Towards Understanding the Links Between Health Literacy and Physical Health

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Towards understanding the links between health literacy and physical health

René Mõttus, PhD
Centre for Cognitive Ageing and Cognitive Epidemiology, University of Edinburgh, UK
Department of Psychology, University of Tartu, Estonia

Wendy Johnson, PhD
Centre for Cognitive Ageing and Cognitive Epidemiology, University of Edinburgh, UK
Department of Psychology, University of Edinburgh, UK
Department of Psychology, University of Minnesota – Twin Cities, USA

Catherine Murray, MSc
Department of Psychology, University of Edinburgh, UK

Michael S. Wolf, PhD
Health Literacy and Learning Program, Division of General Internal Medicine, Feinberg School of Medicine, Northwestern University, USA

John M. Starr, MD
Geriatric Medicine unit, Royal Victoria Hospital, Edinburgh, UK
Centre for Cognitive Ageing and Cognitive Epidemiology, University of Edinburgh, UK

Ian J. Deary. PhD*
Centre for Cognitive Ageing and Cognitive Epidemiology, University of Edinburgh, UK
Department of Psychology, University of Edinburgh, UK

* Corresponding author:
Centre for Cognitive Ageing and Cognitive Epidemiology
Department of Psychology
University of Edinburgh
7 George Square
Edinburgh EH8 9JZ
Scotland, UK
Email i.deary@ed.ac.uk

Abstract

Objective: Low health literacy predicts poor health, but the underpinnings of the associations are yet to be understood. This study tested the associations between health literacy and three objective health outcomes in older people and investigated the extent to which general (not health-related) cognition and earlier life-course factors such as childhood cognitive ability, educational level and occupational class accounted for these associations. **Methods:** Participants were 730 community-dwelling older people (350 women; mean age 72.50 years, *SD* = 0.71). Physical fitness (defined by walk time, lung function, and grip strength), body mass index, and count of natural teeth were used as health outcomes. Rapid Estimate of Adult Literacy in Medicine (REALM), Shortened Test of Functional Health Literacy in Adults (S-TOFHLA), and Newest Vital Sign (NVS) were used to measure health literacy. Age-11 and concurrent general cognitive ability, educational level, and occupational social class were used as co-variates. **Results:** Lower REALM, S-TOFHLA and NVS scores were associated with worse scores on all health outcomes (β = .09 to .17). However, cognitive ability in old age and childhood, educational and occupational levels accounted for the majority of these associations: after adjusting for these co-variates, only physical fitness was significantly associated with REALM and S-TOFHLA (β = .06 and .11). **Conclusions:** Low health literacy was associated with poorer health largely because it reflected general cognitive ability, educational and/or occupational levels. These variables plays some role in health beyond their association with the reading and numeracy skills captured by common health literacy measures.

Keywords: Health literacy; older age; morbidity; cognitive ability.

Introduction

Health literacy, defined as the “capacity to obtain, process and understand basic health information and services needed to make appropriate health decisions” (Institute of Medicine, 2004), is receiving increasing scientific and clinical interest because it appears to matter for people's health (Paasche-Orlow, Wilson, & McCormack, 2010). Recent systematic reviews have demonstrated that low health literacy test scores are associated with numerous adverse health outcomes and poor use of health care services (Berkman, Sheridan, Donahue, Halpern, Viera, et al., 2011; Berkman, Sheridan, Donahue, Halpern, & Crotty, 2011). Likewise, numeracy skills have been implicated in the ability to benefit from health care (Galesic & Garcia-Retamero, 2011; Wood et al., 2011). In order to lift literacy-related barriers to health, enhancing patients’ health literacy and numeracy (Baur & Ostrove, 2011; Galesic & Garcia-Retamero, 2011; Rudd, Soricone, Santos, Zobel, & Smith, 2005) and adjusting services to low literacy levels (Rudd, 2010) have been suggested. Examples of such efforts include interventions to improve diabetes management (Rothman et al., 2004), enhancing information-access skills (e.g., Campbell & Nolfi, 2005), and simplifying patient-doctor communications (e.g., Galesic, Gigerenzer, & Straubinger, 2009). The success of these interventions, however, has been mixed: a systematic review concluded that the interventions targeted at improving literacy per se have limited effect, whereas more specific self- and disease-management and adherence interventions may be moderately effective in improving patients' health (Berkman, Sheridan, Donahue, Halpern, Viera, et al., 2011).

There are various instruments for measuring health literacy, which help in understanding how the concept is typically operationalized. The most widely used instruments are the Rapid Estimate of Adult Literacy in Medicine (REALM; Davis et al., 1993) and the Test of Functional Health Literacy in Adults (TOFHLA; Parker, Baker, Williams, & Nurss, 1995). The REALM is a word recognition test which requires a person to pronounce a series of health-related words. It is assumed that, if participants cannot pronounce the word correctly, they are unlikely to comprehend it. TOFHLA asks people to fill word gaps in health-related passages, and perform numerical tasks commonly encountered in health-management. Another widely used test is the Newest Vital Sign (NVS), where participants are presented with a nutrition label from an ice cream package and asked six questions about it (Weiss et al., 2005). Besides demonstrating comprehension and numeracy abilities, participants must process and extract relevant information while ignoring distractors. The three tests take somewhat different approaches to health literacy, with the REALM focusing more on vocabulary, the TOFHLA reading items on reading fluency and, finally, the TOFHLA numeracy items and the NVS more on practical health-related tasks. Collectively, it might therefore be argued, the three tests cover the health literacy construct somewhat more comprehensively than any one of them alone.

