

1 INTRODUCTION

2 Health literacy is increasingly being recognized as an influence on health.^{1,2} While many
3 definitions of health literacy exist, a basic definition of ‘functional’ health literacy is, ‘the degree
4 to which individuals can obtain, process, understand, and communicate about health-related
5 information and services to make informed health decisions’.³ According to a national
6 assessment of adult literacy, 10-13% of American adults aged 16-64 and 29% aged ≥ 65 have
7 ‘below basic’ health literacy and are often unable to properly self-manage their health.⁴⁻⁸
8 Improvement of the health literacy of the population is therefore a goal of the Healthy People
9 2020 initiative.⁹ Of particular concern are older adults, who are vulnerable to low health literacy
10 due to the negative effects of cognitive aging on health literacy skills.¹⁰⁻¹² At the same time,
11 health literacy is important for health in older age, a period in life when physical, social, and
12 material limitations often increasingly affect one’s capacity for health self-management.¹³
13 Indeed, low health literacy has independently been associated with increased risk of all-cause
14 mortality in older adults in several contexts.¹⁴⁻¹⁷
15
16 Health-promoting lifestyle behaviors, such as engagement in moderate-to-vigorous physical
17 activity (MPVA) may be mediators on the pathway from low health literacy to greater risk of all-
18 cause mortality.^{17,18} Low MVPA is robustly associated with increased risk of all-cause mortality
19 in older adults.¹⁹⁻²² Health literacy may positively affect knowledge, motivation, and self-
20 efficacy for physical activity, which are important factors in the initiation and maintenance of
21 MVPA.^{18,23-27} However, evidence on the relationship between health literacy and MVPA is
22 sparse. An American study of Medicare enrollees and a UK general population survey both
23 found no association between health literacy and weekly physical activity.^{28,29} In contrast, an

24 American study of hypertensive patients from federally qualified health centers and a Dutch
25 study of community dwelling adults found that health literacy explained a modest proportion of
26 variance in physical activity, with self-efficacy acting as a mediator.^{23,30} Health literacy was also
27 positively associated with physical activity in the Rush Memory and Aging Project.³¹ These
28 studies were cross-sectional and did not adjust for physical or cognitive health, which are major
29 limitations in behavioral studies of health literacy. The potential contribution of cognitive
30 function is salient to consider, given its association with health literacy and emerging
31 relationship with physical function and activity in later life.^{11,32,33}

32

33 This study aimed to prospectively investigate the association between health literacy and weekly
34 participation in MVPA among older English adults from 2004 to 2013, while accounting for
35 sociodemographic factors, physical health, and cognitive function.

36

37 **METHODS**

38 **Study sample**

39 The English Longitudinal Study of Ageing (ELSA) is a cohort of English adults aged ≥ 50
40 years.³⁴ The ELSA was approved by the London Multicentre Research Ethics Committee
41 (MREC/01/2/91) and informed consent was obtained from all participants. The cohort was
42 established in 2002 based on a random stratified sample of households in England. Data are
43 collected in biennial waves. The present analysis was conducted in 2015 using data from waves 2
44 (2004/05) through 6 (2012/13). Eligible participants were non-cognitively impaired 'core' ELSA
45 participants aged 52-79 years at wave 2, who completed data collection at all waves with non-
46 proxy interviews (proxy interviews were conducted for institutionalized or physically or

47 cognitively impaired participants). Wave 2 was the baseline for this analysis, as health literacy
48 was first measured in this wave. Hence, the lower limit of the eligible age range was 52 years,
49 rather than 50 years. Of the 11392 core participants recruited in wave 1, 8780 were present in
50 wave 2 (77%). Of these, 7659 were aged 52-79 at wave 2. Of these, 4470 remained in the study
51 and completed data collection at all waves through wave 6 (58%). Of these, 116 (3%) had proxy
52 interviews in at least one wave and were ineligible. In total, 4354 participants were eligible for
53 this analysis.

54

55 **Measures**

56 *Health literacy*

57 Functional health literacy (referred to hereafter as ‘health literacy’) was assessed in the in-person
58 study interview at wave 2 (2004/05) using a validated four-item measure from the OECD
59 International Adult Literacy Survey.³⁵ Participants were presented with a fictitious medicine
60 label and were asked four reading comprehension questions (Appendix). Health literacy was
61 scored as ‘high’ (4/4 correct), ‘medium’ (3/4 correct), or ‘low’ ($\leq 2/4$ correct).¹⁷ Of the 4354
62 eligible participants, n=6 refused the assessment and were excluded and n=70 were unable to
63 complete the assessment due to sight, health, or reading problems. The latter individuals were
64 included and coded as having low health literacy, as they would likely perform with low health
65 literacy in real-life settings.⁷

