Differences in the Mediating Role of HL in Socioeconomic Inequalities in Health Across Age Groups: Results from the Dutch Doetinchem Cohort Study

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ABSTRACT

Background: Although it is known that health literacy (HL) plays an explanatory role in educational inequalities in health, it is unknown whether this role varies across age groups. **Objective:** The purpose of this study was to investigate whether the mediating role of HL in educational inequalities in four health outcomes varies across age groups: age 46 to 58 years, age 59 to 71 years, and age 72 to 84 years. **Methods:** We used data from the Dutch Doetinchem Cohort Study, which included 3,448 participants. We included years of education as predictor, chronic illness prevalence and incidence, mental and self-perceived health as outcomes, and HL, based on self-report, as mediator. We used multiple-group mediation models to compare indirect effects across age groups. **Key Results:** In the complete sample without age stratification, HL partly mediated the effect of education on all health outcomes except for incidence of chronic diseases. These indirect effect estimates were larger for subjective (self-perceived health, proportion mediated [PM] = 37%, and mental health, *PM* = 37%) than for objective health outcomes (prevalence of chronic disease, *PM* = 17%). For the prevalence of chronic disease, the indirect effect estimate was significantly larger among individuals age 46 to 58 years compared to individuals age 59 to 71 years and for incidence of chronic disease also compared to individuals age 72 to 84 years. All other indirect effect estimates did not differ significantly between age groups. Using an alternative cut-off point for HL or adjusting for cognitive functioning did not meaningfully change the results. **Conclusions:** Overall, we found that the explanatory role of HL in educational inequalities in mental and subjective health was stable but that it varied across age groups for chronic diseases, where it was largest among individuals age 46 to 58 years. Future studies may investigate the benefits of starting to intervene on HL from a younger age but means to improve HL may also benefit the subjective health of older adults with lower education. **[*HLRP: HL Research and Practice*. 2023;7(1):e26–e38.]**

Plain Language Summary: This study examined age-group differences in the mediating role of HL in the relationship between education and health. Overall, we found that the explanatory role of HL in educational inequalities in mental and subjective health was stable but that it varied across age groups for chronic diseases, where it was largest among individuals age 46 to 58 years compared to individuals age 59 to 71 years and individuals age 72 to 84 years.

Over the past decades, health literacy (HL) has been a subject of increasing interest for research, practice and policy in health care and health promotion. HL is defined as "the degree to which individuals have the capacity to obtain, process, and understand basic health-related decisions" (Sørensen et al., 2012, p. 3). One reason that HL has received much interest in public health research is because it is seen as a promising entry point for interventions that could reduce socioeconomic inequalities in health (Nutbeam & Lloyd, 2021; Pelikan et al., 2018). This topic is especially relevant because relative socioeconomic inequalities in health have increased over the past decades (Mackenbach et al., 2016; Mackenbach et al., 2018).

On average, individuals with higher education (although not exclusively) have higher HL (Sun et al., 2013; van Der Heide et al., 2013), because they have more cognitive and social resources that promote understanding of health-related information (Wolf et al., 2009). In turn, HL is positively associated with health outcomes (Bennett et al., 2009; Bostock & Steptoe, 2012; Miranda et al., 2020), because it partly determines one's access to health information and health care, improves medication use, and stimulates behaviors that may prevent disease (van der Heide et al., 2014). Consistent with these findings, a small but increasing body of literature has showed that HL partly mediates the effect of education on health (Stormacq et al., 2019). This mediating role has been found for objective health outcomes, such as chronic diseases (van Der Heide et al., 2013; Zou et al., 2016), and subjective outcomes such as self-rated health (Bennett et al., 2009; van Der Heide et al., 2013) and mental health (Howard et al., 2006).

Although various studies have investigated the mediating role of HL in socioeconomic inequalities in health (Stormacq et al., 2019), none have addressed whether this role varies across age groups. However, there are various reasons for why this may be the case. First, evidence shows that relative socioeconomic inequalities in health are largest between ages 50 and 60 years and decrease thereafter (Dupre, 2007; Huisman et al., 2004). Explanations for this fact include variation in the distribution of risk factors across birth cohorts (i.e., smoking and alcohol misuse) and selective survivorship (i.e., lower educated individuals are more likely to die at younger ages than higher educated individuals, thereby reducing the number of unhealthy lower educated individuals in older age groups and narrowing socioeconomic inequalities in health). Because the magnitude of socioeconomic inequalities is smaller among older adult age groups, HL may potentially play a larger role in socioeconomic inequalities in middle-aged groups than in older-age groups.

Second, HL tends to decrease with age, due to deteriorating cognitive functioning in older age (Geboers et al., 2018; Kobayashi et al., 2015). At the same time, particularly for older adults, HL may be more important for maintaining good health, because they tend to face more health problems and become more dependent on care (Timmermans et al., 2019). If the rate of decline in HL and need for health support varies across socioeconomic groups, this might affect the extent to which HL explains socioeconomic inequalities in health in different age groups.