These established assessments and their predictive validity notwithstanding, there remain important questions regarding the nature and utility of the health literacy concept. Whichever route is chosen to respond to low health literacy, its effectiveness may depend on how well the phenomenon's underpinnings are understood. To this end, it may be helpful to know how health literacy is associated with well-established psychological and social constructs and whether these associations can help to explain the health consequences of health literacy. For example, theoretical models of health literacy introduce general cognitive ability as one of its underpinnings (von Wagner, Steptoe, Wolf, & Wardle, 2008; Wolf et al., 2009). Indeed, there is some empirical evidence that performance in health literacy measures is related to general (not health-specific) cognitive differences among people (Federman, Sano, Wolf, Siu, & Halm, 2009; Levinthal, Morrow, Tu, Wu, & Murray, 2008; Murray, Johnson, Wolf, & Deary, 2011). In conjunction with the expanding literature that shows associations between general cognitive ability and a wide range of physical health variables including mortality (Deary, Weiss, & Batty, 2010), this suggests that cognitive ability may account for (confound) some of the associations between health literacy and actual health outcomes. If cognitive ability in general, and not just skills and knowledge specific to health is consequential for health, then plans to improve health by increasing health literacy (Baur & Ostrove, 2011) may be informed by the attempts to raise general cognitive ability (Nisbett et al., 2012). Likewise, prevention and health services could be adjusted to meet people's cognitive skills in a broader set of areas, not just literacy or numeracy alone. We emphasize, however, that there exists very little literature on the role of general cognitive ability in the health literacy-health associations (e.g., Baker et al., 2007).

Alternatively, health literacy may stem from other factors such as educational or occupational experiences (Gazmararian et al., 1999; Murray et al., 2011), suggesting that people develop their health literacy through being embedded in life-long social environments. However, it could also be that the contributions of educational and occupational levels to health literacy result indirectly from their own well-established reciprocal associations with pre-existing levels of cognitive ability (Deary & Johnson, 2010). It is known that cognitive ability differences as they exist before maximum educational attainment is achieved predict level of attainment and that these associations are to a marked degree characterized by shared genetic variance, among other contributors (for a discussion see Deary and Johnson, 2010). Furthermore, given the widely documented education- and social class-related health differences (Mackenbach et al., 2008), another important question is whether educational and social levels themselves can account for some of the associations that health literacy has with actual physical health: that is, better education and occupational experiences may facilitate both higher health literacy and better health. The latter possibility can have important implications for the usefulness of assessing health literacy for practical purposes. Assuming that information on patients' education and occupation is readily available to health-care providers, assessing health literacy *per se* may largely be redundant.

The present study investigated whether the three common health literacy measures (REALM, TOFHLA, NVS) predicted objective health indicators in older people, and whether the associations were to some extent explained by general cognitive ability, the assessment of which was not based on health-related or even verbal content in general. Although the three health literacy measures presumably tap the same underlying construct, they differ markedly in content: we therefore studied, which of the health literacy operationalizations were most strongly associated with health. In addition to concurrent general cognition, the role of childhood (age-11) cognitive ability was considered. By this, it was possible to consider the influence of 'baseline' cognitive ability long before participants absorbed most of the life-course influences on health literacy and health, and before aging and its associated ill-health affected their cognitive skills. Additionally, the roles of life-course characteristics such as education and occupation in the health literacy-health associations were tested. In bringing together this set of variables, we attempted to shed light on the underpinnings of health literacy-health associations and also on the practical utility of health literacy measurements for identifying people at risk. The latter question may also be formulated as follows: does health literacy add something to the known associations of cognitive ability, education and occupational class with health outcomes?

Childhood cognitive ability was measured before maximum educational achievement was typically achieved, which partially allowed us to separate the effects of 'baseline' cognitive ability and education on health literacy, health and their associations. Moreover, health literacy was measured about 50 years after people typically obtained their maximum educational level, making it less likely that the observed literacy itself could have been a direct contributor to educational attainment. Based on all this, we hypothesized that health literacy scores, cognitive ability in older age and childhood and educational and occupational levels would all be intercorrelated; that low health literacy would be linked to poorer health and that the association would be attenuated after adjusting for concurrent general cognitive ability, suggesting that it is not only literacy as such but cognition more broadly that matters for health; that the health literacy-health association also would also be attenuated after adjusting for childhood cognition, suggesting that life-long and not only older-age cognitive ability is relevant for health; and that educational and occupational levels would also explain (confound) some of the health literacy-health associations.

As health indicators, general physical fitness (a composite of 6 meter walk time, lung function and grip strength), body mass index (BMI), and number of natural teeth were used. We hypothesized that if low health literacy or cognitive ability in general incurs poor ability to take care of one's health, then, irrespective of the particular mechanisms involved, this would be evident in lower physical fitness. Likewise, low literacy, or cognitive ability in general, may create difficulties in understanding (often written or spoken) information on why and how to develop healthy dietary habits and maintain sufficient levels of physical ability and take care of oral health, resulting in associations with elevated BMI and tooth loss. These indicators are associated with various other aspects of general health including mortality (Gale, Martyn, Cooper, & Sayer, 2007; Lord & Menz, 2002; Prospective Studies Collaboration, 2009; Tu et al., 2007; Young, Hopkins, & Eaton, 2007).