66

67 *Cognitive function*

68 Aspects of cognitive function that are essential for everyday functioning and sensitive to decline
69 during aging were assessed in the study interview at wave 2 (2004/05).³⁶ Aspects of cognitive

70 function that would be minimally affected by literacy skills were included: time orientation
71 (continuous, out of four for the ability to state the correct day, week, month, and year),
72 immediate recall (continuous, out of 10 aurally presented words), delayed recall (continuous, out
73 of the same 10 aurally presented words), and verbal fluency (continuous; the number of animal
74 names listed in one minute). The former three variables were grouped together to create a
75 memory index, with possible scores ranging from 0 to 24.³⁷ The latter variable was coded as '0',
76 '1-7', '8-12', '13-15', '16-17', '18-19', '20-21', '22-24', '25-29', and '≥30' animals and scored
77 from 0 to 9.³⁷ A measure of mental processing speed was not included as it required literacy
78 skills by assessing the number of Ps and Ws crossed out in a grid of random alphabet letters.

79

80 *Moderate-to-vigorous physical activity*

81 Physical activity was assessed in the study interview at each wave, where participants were
82 asked about their typical frequency of participation in mild, moderate, and vigorous sports and
83 activities, with examples given on show cards (Appendix). Response options were 'hardly ever
84 or never', 'one to three times a month', 'once a week', and 'more than once a week'. At each
85 wave, physical activity was coded dichotomously as engagement in MVPA once per week or
86 more vs. less than once per week.^{22,38} The outcome variable was consistent weekly participation
87 in MVPA at every wave from 2004/05 to 2012/13 (yes vs. no).

88

89 *Covariates*

90 Sociodemographic covariates were assessed in the wave 2 (2004/05) interview: age (continuous),
91 sex (male; female), marital status (married or living as married; single, divorced, or widowed),
92 net non-pension wealth (calculated in quintiles stratified at age 65 to account for the effect of

93 retirement on wealth), education (degree-level; up to degree-level; no qualifications), and
94 ethnicity (white; non-white). Other covariates were those known to be associated with health
95 literacy or with MVPA in the ELSA: working status (yes vs. no), access to a car when needed
96 (yes vs. no), self-rated health (excellent/very good/good vs. fair/poor), having a limitation in one
97 or more instrumental activity of daily living (IADL; yes vs. no) having a limiting long-standing
98 illness (yes vs. no), presence of depressive symptoms, defined as scoring >4 on the 8-item Centre
99 for Epidemiological Studies Depression Scale (yes vs. no).^{39,40}

100

101 **Statistical analysis**

102 The final sample was 4345/4354, as six participants declined the health literacy assessment and a
103 further three were missing physical activity data. All other variables were missing on a case-by-
104 case basis. Weekly MVPA over eight years was examined bivariate against participant
105 characteristics using frequency counts for categorical variables and means for continuous
106 variables, and unadjusted logistic regression to generate odds ratios (ORs) and 95% confidence
107 intervals (CIs). All covariates were then included in a multivariable-adjusted logistic regression
108 model to predict the relationship between health literacy ('medium' vs. 'low' and 'high' vs.
109 'low') and weekly MVPA over eight years. With the exception of age, sex, and education, which
110 were forced into the model, all covariates that were not significantly associated with weekly
111 MVPA with $p < 0.05$ in the model were removed, as long as their removal did not alter the ORs
112 between health literacy and long-term MVPA by $\geq 10\%$.⁴¹ The final model is shown both with
113 and without the cognitive function variables, to examine the degree to which poor cognitive
114 functioning might explain any relationship between health literacy and weekly MVPA. All
115 regression modeling was performed with population weights applied to account for study non-

116 response and attrition.⁴² The ELSA User Guide provides in-depth technical information on the
117 population weights, but, briefly, they were calculated as the inverse of the estimated probability
118 of responding for a given participant based on demographic, health-related, social, and
119 geographic factors associated with non-response and attrition.⁴² All statistical analyses were
120 performed using StataSE 13.1 (College Station, Texas)

121

122 **RESULTS**

123 Table 1 shows the baseline characteristics of the study participants. Participation in weekly
124 MVPA declined over time in the study population, but decline was more pronounced in adults
125 with low and medium than in those with high health literacy (Figure 1). Overall, 54%
126 (2350/4345) consistently reported participating in MVPA at least once per week at all waves
127 (Table 2). This proportion was 59% (1840/3128) in those with high health literacy, 47%
128 (372/797) in those with medium health literacy, and 33% (138/420) in those with low health
129 literacy. The unadjusted OR for eight-year participation in weekly MVPA associated with high
130 vs. low health literacy was 2.83 (95% CI: 2.25-3.87). Mean baseline memory and verbal fluency
131 scores were higher among those with consistent weekly participation in MVPA, with unadjusted
132 OR=1.13 (95% CI: 1.11-1.15) per one point memory increase and unadjusted OR=1.21 (95% CI:
133 1.17-1.25) per one point verbal fluency increase. The other predictors of weekly MVPA in
134 unadjusted models are also shown in Table 2.