Third, over the last decades, individuals are increasingly expected to manage their own health (Du & Yuan, 2010; Geboers, 2017). Much more than in the past, care systems are characterized by shared decision-making and the expectation that patients play a proactive role in their own health and health care (Bodenheimer et al., 2002; Epstein & Street, 2011). Citizens are nowadays more intensively informed about prevention and health behaviors and expected to use this information to monitor and optimize their health (Mackenbach, 2012). Nevertheless, current younger-age groups may be more intensively exposed and receptive to this development than older-age groups. Therefore, HL may be more important

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in younger age groups as an explanatory mechanism for education inequalities in health.

Taken together, we expect that the extent to which HL explains socioeconomic inequalities in health differs between younger- and older-age groups. As such, there is a need to better understand the way in which aging influences the mechanisms underlying socioeconomic inequalities in health. In this study, we explore whether and how the explanatory role of self-perceived HL varies across age groups of 46 to 58, 59 to 71, and 72 to 84 years.

METHODS

We used data from the Doetinchem Cohort Study (DCS) in the Netherlands (Picavet et al., 2017). DCS focuses on the association of lifestyle and biological risk factors over the life course on positive and negative health outcomes with aging. Based on a random, age- and sex-stratified sample from civil registries, inhabitants of the Dutch town of Doetinchem age 20 to 59 years were invited for the study. The first examination (N = 1,2405, response rate 62%) took place between 1987 and 1991. From the first examination, a random sample of 7,768 persons age 26 to 65 years was invited to participate in a second examination (1993-1997). Thereafter, re-examinations took place every 5 years for five subsequent waves, with the seventh wave currently ongoing (2018-2022). We use data from the sixth examination from 2013-2017, because this examination included HL for the first time. For incidence of chronic diseases information from all previous measurements were used. The total sample included 3,448 participants (response rate 77%) of whom 3,442 people age 46 to 84 years completed the HL questionnaire and were included in the present study.

Measures

Health outcomes. We dichotomized all health outcomes due to nonnormal distribution of residuals and to increase comparability of effects across outcomes.

Self-perceived health was based on the question “how would you rate your health in general?” using a five-point scale ranging from *poor* to *excellent*, which we dichotomized into either good (*excellent*, *very good*, and *good* = value 1) or poor perceived health (*moderate* and *poor* = value 0) (DeSalvo et al., 2006).

Mental health was measured using the Mental Health Inventory (MHI-5) with five items, such as “how much time during the last month have you felt downhearted and blue?” and a 5-point response scale (anchored at 1 = *all of the time* and 5 = *none of the time*). MHI-5 was scored from 0 (poor mental health) to 100 (good mental health) and dichotomized in poor mental health status (≤60) and good mental health (>60) (Berwick et al., 1991). Cronbach’s alpha was .85.

Prevalence of chronic conditions (PCD) included self-reported chronic conditions reported in the sixth examination that were already mentioned in earlier rounds and included the following: myocardial infarction, stroke, asthma, chronic obstructive pulmonary disease, cancer, diabetes, severe or persistent bowel disorders, joint inflammation, chronic joint inflammation (inflammatory rheumatism, chronic rheumatism, rheumatoid arthritis), diseases of the nervous system (Parkinson’s disease, multiple sclerosis, epilepsy), and diabetes mellitus. The conditions were summed and subsequently coded as having no versus having ≥1 chronic condition.

Incidence of chronic conditions (ICD) was included to account for the fact that HL may influence the occurrence of chronic diseases (Baker et al., 2000). It was based on whether participants reported one of the above-mentioned chronic conditions for the first time in the sixth examination that were not mentioned in any of the previous examinations. Similarly, as for prevalence of chronic diseases the conditions were summed and coded as having no versus having ≥1 chronic condition.

Education was obtained as the highest obtained school level, divided into nine levels. The levels 1 (elementary not completed) to 9 (university education) were recoded into the nominal number of years it takes to complete a level and ranged from 5 to 18 (5 = elementary not completed to 18 = university education).

HL was measured by the validated Brief HL Screening (Chew et al., 2004; Chew et al., 2008), which consists of the following three items:

1. “How often do you have someone help you read hospital materials?”
2. “How confident are you filling out medical forms by yourself?”
3. “How often do you have problems learning about your medical condition because of difficulty understanding written information?”

Response categories ranged from 1 to 5 (1 & 3: 1 = *never* to 5 = *always*; 2: 1 = *very much* to *really not*), resulting in a total score between 3 and 15. Cronbach’s alpha was .63. Because of a nonnormal distribution of residuals the measure was dichotomized into high (score of 13 or higher) and low HL (score of 12 or lower), based on prior studies (Geboers, 2017; Geboers et al., 2018).

Age was categorized in three age groups: 46 to 58, 59 to 71, and 72 to 84 years. Age ranges were chosen based on the age-range available in the sample and making sure the range was equal across age groups.

Sex (0 = male and 1 = female) was included as potential co-founder.

Global cognitive functioning. Because cognitive functioning is associated with age, education, and HL (Geboers et al., 2018; Kobayashi et al., 2016), we pre-planned a sensitivity analysis to examine the impact of cognitive functioning on the effect estimates. Following previous studies (Nooyens et al., 2011), we calculated a composite score comprised of four cognitive tests, including the 15-word verbal learning test (Van Der Elst et al., 2005), the Stroop Colour Word test (Van der Elst et al., 2006c), the Verbal Fluency Test (Van Der Elst et al., 2006b) and the Letter-Digit Substitution Test (Van der Elst et al., 2006a). For computing a composite score, all test scores were standardized and then summed to construct a global index of cognitive functioning (range, –2.9-2.5) (Nooyens et al., 2011).