Method

Participants

The Lothian Birth Cohort 1936 is a study of healthy aging in the Edinburgh area of Scotland. At the first testing wave (not used here), 1,091 community-dwelling people (548 males; mean age 69.6, *SD* = 0.80, range from 67.7 to 71.3 years) were recruited between 2004 and 2007. Full details on the background and recruitment of the cohort and testing procedures are available elsewhere (Deary et al., 2007). The present study was based on data collected at the second wave of testing (Deary, Gow, Pattie, & Starr, in press), at around age 73 years (N = 730; 350 women; mean age 72.50 years, SD = 0.71), when assessment of health literacy was introduced. All participants provided informed consent. The prevalences of self-reported chronic/common health conditions were: diabetes (10.4%), high blood-pressure (49.5%), cardiovascular disease (28.8%), and cancer history (14.7%). Ethics permissions were obtained from the Multi-Centre Research Ethics Committee for Scotland.

Measures

Health literacy

Rapid Estimate of Adult Literacy in Medicine (REALM). In this test (Davis et al., 1993), described above, participants are asked to read aloud 66 words of increasing difficulty. Each word pronounced correctly gives 1 point. Initially developed in the US, the REALM has also been used in British samples (Ibrahim et al., 2008). REALM, and all other tests, were administered by native English speakers.

Shortened Test of Functional Health Literacy in Adults (S-TOFHLA). This test, (Baker, Williams, Parker, Gazmararian, & Nurss, 1999; Parker et al., 1995), also described above, contains a 4-item numeracy section, where participants' understanding of numerical medical instructions (such as time for taking medication) is assessed (each correct answer gives 7 points), and a 36-item reading comprehension section, in which participants have to read passages and select missing words from four possible options (each correct answer gives 2 points). The British version of Passage B (Wagner, Knight, Steptoe, & Wardle, 2007), which refers to government medical systems, was used.

Newest Vital Sign (NVS). In the NVS (Weiss et al., 2005), also described above, participants have to answer six questions about a ice-cream nutrition label (each correct answer gives 1 point).

Current general cognitive ability

Along with health literacy measurement, participants completed six non-verbal subtests of the UK version of the Wechsler Adult Intelligence Scale III (Wechsler, 1997): Matrix Reasoning, Block Design, Letter-Number Sequencing, Symbol Search, Digit Span Backwards, and Digit Symbol. In principal components analysis (PCA), only the first component (PC) had an eigenvalue (3.07) greater than 1; therefore only this component (explaining 51.2% of the total variance in subtest scores) was retained for further analyses. Scores from the first PC (mean = 0, SD = 1) were used as a measure of general cognitive ability. The correlations (loadings) of the subtest scores with the PC varied between .65 (Digit Span Backwards) and .76 (Symbol Search). The tests that were used to derive the PC had minimal verbal content and were not based on health- or medicine-related information; therefore the content overlap with the health-literacy measures was minimal.

Childhood cognitive ability

At age 11 years, almost all the participants were administered the Moray House Test no. 12 as part of the year-of-birth-cohort-wide Scottish Mental Survey 1947 (Deary, Whalley, & Starr, 2009). This group-administered test of general cognitive ability included mental tasks such as word classifications, proverbs, arithmetic, and spatial items (Deary et al., 2009). Raw scores were adjusted for age at time of testing and converted to a typical IQ-scale with mean of 100 (SD = 15).

Physical health

All assessments were carried out by a trained nurse. Six-meter walk time was the time to walk a measured length of 6 meters at normal pace. Grip strength was measured with a Jamar Hydraulic Hand Dynamometer; the best of three trials with the dominant hand was used. Forced expiratory volume in 1 second (FEV_1, an indicator of lung function) was measured using a microspirometer; the best of three trials was recorded. Natural teeth were counted. Weight and height, used for calculating BMI (weight in kilograms/height in meters^2), were measured at the clinic visit. Six-meter walk time and BMI values were log-transformed to obtain normal-like distributions.

Akin to Deary and colleagues (2006), six-meter walk time, FEV_1 and grip strength were subjected to PCA and scores of the resulting first unrotated principal component (PC) were used as a latent index of physical fitness. The PC explained 47.1% of variance in the three indicator scores, which loaded -.43, .78, and .79 on the PC (respectively for six-meter walk time, FEV_1 and grip strength).

Education and occupational social class

Highest level of educational attainment was coded into five ordinal categories ranging from ‘no qualification’ (0) to ‘university degree’ (4). Occupational class prior to retirement was captured on a scale ranging from manual labor (1) to professional (5) (Office of Population Censuses and Surveys, 1980). Women who reported higher occupational class for their spouses were classified according to their spouses. We treated educational level and social class as continuous measures.

