a complex set of knowledge and skills.

Additionally, the accounting of behavioral and biomedical factors was negligible suggesting that SES inequities in mortality cannot be entirely ascribed to a higher prevalence of risky behaviors and adverse biomedical profiles in low SES groups. At variance, other indicators of material resources, such as occupation, housing tenure and socioeconomic conditions during childhood did contribute substantially to the health advantages reported by subjects with a more desirable combination of income and education. Finally, the study shows that a socioeconomic gradient in mortality exists also in Italy, a country traditionally considered as having smaller inequalities than most European Countries (Federico et al. 2013; Mackenbach et al. 2008).

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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Informed consent Informed consent was obtained from all individual participants included in the study.

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