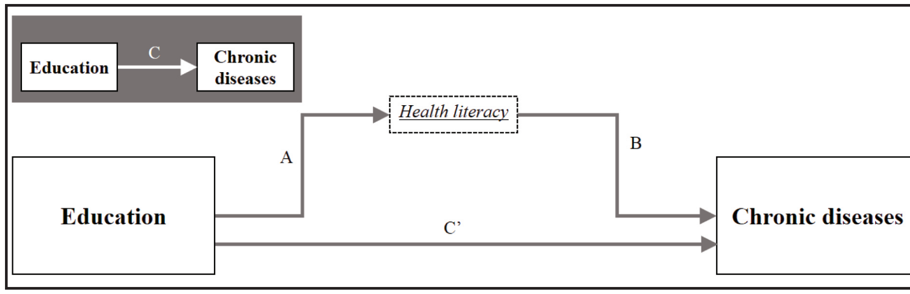

Figure 1. Visual presentation of the mediation model with chronic diseases as an example. y = year.

Procedure

We conducted mediation analyses using multiple group generalized structural equation models in STATA version 16 for each of the health outcomes separately. We first estimated the indirect effects for the pooled sample, without stratification for age groups. We calculated the indirect effects of education on the health outcome through HL using the following steps. We first estimated the total effect of education on the health outcome (c path in **Figure 1**) using logistic regression. Next, we used logistic regression to estimate the direct effects of education on HL (a path in **Figure 1**), education on the health outcomes (c' path in **Figure 1**), and HL on the health outcomes (b path in **Figure 1**). Subsequently, we calculated indirect effects by transforming the effect estimates of the a and b paths in **Figure 1** into to a risk difference scale (Valeri & VanderWeele, 2013) and then estimating 95% confidence intervals (CI) around these indirect effects using bootstrapping based on 1,000 bootstrap resamples (MacKinnon et al., 2004). Lastly, to allow comparison of indirect effects across outcomes, we calculated the proportion mediated through dividing the indirect effect by the total effect [ab/(ab+c')] (Rijnhart et al., 2019).

Subsequently, to test whether the strength of the indirect effects differed across age groups of 46 to 58 years, 59 to 71 years, and 72 to 84 years, we estimated 95% CI around the difference (hereafter difference). This tested whether the indirect effect estimates were statistically significantly different between age groups. For example, if the indirect effect of HL was significantly larger in the older age group, this indicated that the explanatory role of HL was more important in the older age group. To investigate if age group differences in the indirect effects were due to differences in the strength of the a path, the b path, or both of **Figure 1**, we additionally tested the equality of these specific direct effects with a Wald test. All estimated models were adjusted for sex and missing data were handled with equation wise deletion.

Sensitivity Analysis

We conducted two sensitivity analyses. First, we investigated whether the use of an alternative cut-off for high HL (≥14 instead of ≥13) would influence our results. The cut-off point of 14 or higher resulted in a prevalence of high HL of 66% versus 83% in the main analyses. Second, to test whether confounding by cognitive functioning would affect our conclusions, we estimated a separate model in which we adjusted the b paths and c paths of **Figure 1** for cognitive functioning.

RESULTS

Descriptive Statistics

Descriptive statistics are shown in **Table 1**.

The average number of years of education completed was highest in the age 46-58 years and age 59 to 71 years groups and lowest in the age 72 to 84 years group. The oldest age group had the highest percentage of chronic diseases (prevalence and incidence), poorest self-perceived health, and poorest mental health of the three age groups. The oldest age group also more often reported poor HL and on average scored lower on global cognitive functioning.

Total, Direct, and Indirect Effects in the Pooled Age Groups

Table 2 depicts the indirect and direct effects for the four health outcomes in the pooled age groups. The c paths (**Table 2**) represent the total effects of education on the health outcomes. For example, the total effect of education

TABLE 1

Characteristics in the Total Sample and Across Three Age Groups

Characteristic	Total *N* = 3,042	Age 46-58 Years *N* = 965	Age 59-71 Years *N* = 1,428	Age 72-84 Years *N* = 649	*p* Value[a]
Sex (% females)	53	56	52	49	< .01
Low education[b] (%)	42	31	43	55	< .001
Education (mean [*SD*] range: 5-18)	10.9 (2.5)	11.2 (2.7)	11.2 (3.0)	10.6 (3.1)	< .01
Health literacy (mean [*SD*] range: 3–15)	13.8 (1.6)	13.8 (1.6)	13.7 (1.4)	13.1 (1.9)	< .01
Low health literacy (<13%)	17	16	15	24	< .01
Low health literacy (<14%)	34	29	32	45	< .01
Incidence of chronic diseases (≥1% chronic disease)	17	14	20	32	< .001
Prevalence of chronic diseases (≥1% chronic disease)	37	28	40	61	< .001
Self-perceived health (% poor self-perceived health)	15	12	14	24	< .001
Mental health (% poor mental health)	12	12	11	16	< .01
Global cognitive functioning (mean [*SD*] range: –2.9-2.5)	–0.0 (0.8)	0.3 (0.7)[c]	0.1 (0.7)	–0.6 (0.7)	< .001

[a]*p* Values reflect the differences between the three age groups.
[b]Intermediate secondary education or less.
[c]Only available for respondents who were older than age 55 years, which resulted in 759 respondents.

on prevalence of chronic diseases was –0.07 (95% CI [–0.09, –0.04]), indicating that per one additional year of education the risk of having one or more chronic diseases was 7% lower. For all health outcomes, we found a negative association with education, confirming educational inequalities in health.