Analytic procedur*e*

Rank-order correlations were used to test bivariate associations among all predictors of the health outcomes. Any associations with health outcomes were estimated using general linear models, always controlling for age and sex (for brevity, their effects are not reported). Cases with missing data on either health outcomes or health literacy scores were included but all regression models concerning particular health outcome-health literacy associations were based on the same numbers of observations, regardless of the number of co-variates included. Analyses were carried out using R 2.15 (R Development Core Team, 2012). Although numerous models were tested, we used 5% alpha level as the criterion for statistical significance because we were less interested in particular predictor-outcome combinations than in general univariate and multivariate patterns of associations.

Results

Table 1 gives descriptive statistics for the variables. The REALM and S-TOFHLA scores were strongly skewed, with most people obtaining very high scores: for example, 66.8% and 43.3% of people obtained maximum scores, respectively in REALM and S-TOFHLA. In the NVS, in contrast, the distribution of the six possible scores was more symmetric but uniform.

Table 2 shows that childhood and concurrent general cognitive ability, educational level, and occupational social class were all positively correlated among themselves and with the health literacy measures, with the rank-order correlations ranging from .30 to .56 (median .41). A particularly noteworthy aspect of those associations is that the health literacy measures tended to have, as a pattern, higher correlations with cognitive ability tests (mean r = .48)—even if these had been administered in childhood—than among themselves (mean r = .38). This may suggest poor convergent-discriminant validity of the health literacy tests, but it may also have resulted from the poor distributional properties and possibly lower reliability of these short instruments compared to the longer and psychometrically more sound cognitive ability tests. The health literacy test scores were also associated with education (mean r = .37) and occupational class (mean r = .31).

Table 3 shows that concurrent and childhood cognitive ability, educational level, and occupational social class were all significantly associated with physical fitness, BMI and number of teeth, with effect sizes ($|\beta|$) ranging from .09 to .26 (median .15), except for the association between concurrent general cognitive ability and BMI (β = -.07, p = .06).

Associations between health literacy and health outcomes

The associations between the health literacy measures and the three health outcomes are reported in the top rows of Tables 4 to 6. All three health outcomes were significantly associated with all three health literacy measures, with the associations ($|\beta|$) ranging from .17 to .20 ($p < .001$) for the number of teeth, from .11 to .16 ($p < .001$) for physical fitness, and from .08 to .10 ($p < .05$) for BMI.

Based on the findings that (a) the three health literacy measures tended to have fairly similar associations with the health outcomes, despite their different and non-normal distributions, and (b) the three health literacy test were at least moderately intercorrelated, we created a latent health literacy factor (HL). The HL was expected to summarize the common core of the three health literacy indicators and be more reliable and better distributed than any single health literacy test, thereby giving the health literacy construct a fairer chance to compete with cognitive ability test scores. To this end, a confirmatory factor model was constructed, whereby a latent HL factor was loaded by the REALM (defined as a count variable due to its distribution, although the scores had to be reversed so that the maximum score was 0), S-TOFHLA (also defined as a count variable after reversal of scores) and NVS (ordinal-categorical variable). The model was run in Mplus 6 (Muthén & Muthén, 2010) with Robust Maximum Likelihood estimator. The resulting HL factor scores were saved and used for further analyses. The HL scores were less skewed (-1.08) than the REALM and TOFHLA scores. The rank-order correlations of the three health literacy tests with the HL were r = .55, .94, and .62, respectively for the REALM, TOFHLA, and NVS.

The HL had the following correlations with other predictors: $r = .55$ and .60 (ages 11 and 73 cognitive ability, respectively), .44 (educational level) and .37 (occupational class; for all $p < 0.001$). It is noteworthy that the age-73 HL scores had correlations nearly in the same range with the two cognitive ability scores measured more than 60 years apart. In multivariate regression, the HL was strongly predicted by age-11 cognitive ability ($\beta = .45$, $p < .001$) and to a lower degree by educational level and occupational class (respectively $\beta = .14$ and .12, $p < .001$). For reference, the respective multivariate regression weights for concurrent general cognitive ability were ($\beta = .45$ and .20, $p < .001$, for age-11 cognitive ability and education; the effect of occupational class, $\beta = .07$, was not significant). In what follows, we focus on the associations of the HL scores with the health outcomes (the associations of individual health literacy tests are also given in Tables 4 to 6).

Physical fitness. After adjusting the associations between HL and physical fitness (Table 4) for concurrent general cognitive ability, the original HL associations ($\beta = .16$, $p < .001$) dropped by 43% to $\beta = .09$ ($p < .01$): according to the Sobel test, used throughout to make this kind of comparison, the attenuation was highly significant, $p < .001$. Adjustment for childhood ability did not have any effect but adjustments for educational level and occupational class attenuated the original associations by 24% ($p < .01$) and 15% ($p < .05$), respectively. Finally, full adjustment for all co-variates (concurrent and childhood cognitive abilities and educational and occupational levels) attenuated the original beta weight of the HL by 43% (as had done concurrent general ability alone). In the full model, HL, concurrent general cognitive ability and educational attainment had significant associations with physical fitness, with effect sizes ranging from $\beta = .07$ to .11 ($p < .05$). Controlling for everything else, higher childhood cognitive ability was associated with lower fitness ($\beta = -.07$, $p < .05$), possibly indicating overcorrection.