135

136 The final adjusted, population weighted logistic regression models are shown in Table 3.
137 Without memory and verbal fluency in the model, the adjusted OR for eight-year participation in
138 weekly MVPA with medium vs. low health literacy was 1.29 (95% CI: 0.95-1.75) and high vs.

139 low was 1.53 (95% CI: 1.16-2.01). With cognitive function in the model, these associations were
140 attenuated by about one-third, to 1.21 (95% CI: 0.89-1.64) for medium vs. low and 1.37 (95%
141 CI: 1.04-1.81) for high vs. low. The borderline statistically significant OR for memory was 1.03
142 (95% CI: 1.00-1.05 per point increase) and for verbal fluency was 1.05 (95% CI: 1.01-1.09 per
143 point increase). The other independent predictors of weekly MVPA were: being male (OR=1.42;
144 95% CI: 1.23-1.66), having degree-level education (OR=1.64; 95% CI: 1.33-2.02), having higher
145 net non-pension wealth (OR=3.02; 95% CI: 2.35-3.88 for the richest vs. poorest quintiles),
146 having good self-rated health (OR=1.76; 95% CI: 1.42-2.18), having no limiting long-standing
147 illness (OR=2.13; 95% CI: 1.77-2.56), having no functional limitations (OR=1.78; 95% CI: 1.46-
148 2.17).

149

150 **DISCUSSION**

151 In this longitudinal study of older English adults, health literacy was prospectively associated
152 with weekly participation in MVPA over an eight-year follow-up period. These results are
153 consistent with evidence that health behaviors, such as MVPA, may contribute to the link
154 between low health literacy and increased risk of all-cause mortality.¹⁷ Memory and verbal
155 fluency were weakly positively associated with long-term MVPA, in addition to indicators of
156 social advantage including being male, having degree-level education, being wealthier, and being
157 healthier. Disparities in the long-term participation in MVPA may lead to inequalities in the
158 health outcomes associated with physical inactivity, such as cardiovascular disease, cancer, and
159 all-cause mortality.^{22,43} Research is needed on the development of health inequalities during the
160 aging process and how they may be prevented. Low health literacy may represent a target point

161 for interventions, and may be a way of identifying adults who need more support to optimize
162 MVPA throughout their lifespan.⁴⁴

163

164 These results indicate a graded, rather than a threshold effect of health literacy on MVPA,
165 consistent with previous research showing a linearly graded relationship between health literacy
166 and physical functioning in older adults.⁴⁵ However, the odds ratio for medium health literacy
167 and MVPA was somewhat imprecise and crossed the null. The present results are also consistent
168 with two American studies and a Dutch study of health literacy and physical activity,^{23,30,31} but
169 they conflict with an American study of new Medicare enrollees finding null associations
170 between health literacy and several behaviors²⁸ and a UK study of adults in a younger and wider
171 age range.²⁹ The present results may differ due to the longitudinal nature of this study, the
172 differing assessment methods for health literacy and MVPA, and the older age range of the
173 participants. The results are longitudinal, population-weighted, and were adjusted for important
174 aspects of cognitive function that are independent of literacy skills, improving upon previous
175 research.

176

177 The findings that memory and verbal fluency were weakly positively associated with long-term
178 MVPA are consistent with a recent study of older American adults finding that the cognitive
179 functions of task coordination and inhibition of habitual response were associated with physical
180 exercise through self-efficacy.⁴⁶ The reverse association, where physical activity improves
181 cognitive health in older adults, has been well-characterized in prospective cohort studies and
182 randomized controlled trials.⁴⁷⁻⁵⁰ In a *post-hoc* analysis, the reverse association between weekly
183 MVPA at baseline (yes vs. no) and change in memory, verbal fluency, or health literacy over the

184 follow-up was not observed (Appendix Table 1). In a second *post-hoc* analysis with mental
185 processing speed (an aspect of executive function) included in the final model, it was not
186 associated with long-term MVPA (OR=1.01; 95% CI: 0.97-1.05).