The indirect effect of education on the prevalence of chronic diseases was –0.012 (95% CI [–0.021, –0.003]), indicating that 1.2% lower risk of chronic diseases per additional year of education can be attributed to inequalities in HL (**Table 2**). Indirect effects were also statistically significant and in the same direction for self-perceived health (B = –0.028, 95% CI [–0.036. –0.019]) and mental health (B = –0.035, 95% CI [–0.043. –0.026]) but not for incidence of chronic disease. The proportion of the effect of education on health mediated by HL was larger for mental health (37%) and self-perceived health (37%) than for prevalence (17%) and incidence of chronic diseases (13%).

Age Group Differences in Indirect Effects

The indirect effect of education through HL on the prevalence and incidence of chronic disease was significantly larger in the age 46 to 58 years group than in the age 59 to 71 years group (PCD: B = –0.027, 95% CI [–0.049, –0.005] and ICD: B = –0.038, 95% CI [–0.067, 0.009], **Table 3**, **Figures 2A-2C**). For the incidence of chronic disease, the indirect effect was also significantly larger in the age 46 to 58 years group than in the age 72 to 84 years group (B = –0.003, 95% CI [–0.057, –0.005], **Table 3**, **Figures 2A, 2D**, and **2E**). These differences in the indirect effect between age groups were mainly due to differences in the direct effect of HL on chronic diseases (the b path of **Figure 1**). This direct effect was substantially larger in the age 46 to 58 years group than in the other age groups, indicating that particularly in this younger age group, higher HL was associated with a lower likelihood of prevalence and incidence of chronic disease. The direct effect of education on HL (the a path of **Figure 1**) was equal across age groups. For self-perceived health and mental health, no statistically significant differences in indirect effects across age groups were found (**Figure 3**).

Sensitivity Analysis

The sensitivity analyses with the alternative cut-off point for low HL did not lead to meaningful changes in the effect estimates between education, HL and various health outcomes (**Table A**).

After adjusting for global cognitive functioning, most indirect effect estimates diminished slightly, with the exception of the positive indirect effect estimates education on the prevalence and incidence of chronic diseases through HL, which slightly increased in older age groups. There were no differences in the variation of the mediating effects of HL across age groups of HL from the main analysis **(Table B)**.

DISCUSSION

This study investigated whether the mediating role of HL in educational inequalities in objective and subjective health varies across age groups of 46-58 years, 59-71 years, and 72-84 years. We observed that HL partly explained the relationship between education and health, and that the explanatory role was slightly larger for subjective (i.e., self-perceived and mental health) than for objective (i.e., prevalence and incidence of chronic disease) health outcomes. We found few age group differences in the mediating role of HL. Only for the prevalence and incidence of chronic diseases, the mediating role of HL was larger in the age group of 46 to 58 years compared to the age group of 59 to 71 years and for incidence of chronic diseases the mediating role was also larger than in the age group of 72 to 84 years. These findings were not due to differences in educational inequalities in HL between age groups, but rather because HL was more strongly associated with chronic diseases in the younger age group.

Our finding that HL partly mediated the relationship between educational inequalities in chronic diseases (proportion mediated: 19%), self-perceived health (37%) and mental health (37%), is consistent with the literature (Stormacq et al., 2019). The finding that its role was larger in subjective than objective outcomes is also consistent with prior studies (Bennett et al., 2009; van Der Heide et al., 2013) that used HL measures based on health-related tasks. An explanation that has been suggested for the latter finding is that HL benefits health and wellbeing via two different pathways. First, via disease prevention, such as access to health information and promoting a healthy lifestyle (Bennett et al., 2009). And second, via mitigating disease severity, such as through adherence to medication use and seeking health care (van der Heide et al., 2014). Whereas the chances of developing a chronic disease might mainly reflect the preventive pathway, more holistic measures of health such as self-rated health may reflect both the preventive and curative aspects of HL. Perhaps this is why the mediating role of HL is larger in subjective outcomes.

Nevertheless, an alternative, methodological explanation could be that the relationship between HL and health might be due to same-source bias. Research has shown that

TABLE 2

Direct and Indirect Effect Estimates of Education and Health Literacy on Health Outcomes

Coefficient	PCD			ICD			SPH			MH		
	B	95% (CI)	PM	B	95% (CI)	PM	B	95% (CI)	PM	B	95% (CI)	PM
A	0.26	[0.22, 0.30]		0.26	[0.22, 0.30]		0.26	[0.22, 0.30]		0.26	[0.22, 0.30]	
B	−0.26	[−0.46, −0.06]		−0.15	[−0.40, 0.10]		−0.66	[−0.9, −0.42]		−0.89	[−1.11, −0.64]	
C'	−0.06	[−0.08, −0.03]		−0.05	[−0.08, −0.02]		−0.08	[−0.11, −0.04]		−0.06	[−0.10, −0.02]	
C	−0.07	[−0.09, −0.04]		−0.05	[−0.09, −0.02]		−0.10	[−0.14, −0.06]		−0.09	[−0.14, −0.05]	
AB	−0.012	[−0.021, −0.003]	17%	−0.007	[−0.019, 0.004]	13%	−0.028	[−0.036, −0.019]	37%	−0.035	[−0.043, −0.026]	37%