BMI. Among the three health outcomes, BMI had the weakest association with HL ($\beta = -.08$, $p < .05$; Table 5; the effect size difference with the number of teeth was significant at $p < .05$ and marginally non-significant with physical fitness, $p = .06$). Adjusting the association for concurrent cognitive ability attenuated it by 31% ($p = .40$). In contrast, adjustment for childhood cognitive ability reduced the association to near zero (attenuation 88%, $p < .01$), whereas childhood ability itself predicted older age BMI ($\beta = -.12$, $p < .01$). Likewise, adjustments for educational level and occupational class significantly (respectively 77%, $p < .001$, and 56%, $p < .01$) attenuated the contributions of HL to BMI. In the full model, only educational level significantly predicted high BMI ($\beta = -.20$, $p < .001$), whereas the contribution of health literacy was negligible ($\beta = -.02$, $p = .64$).

Number of teeth. After adjusting the associations between HL and the number of natural teeth for concurrent and childhood cognitive ability, the original association ($\beta = .20$, $p < .001$) attenuated by 39% ($p < .01$) and 30% ($p < .05$), respectively. Adjustments for educational level and occupational class attenuated the association by 49% and 34% ($p < .001$), respectively. In the fully adjusted model, only educational level and occupational class significantly predicted high the number of teeth ($\beta = .16$, $p < .01$, and $\beta = .10$, $p < .05$), whereas the contribution of health literacy was $\beta = .05$ ($p = .29$).

The incremental value of health literacy. Finally, we formally tested if the inclusion of the HL improved the explanatory power of the models already including concurrent and age-11 cognitive abilities, educational level, occupational class, age and sex for these three health outcomes. For physical fitness, the models including (adjusted R^2 = .59; the adjusted R^2 for sex and age alone was .56) versus excluding the HL (adjusted R^2 = .59) were statistically different (p < .01), although the improvement of prediction was only ΔR^2 = .004. For BMI, the models including (adjusted R^2 = .05; R^2 for sex and age alone was .01) versus excluding HL (adjusted R^2 = .05) were not statistically different (p = .64). For the number of teeth, the models including (adjusted R^2 = .08; R^2 for sex and age alone was .00) versus excluding HL (adjusted R^2 = .08) were not statistically different (p = .29).

Discussion

We hypothesized that low health literacy, or cognitive ability in general, would be associated with lower physical fitness, higher BMI and lower number of natural teeth because they may indicate poor care of one's health, for example, due to difficulties in understanding information on healthy dietary habits, sufficient levels of physical ability, or maintenance of oral health. Indeed, lower levels of health literacy, as measured by its three most common tests, were associated with worse general physical fitness, greater BMI, and fewer natural teeth. These findings thus support the common health literacy measures as being valid predictors of actual health and possibly justify their use as potential screening tools (Weiss et al., 2005).

However, as expected, health literacy scores were not the only variables associated with these health outcomes. The popular health literacy measures were not only substantially correlated with concurrent general cognitive ability (measured with tasks that were based on neither health-related information nor verbal content in general) but also with childhood cognitive ability, which had been measured about 60 years earlier. In fact, as a pattern, the correlations with cognitive ability tended to be even higher than those among the three different health literacy tests themselves, suggesting that the health literacy measurements reflected to a large degree lifelong cognitive ability more generally. Likewise, the health literacy tests were associated with educational level and occupational class, which, themselves, were predicted by childhood cognitive ability. Most important, these correlates of health literacy were also significantly associated with all of the health outcomes, with comparable and often larger effect sizes. In multivariate models, only general physical fitness remained significantly associated with health literacy (REALM and S-TOFHLA, in particular), whereas educational level remained a significant predictor of all health outcomes. We therefore concluded that the observed associations between health literacy and health outcomes largely occurred because health literacy was correlated with other—and often stronger—associates of old-age health, in particular educational level. That is, health literacy as such may have somewhat limited incremental predictive value over and above well-established predictors of health such as socioeconomic success (education, occupation) and cognitive ability. Overall, the results are likely to have four main implications.

First, one way to conceptualize the associations of educational and occupational attainment (socioeconomic success) and health literacy with health is to see health literacy as a mediator of the effects of socioeconomic success on health: poor socioeconomic success may contribute to low health literacy and this, in turn, may imply poor health management. However, the finding that health literacy was strongly linked to general cognitive ability even when this is measured with non-verbal tasks or 60 years earlier—potentially suggesting that health literacy is an aspect (or reflection) more general cognition—makes this reasoning problematic. Essentially, then, this may mean postulating cognitive ability as a mediator between socioeconomic status and health. However, as discussed above, pre-existing cognitive ability itself is known to be highly predictive of later educational attainment, suggesting that cognitive ability (whatever its earlier causes) is among the contributors to educational attainment. As a result, postulating health literacy (i.e., cognition more broadly) as a mediator between socioeconomic success and health evokes circular reasoning. Note that in the multivariate models presented above, older-age cognitive ability and health literacy had markedly stronger associations with childhood cognitive ability compared to educational attainment and occupational class, suggesting a continuity in the life-long trait of cognitive ability and its role in health literacy over and above educational level.

Second, the finding that educational level in particular often outperformed health literacy measures in predicting the health outcomes may cast some doubt on the usefulness of the health literacy measures for practical screening of high-risk people. Information about patients' educational levels is often likely to be at least as easily obtainable as information about their health literacy levels. Additionally, it has been noted that health literacy assessments may potentially have harmful side-effects such as stigmatization and shame in clinical settings (Paasche-Orlow & Wolf, 2008). Nevertheless, we note that greater predictive validity of educational level compared to that of health literacy has not always been reported in prior studies. Baker and colleagues (2007) found that health literacy as measured by the TOFHLA was not only associated with mortality risk, but that it was a stronger predictor than educational attainment. This, however, might reflect a poorer quality in the US compared to the UK pertaining to the skills conveyed by an educational system.

Third, the findings that cognitive ability in general, even if it had been measured many decades prior to health literacy and health variables, accounted for a share of health literacy-health associations suggest that it is probably not only the knowledge and cognitive skills specific to the health domain that are ultimately important for health. Better health management is often posited to be a potential causal pathway for the associations between health literacy and health outcome (Deary et al., 2010). To the extent that this is the case, health management may depend on a set of cognitive skills well beyond those individually or collectively captured by the three popular health literacy measures. Effective health management may be a complex and cognitively demanding aspect of people's daily lives (Gottfredson, 2004) that requires more than just knowing health-related words or being able to cope with health-related texts and math tasks. Effective health management may involve understanding why and how to develop a generally healthy life-style (i.e., disease prevention), how to notice symptoms of impending illness and locate help, how to navigate health-care systems—a particularly challenging task for many (Williams et al., 1995)—and how to manage the disease itself and its consequences. All these tasks may call on many different aspects of information processing abilities including general problem solving—the variety that is especially well summarized by general cognitive ability.

If such a broader set of health management skills is in fact the key, the field of health literacy may benefit from operationalizing its core concept so that it considers a wider range of cognitive skills than those collectively tapped by the current common measures. Likewise, interventions to increase skills of managing one's health may need to address the health-management process in a wider sense. Enhancing levels of specific health literacy skills or lowering the barriers in doctor-patient communication may simply be suboptimal when a wider range of cognitive skills is implicated. Given that health literacy is linked to long-term stable characteristics such as general cognitive ability and educational and occupational attainment, however, interventions may be constrained by the difficulties in altering those characteristics. Efforts may instead be more productively focused on helping people to master the specific skills and behaviors necessary to manage their particular circumstances rather than boosting their health literacy more generally. This conclusion is clearly in line with the literature on the effectiveness of various health literacy interventions: attempts to tackle the low literacy *per se* appear to be suboptimal, whereas intensive interventions tailored to the management of specific diseases show more promising results (Berkman, Sheridan, Donahue, Halpern, Viera, et al., 2011).

Fourth, the finding that cognitive ability at age 11 alone was predictive of the health outcomes in old age suggests that, for most people, the involvement of cognitive ability in health differences in later life had already been set in motion in childhood. However, this does not imply that the cognition-related sources of health differences are fixed throughout life and cannot be modified. The reason for this is that childhood cognitive ability, or its earlier unmeasured determinants which it marked, did not appear to contribute to health in old age directly: their effects were absorbed (and likely mediated) by factors characterizing later periods of life, such as educational level, occupational class (for number of teeth), or old-age general cognitive ability and health literacy (for physical fitness). That is, childhood cognitive ability predicted educational attainment, occupational class and old-age general cognitive ability and literacy, but the latter four were among the unique correlates of the older age health-outcomes. Therefore, it may be that the factors that people experience from childhood to old age that contribute to educational level and late-life cognitive functioning and literacy on top of their initial cognitive ability levels, may be consequential to their health. These factors may well be modifiable.

An interesting finding is that for BMI and number of teeth educational level appeared to be the unique predictor (and occupational level for the number of teeth) but for general physical fitness concurrent cognitive ability and health literacy appeared to contribute too. First, this may indeed indicate that poor cognitive functioning and performance on the literacy tests may contribute to the factors—which may often be quite idiosyncratic—that impair physical fitness (e.g., specific diseases or general wear and tear). For instance, poor cognition in general but also its health literacy aspect may hamper ability to manage diseases or benefit from health care, which, of course, exactly reflects the main hypothesis of health literacy research (Berkman, Sheridan, Donahue, Halpern, & Crotty, 2011). There is, however, an alternative explanation for why general fitness—although also uniquely predicted by educational level—had significant associations with concurrent cognitive functioning and literacy test performance whereas other selected health outcomes did not: it is possible that concurrently measured poor fitness itself (possibly reciprocally) contributes to poor cognitive/literacy test performance. High BMI and low number of teeth that often build up across a long time period, in contrast, may not directly influence older age cognitive test performance. Instead, they may be influenced by educational levels and/or occupational class and antecedents of these such as, possibly, earlier cognitive ability.

The strengths of the study included a quite large sample, well-phenotyped cognitive ability and heath literacy, objective and comprehensive measurements of health, and ability to test for the role of cognitive abilities, as they existed long before most life-course factors (education, occupational class, ill-health, aging) started contributing to people's health literacy and health. The limitations included lack of information on people's health literacy before health measurements (the direction of causality was impossible to ascertain based on only cross-sectional results), limited ability to test for specific pathways from cognitive ability, education, occupation or health literacy to health (e.g., knowledge or skills related to specific health outcomes or health behaviors), and lack of prior validation data for the NVS in the UK. Future research could also incorporate information on people's childhood conditions that could have influenced all variables studied here and thereby confounded their associations.