Note. All effect estimates are adjusted for sex. PCD and ICD were coded as 0 for no chronic disease and 1 one or more for chronic diseases. SPH was coded as 0 for good to excellent self-perceived health and 1 for poor to moderate self-perceived health. MH was coded as 0 for good mental health and 1 for poor mental health. A = education on health literacy; AB = indirect effect; B = health literacy on outcome, C' = education on outcome after adjusting for health literacy, C = education on outcome; CI = confidence interval; ICD = incidence chronic disease; MH = mental health; PCD = prevalence chronic disease; PM = proportion mediated.

TABLE 3

Indirect and Direct Effect Estimates of Education and Health Literacy on Health Outcomes Across Age Groups

	PCD			ICD			SPH			MH		
Coefficient	B	95% (CI)	PM	B	95% (CI)	PM	B	95% (CI)	PM	B	95% (CI)	PM
	Age 46-58 years											
A	0.27	[0.19, 0.35]		0.27	[0.18, 0.35]		0.27	[0.18, 0.35]		0.27	[0.18, 0.35]	
B	–0.60[b]	[–1.00, –0.22]		–0.64[b,c]	[–1.11, –0.17]		–0.64	[–1.11, –0.16]		–1.00	[–1.45, –0.55]	
C′	–0.06	[–0.12, –0.00]		–0.08	[–0.16, –0.00]		–0.05	[–0.21, 0.60]		–0.07	[–0.16, 0.01]	
C	–0.08	[–0.13, –0.02]		–0.10	[–0.18, –0.02]		–0.07	[–0.15, 0.01]		–0.11	[–0.20, –0.03]	
AB	–0.026[b]	[–0.041, –0.011]	33%	–0.028[b,c]	[–0.045, –0.010]	37%	–0.027	[–0.045, –0.009]	26%	–0.039	[–0.054, –0.023]	40%
	Age 59-71 years											
A	0.24	[0.17, 0.30]		0.24	[0.17, 0.30]		0.24	[0.15, 0.30]		0.24	[0.17, 0.32]	
B	0.02[a]	[–0.29, 0.34]		0.20[a]	[–0.23, 0.62]		–0.50	[–0.88, –0.11]		–0.78	[–1.19, –0.36]	
C′	–0.05	[–0.08, –0.00]		–0.02	[–0.06, 0.31]		–0.09	[–0.15, –0.03]		–0.04	[–0.10, 0.02]	
C	–0.08	[–0.08, –0.08]		–0.01	[–0.10, –0.16]		–0.10	[–0.16, –0.05]		–0.06	[–0.13, –0.00]	
AB	0.001[a]	[–0.016, 0.018]	-	0.010[a]	[–0.013, 0.034]	-	–0.024	[–0.040, –0.007]	27%	–0.035	[–0.050, –0.019]	39%
	Age 72-84 years											
A	0.26	[0.18, 0.34]		0.26	[–0.13, 0.18]		0.26	[0.18, 0.34]		0.26	[0.18, 0.34]	
B	–0.10	[–0.50, 0.30]		0.07[a]	[–0.36, 0.50]		–0.73	[–1.14, –0.32]		–0.84	[–1.31, –0.37]	
C′	–0.06	[–0.12, –0.01]		–0.07	[–0.04, –0.11]		–0.02	[–0.12, 0.03]		–0.05	[–0.14, 0.03]	
C	–0.06	[–0.11, –0.01]		–0.06	[–0.12, –0.01]		–0.07	[–0.13, –0.01]		–0.09	[–0.17, 0.01]	
AB	0.004	[–0.021, 0.012]	-	0.003[a]	[–0.016, 0.022]	-	–0.025	[–0.038, –0.013]	35%	–0.028	[–0.042, –0.014]	58%

Note. All effect estimates are adjusted for sex. Proportion mediated is not shown due to inconsistent mediation, which occurs when the direct and indirect effect estimates have opposite signs (MacKinnon, 2008). A = education on health literacy; AB = indirect effect; B = health literacy on outcome, C′= education on outcome after adjusting for health literacy, C = education on outcome; CI = confidence interval; ICD = incidence chronic disease; MH = mental health; PCD = prevalence chronic disease; PM = proportion mediated.

[a]Different from age 46-58 years.
[b]Different from age 59-71 years.
[c]Different from age 72-84 years.