In summary, low health literacy test scores were associated with various aspects of poorer health in older community-dwelling people. To that extent, these three popular health literacy scales were successful, although their practical usefulness might be debatable (Paasche-Orlow & Wolf, 2008). Shedding light on the underpinnings of these associations, we found that they could largely be explained by considering health literacy one aspect of general cognition and/or linked with educational attainment, which themselves have well-replicated direct associations with health outcomes (Mackenbach et al., 2008; Deary et al., 2010). Finally, we were in a unique position to show that early-life general cognitive ability levels contributed to older age health via later—and potentially modifiable—characteristics such as educational level and older age cognitive functioning.

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Table 1. Descriptive statistics of the study variables.

	N	Mean or %	*SD*	Skewness
Sex	730			
Men	380	52.1%		
Women	350	47.9%		
Educational level	730	1.70	1.31	-0.92
No qualification	124	17.0%		
O-level	285	39.0%		
A-level	119	16.3%		
(Semi)professional	89	12.2%		
University degree	113	15.5%		
Occupational social class	730	3.65	0.92	-0.90
Unskilled	4	0.5%		
Semiskilled	25	3.4%		
Skilled manual	121	16.6%		
Skilled non-manual	157	21.5%		
Intermediate	279	38.2%		
Professional	144	19.7%		
Age 11 cognitive ability	730	100.0	15.00	1.31
Age 73 general cognitive ability	730	0.00	1.00	0.23
REALM	730	65.05	2.44	28.64
S-TOFHLA	678	94.39	9.20	8.59
NVS	726	2.86	1.91	-1.15
Six meter walk time (sec)	725	4.31	1.15	13.70
Forced expiratory volume in 1 sec (L/sec)	722	2.30	0.67	-0.18
Grip strength (kg)	730	29.65	9.32	-0.77
Number of natural teeth	673	16.73	8.89	-0.84
Body mass index (kg/m^2)	730	27.95	4.48	1.87

NOTE: *N* = number of participants with valid data; *SD* = standard deviation; REALM = Rapid Estimate of Adult Literacy in Medicine; S-TOFLA = Shortened Test of Functional Health Literacy in Adults; NVS = Newest Vital Signs.

Table 2. Correlations among the predictors of health outcomes.

	1	2	3	4	5	6
1. Education						
2. Occupation	.52					
3. Age-11 IQ	.51	.40				
4. Age-73 *g*	.45	.35	.56			
5. REALM	.34	.31	.44	.37		
6. S-TOFHLA	.36	.30	.45	.54	.38	
7. NVS	.41	.32	.51	.54	.34	.43

NOTE: Spearman rank-order correlations. IQ = Intelligence Quotient; *g* = general cognitive ability; REALM = Rapid Estimate of Adult Literacy in Medicine; S-TOFLA = Shortened Test of Functional Health Literacy in Adults; NVS = Newest Vital Sign. All correlations were significant at $p < .0001$ or lower, with no corrections for multiple testing.

Table 3. Associations [β (standard error)] between the health outcomes and the variables used as covariates in health literacy-health relations.

	Fitness	BMI	Number of teeth
Age-11 IQ	.088 (.025)[c]	-.125 (.037)[c]	.187 (.040)[d]
Age-73 *g*	.167 (.024)[d]	-.071 (.037)	.197 (.038)[d]
Educational level	.138 (.024)[d]	-.208 (.036)[d]	.263 (.037)[d]
Occupational class	.114 (.025)[d]	-.132 (.037)[d]	.232 (.038)[d]

NOTE: BMI = body mass index; IQ = Intelligence Quotient; *g* = general cognitive ability. Sex and age were included as covariates. [a] $p < .05$, [b] $p < .01$, [c] $p < .001$, [d] $p < .0001$. No corrections for multiple testing.

Table 4. Associations [β (standard error)] between physical fitness and the three health literacy measures and their latent composite score before and after adjusting for various co-variates.

	REALM	S-TOFHLA	NVS	Latent health literacy scores
Literacy	.106 (.025)[c]	.150 (.025)[c]	.115 (.025)[c]	.160 (.025)[c]
Literacy	.058 (.026)[a]	.102 (.029)[b]	.036 (.029)	.092 (.030)[b]
Age 73 *g*	.148 (.026)[c]	.093 (.030)[b]	.150 (.029)[c]	.136 (.028)[c]
Literacy	.084 (.028)[b]	.147 (.029)[c]	.094(.028)[b]	.160 (.030)[c]
Age11 IQ	.051 (.028)	.007 (.029)	.044 (.028)	-.001 (.030)
Literacy	.073 (.026)[b]	.124 (.026)[c]	.070 (.027)[a]	.122 (.027)[c]
Educational level	.118 (.025)[c]	.081 (.026)[b]	.108 (.027)[c]	.086 (.027)[b]
Literacy	.085(.025)[b]	.135 (.026)[c]	.089 (.026)[b]	.136 (.026)[c]
Occupational class	.095 (.025)[c]	.060 (.026)[a]	.086 (.026)[b]	.066 (.026)[a]
Literacy	.062 (.027)[a]	.107 (.030)[c]	.026 (.030)	.092 (.032)[b]
Age 73 *g*	.141 (.031)[c]	.091 (.033)[b]	.141 (.032)[c]	.113 (.033)[b]
Age11 IQ	-.071 (.033)[a]	-.069 (.033)[a]	-.054 (.032)	-.075 (.033)[a]
Educational level	.072 (.031)[a]	.066 (.032)[a]	.069 (.032)[a]	.068 (.031)[a]
Occupational class	.038 (.029)	.028 (.030)	.038 (.030)	.033 (.029)