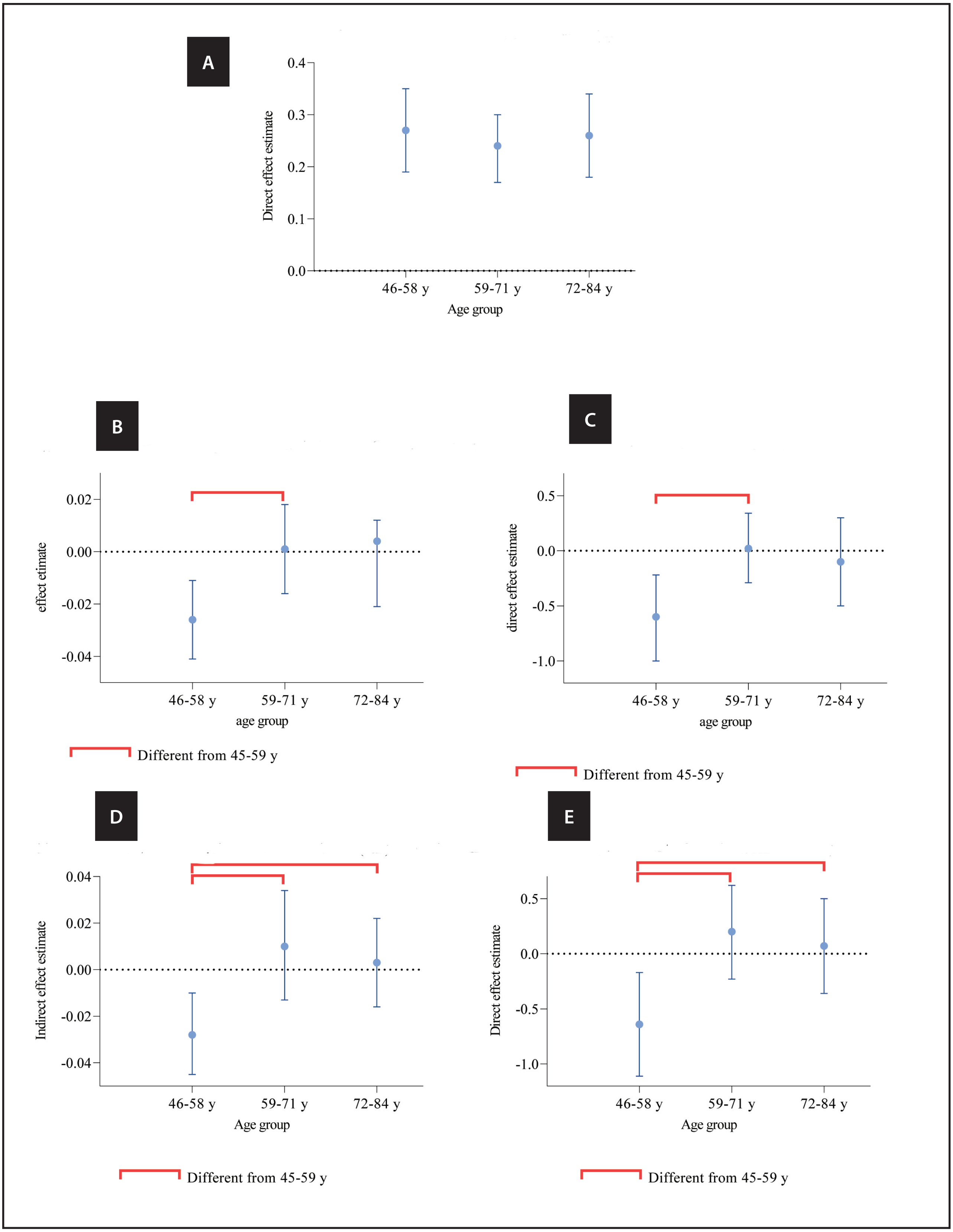

Figure 2. (A) Direct effect estimate education on health literacy (HL). (B) Indirect effect estimates prevalence chronic diseases (PCD) via HL. (C) Direct effect estimates HL on PCD. (D) Indirect effect estimates incidence chronic diseases (ICD) via HL. (E) Direct effect estimates HL on ICD. y = year.

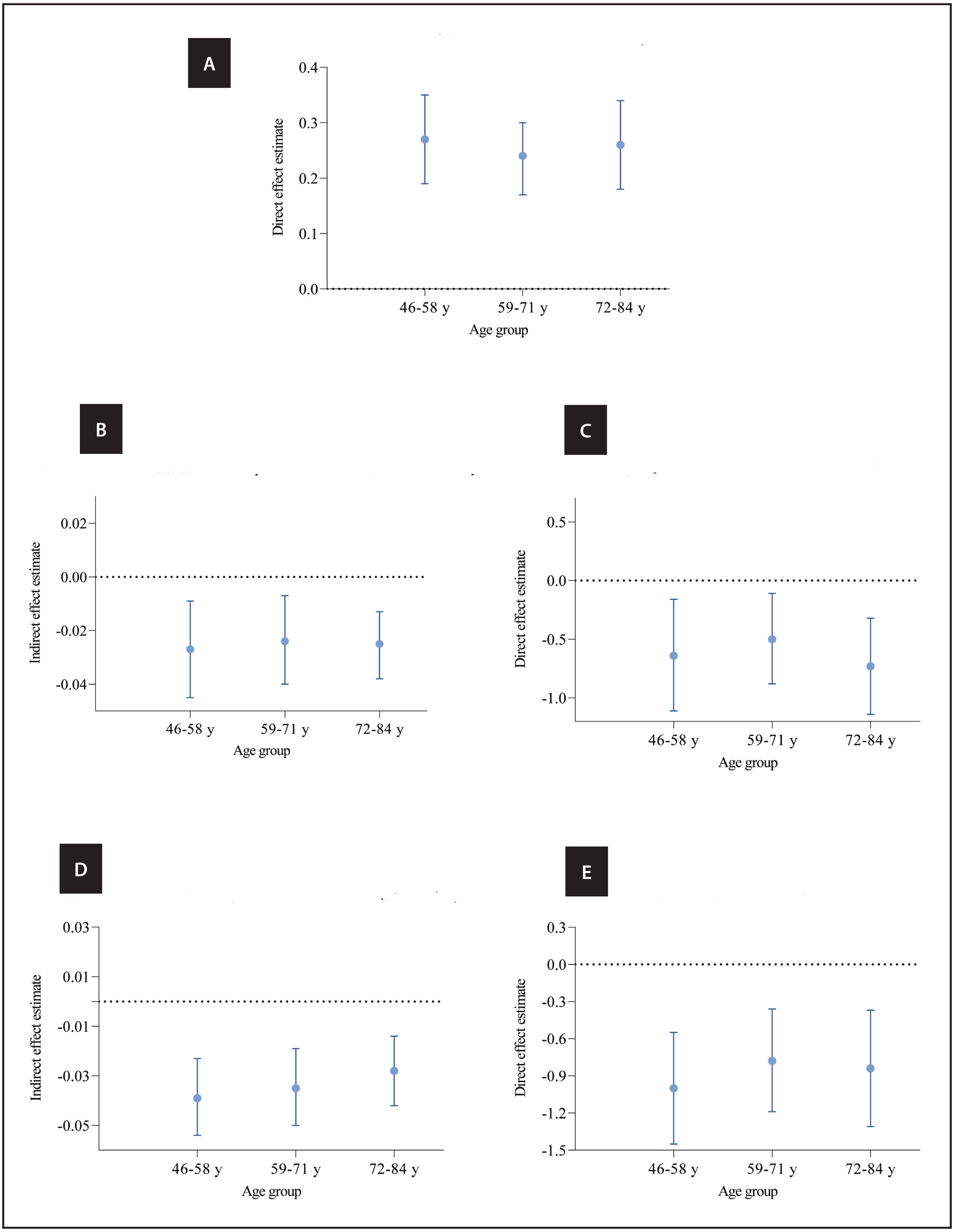

Figure 3. (A) Direct effect estimate education on health literacy (HL). (B) Indirect effect estimates self-perceived health (SPH) via HL. (C) Direct effect estimates HL on SPH. (D) Indirect effect estimates mental health (MH) via HL. (E) Direct effect estimates HL on MH. y = year.

individuals who report poor subjective health outcomes are also likely to evaluate other aspects in their life, including HL, more negatively (Fiedler et al., 2018). In addition, self-reported measures may be influenced by psychological traits such as self-confidence (Hofmann et al., 2005). Together, this could then inflate the association between HL and health outcomes. This may be particularly the case for more subjective health outcomes such as self-perceived health and mental health that are known to be prone to this type of bias (Chum et al., 2019).

The results were suggestive of a stronger mediating role of HL on educational inequalities in health for younger compared to older age groups, specifically for chronic diseases. Moreover, we found that this difference was largely because HL was a stronger predictor of chronic disease in the younger compared to the older age groups. This finding could be due to a combination of cohort and age effects in the importance of HL for health and health care. The younger age groups may have benefited more from the societal developments as patient-centered care and more knowledge on prevention (Epstein & Street, 2011). Therefore, the importance of HL for educational inequalities in health has increased relatively more among younger compared to older age groups. Our findings suggest that this is particularly the case for the objective outcomes of incidence and prevalence of chronic diseases. Our finding that HL was particularly important for chronic diseases in age groups of 46 to 58 years concurs with research showing that age dependent chronic diseases start to manifest largely within these age groups (Brody & Schneider, 1986). This may drive a larger wedge between higher and lower educated individuals as well as increase the importance of the role of HL in educational inequalities in health. Furthermore, younger individuals may be exposed to the contemporary promotion of individual responsibility for health, and to patient-centered care systems that encourage people to play an active and informed role with regards to their own health (Bodenheimer et al., 2002; Epstein & Street, 2011). These developments suggest that HL will even become more important for educational inequalities among future generations.

Nevertheless, part of the age-differences in the mediating role of HL might be attributable to the way in which HL was measured in our study. Our measure of HL assessed how often individuals needed help with understanding hospital materials and written information as well as their confidence in filling out forms. Older adults may be more likely to have answered these questions affirmatively simply because they are more likely to experience chronic diseases (Tsang et al., 2008) and have more frequent contact with medical care (Hibbard & Pope, 1986; Levesque et al., 2013). Nevertheless, it might also be that younger adults who do not encounter medical care themselves still acquire knowledge about their HL through shared decision-making while caring for a loved one (Rapley, 2008). Taken together, it is important for future studies to include performance-based measures of HL, that rely less heavily on whether participants actually had contact with health services (Blom et al., 2018).

STRENGTHS AND LIMITATIONS

We used a rich data source and were able to include both subjective and objective outcomes as well to adjust for cognitive functioning. Furthermore, we used a measure of HL that has been previously validated (Chew et al., 2004; Chew et al., 2008) and has been frequently used in research (Fransen et al., 2011; Geboers, 2017). Another strength is that we used contemporary methods derived from the most recent insights form causal mediation literature (Rijnhart et al., 2019) to establish both the indirect effect and the variations across age groups of HL in educational inequalities.