NOTE: Sex and age were included as co-variates. IQ = Intelligence Quotient; *g* = general cognitive ability; REALM = Rapid Estimate of Adult Literacy in Medicine; TOFLA = Shortened Test of Functional Health Literacy in Adults; NVS = Newest Vital Sign. [a] $p < .05$, [b] $p < .01$, [c] $p < .001$. No corrections for multiple testing.

Table 5. Associations [β (standard error)] between BMI and the three health literacy measures and their latent composite score before and after adjusting for various co-variates

	REALM	S-TOFHLA	NVS	Latent health literacy scores
Literacy	-.093 (.038)[a]	-.094 (.040)[a]	-.097 (.037)[b]	-.077 (.037)[a]
Literacy	-.078 (.040)	-.091 (.046)	-.083 (.044)[a]	-.053 (.047)
Age 73 *g*	-.046 (.039)	-.006 (.047)	-.025 (.044)	-.040 (.047)
Literacy	-.047 (.042)	-.048 (.045)	-.049 (.042)	-.009 (.045)
Age11 IQ	-.105 (.041)[a]	-.096 (.045)[a]	-.101 (.042)[a]	-.121 (.045)[b]
Literacy	-.037 (.038)	-.030 (.041)	-.011 (.040)	.018 (.041)
Educational level	-.198 (.038)[c]	-.198 (.041)[c]	-.203 (.040)[c]	-.216 (.040)[c]
Literacy	-.067 (.038)	-.065 (.041)	-.062 (.039)	-.034 (.040)
Occupational class	-.118 (.038)[b]	-.115 (.041)[b]	-.114 (.039)[b]	-.120 (.040)[b]
Literacy	-.036 (.041)	-.054 (.047)	-.020 (.045)	.023 (.049)
Age 73 *g*	.059(.046)	.093 (.052)	.065 (.049)	.047 (.050)
Age11 IQ	-.039 (.049)	-.037 (.052)	-.047 (.048)	-.057 (.049)
Educational level	-.193 (.047)[c]	-.201 (.050)[c]	-.191 (.048)[c]	-.197 (.048)[c]
Occupational class	-.024 (.044)	-.022 (.047)	-.026 (.045)	-.027 (.045)

NOTE: Sex and age were included as co-variates. IQ = Intelligence Quotient; *g* = general cognitive ability; REALM = Rapid Estimate of Adult Literacy in Medicine; TOFLA = Shortened Test of Functional Health Literacy in Adults; NVS = Newest Vital Sign. [a] $p < .05$, [b] $p < .01$, [c] $p < .001$. No corrections for multiple testing.

Table 6. Associations [*β* (standard error)] between the number of natural teeth and the three health literacy measures and their latent composite score before and after adjusting for various co-variates

	REALM	S-TOFHLA	NVS	Latent health literacy scores
Literacy	.168 (.039)[c]	.166 (.041)[c]	.167 (.038)[c]	.197 (.039)[c]
Literacy	.113 (.041)[b]	.078 (.047)	.091 (.045)[a]	.120 (.048)[a]
Age 73 *g*	.160 (.040)[c]	.168 (.047)[c]	.144 (.045)[b]	.125 (.048)[a]
Literacy	.109 (.043)[a]	.099(.045)[a]	.106 (.043)[a]	.138 (.046)[b]
Age11 IQ	.141 (.044)[b]	.154 (.047)[b]	.134 (.045)[b]	.111 (.047)[a]
Literacy	.099 (.040)[a]	.087 (.041)[a]	.070 (.041)	.100 (.042)
Educational level	.237 (.038)[c]	.245 (.040)[c]	.230 (.041)[b]	.222 (.041)[c]
Literacy	.121 (.040)[b]	.114 (.041)[b]	.105 (.040)[b]	.130 (.041)
Occupational class	.205 (.039)[c]	.208 (.041)[c]	.196 (.040)[c]	.185 (.041)[a]
Literacy	.077 (.043)	.042 (.047)	.029 (.046)	.054 (.050)
Age 73 *g*	.067 (.047)	.07 (.052)	.059 (.050)	.055 (.051)
Age11 IQ	-.004 (.051)	.017 (.053)	.019 (.050)	.007 (.052)
Educational level	.159 (.048)[b]	.166 (.050)[b]	.155 (.049)[b]	.158 (.048)[b]
Occupational class	.103 (.046)[a]	.104 (.048)[a]	.106 (.046)[a]	.102 (.046)[a]

NOTE: Sex and age were included as co-variates. IQ = Intelligence Quotient; *g* = general cognitive ability; REALM = Rapid Estimate of Adult Literacy in Medicine; TOFLA = Shortened Test of Functional Health Literacy in Adults; NVS = Newest Vital Sign. [a] $p < .05$, [b] $p < .01$, [c] $p < .001$. No corrections for multiple testing.