The study also has some limitations. First, it should be noted that our measure of HL was a self-report instrument and focused on one aspect of HL, namely functional HL. Functional HL mainly refers to reading skills and reading comprehension (Kobayashi et al., 2016). Other aspects may be important to examine the mediating role of HL across age groups, such as decision-making, problem solving and critical thinking (Fransen et al., 2011). The fact that our measure was self-reported may have led to an under- or overestimation of some associations, as people may not always be aware of their HL. Other measures, such as performance-based HL tests (Blom et al., 2018) or reading tests may solve this issue (Mancuso, 2009). Second, we were not able to apply the more generally accepted clinically relevant cut off point of 2 (averaged scale) previously described in the literature (Chew et al., 2008; Fransen et al., 2011). This yielded groups that were too small for further analysis (N = 23). This illustrates that HL, measured by self-report, was generally high in our sample, and that we may underestimate the role of inadequate HL in explaining educational inequalities in health. Moreover, it is possible that the individuals who were categorized in the lowest HL group only sometimes experienced trouble reading materials, filling out medical forms or understanding health information. Third, we used cross sectional data analysis and are therefore not able to determine reverse-causality and to distinguish life course and cohort differences. On the one hand, the degree to which individuals are aware of their lack of understanding of medical forms and hospital materials may only be realized after a chronic disease has appeared and individuals are actually confronted with medical materials (van der Heide et al., 2018). This may especially so among older adults who more likely to experience health problems (Tsang et al., 2008). On the other hand, there might be a learning effect when individuals have continuous contact with health care professionals following health problems (Edwards et al., 2015). Since we have measured the health outcomes at the same time as HL, neither of these explanations can be ruled out. Replicating the analysis using cross-sequential cohort studies with longitudinal data is needed to further explain these causal pathways.

CONCLUSION

Our results support an important role of HL in explaining educational inequalities in health. Although the differences in the mediating role of HL across age groups were not the same across health outcomes, we did find specific groups that are vulnerable to low HL, namely individuals with lower education between ages 46 and 58 years in the case of prevalence of chronic disease. This suggests that people with lower education in age younger than age 58 years may be more vulnerable to experiencing negative health effects from a low HL. As such, it may be relevant for future studies to investigate ways to improve HL from a younger age to tackle educational inequalities in health. Nevertheless, improving HL in all age groups remains important for subjective health outcomes. Overall, better support is needed among individuals who need help in understanding health information.

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Table A. Indirect effect estimates of education and health literacy (score of 13 or higher) and health outcomes across age groups

	Prevalence chronic disease (PCD)				*Incidence chronic disease (ICD)*				*Self-perceived health (SPH)*				*Mental health (MH)*			
	B	95% CI		PM	B	95% CI		PM	B	95% CI		PM	B	95% CI		PM
46-58 y	-0.012[B]	-0.021	-0.004	15%	-0.012[B.C]	-0.022	-0.003	16%	-0.017	-0.027	-0.007	17%	-0.019	-0.029	-0.010	19%
59-71 y	-0.000[A]	-0.008	0.008	0.1%	0.002[A]	-0.005	0.018	-	-0.020	-0.027	-0.013	23%	-0.022	-0.029	-0.015	24%
72-84 y	-0.002	-0.010	0.004	4%	0.000[A]	-0.008	0.009	-	-0.012	-0.018	-0.006	18%	-0.014	-0.017	-0.004	29%

Notes: A = different from 46-58 y, B = different from 59-71 y, C =different from 72-84 y, all effect estimates are adjusted for sex, all effect estimates are adjusted for sex, - Proportion mediated was not computed due to inconsistent mediation. which occurs when the direct and indirect effect estimates have opposite signs (MacKinnon 2008)

Table B. Indirect effect estimates of education and health literacy and health outcomes across age groups (adjusted for cognitive functioning)

	Prevalence chronic disease (PCD)				*Incidence chronic disease (ICD)*				*Self-perceived health (SPH)*				*Mental health (MH)*			
	B	95% CI		PM	B	95% CI		PM	B	95% CI		PM	B	95% CI		PM
46-58 y*	-0.021[B]	-0.039	-0.004	26%	-0.027[B.C]	-0.048	-0.007	36%	-0.020	-0.043	-0.003	20%	-0.036	-0.054	-0.018	37%
59-71 y	0.006[A]	-0.012	0.024	-	0.011[A]	-0.0137	0.035	-	-0.019	-0.038	0.001	21%	-0.035	-0.051	-0.020	39%
72-84 y	-0.003	-0.022	0.016	-	0.008[A]	-0.015	0.030	-	-0.013	-0.030	0.004	18%	-0.020	-0.037	-0.003	41%

Notes: A = different from 46-58 y, B = different from 59-71 y, C =different from 72-84 y, all effect estimates are adjusted for sex, - Proportion mediated was not computed due to inconsistent mediation. which occurs when the direct and indirect effect estimates have opposite signs (MacKinnon 2008), *only for 759 respondents for whom the global cognitive functioning measure was available