187

188 More broadly, results of this study are consistent with another study using data from the English
189 Longitudinal Study of Ageing to examine the predictors of sustained physical activity over 10
190 years,³⁹ and other cross-sectional and short-term longitudinal studies on the predictors of MVPA
191 in older adults.^{51,52} Although physical activity levels are accepted to often decline during aging,
192 few studies have examined the sociodemographic and health-related predictors of MVPA during
193 aging over a long follow-up. This study underscores the role of the ability to regularly engage in
194 MVPA over a long time period as a potential mechanism leading to later-life health inequalities.
195 MVPA is associated with reduced risk for several health outcomes,⁴³ but it is increasingly
196 difficult to maintain in later life due to increased physical, social, and material limitations.⁴⁷
197 Health literacy may represent a modifiable target for intervention, whereby the maintenance of
198 literacy skills may aid in maintenance of the self-efficacy and level of physical function required
199 to engage in MVPA.⁵³

200

201 **Limitations**

202 MVPA was assessed at multiple time points by self-report and is subject to recall error.^{54,55} If
203 recall error in reporting MVPA is non-differential by health literacy, then the odds ratios will
204 underestimate the true associations. If the high health literacy group is relatively accurate in
205 reporting MVPA and low health literacy group systematically under-reports (over-reports)
206 MVPA, then the odds ratios will overestimate (underestimate) the true association. There has not

207 been any validation study of self-reported physical activity according to the health literacy of
208 study participants. Overall, the frequency of self-reported MVPA in this sample was slightly
209 higher than that assessed in the population-representative Health Survey for England (HSE),
210 possibly because the longitudinal ELSA sample is slightly healthier and wealthier than the
211 general population of England due to study attrition.³⁴

212
213 The self-report physical activity assessment used in the ELSA has been validated in a sub-sample
214 of 116 study participants using objective accelerometer data, showing a modest correlation
215 (Spearman's $r=0.21$; $p=0.02$).³⁸ Physical activity was not measured with reference to a specific
216 time frame (e.g. the past 12 months), which may have limited participants' abilities to accurately
217 respond. Because of the way the physical activity data were collected in the ELSA, a variable
218 that mapped onto the WHO recommendation of 150 minutes/week of moderate intensity or 75
219 minutes/week of vigorous intensity, or an equivalent combination of the two could not be
220 defined.⁵⁶ However, the weekly physical activity variables in the ELSA have been associated
221 with a range of health outcomes including all-cause mortality, demonstrating their biological and
222 clinical relevance.^{22,38}

223
224 The health literacy measure used in this study was validated,³⁵ but displayed a ceiling effect that
225 is common to other standard measures of functional health literacy.^{57,58} However, the measure
226 has predictive ability for health outcomes including the uptake of preventive health services and
227 risk of all-cause mortality in older adults.^{7,17} Another limitation is that attrition was differential
228 by baseline wealth, as 15% of participants who remained in the study through wave 6 were in
229 quintile 1 (poorest) and 24% were in quintile 5 (richest); if no attrition occurred these

230 proportions would be 20%. The association between net non-pension wealth and weekly MVPA
231 is therefore likely to be an underestimate. Participants with medium or low health literacy at
232 baseline and with no educational qualifications were also more likely to drop out of the study.
233 Attrition was 30.6% in the ‘high’, 37.6% in the ‘medium’, and 48.6% in the ‘low’ health literacy
234 groups, and was 34.3% in the ‘degree-level’, 36.5% in the ‘up to degree-level’, and 52.1% in the
235 ‘no qualifications’ educational groups. The observed associations between these variables and
236 weekly MVPA may therefore underestimate the true associations.

237

238 Despite these limitations, this study provides important evidence on the simultaneous roles of
239 health literacy and cognitive function in contributing to long-term participation in MVPA during
240 aging. Strengths of this study include its large sample size and its longitudinal nature. Health
241 literacy measurements with follow-up data are rare, especially for an eight-year period. The
242 ELSA is one of the first available data sources that can investigate the behavioral outcomes of
243 health literacy, especially jointly with other sociodemographic and health-related factors.
244 Population-representative weights were applied to the regression models to account for
245 differential degrees of non-response and attrition across population subgroups.⁴²

246

247 **Conclusions**

248 Health literacy and cognitive function had independent positive associations with long-term
249 participation in weekly MVPA in this prospective cohort of older English adults. These factors
250 may be useful markers of capacity for engagement in this health-promoting lifestyle behavior in
251 older adults. However, there were marked inequalities in weekly MVPA during aging. Adults
252 who were male, highly educated, wealthier, and healthier were the most likely to participate in

253 weekly MVPA over the eight-year follow-up period. These long-term patterns of MVPA may
254 translate to inequalities in health outcomes. Further research is needed on how the trajectories of
255 health behaviors during aging may contribute to health inequalities among older adults.

256

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470 **List of figure titles:**

471 Figure 1. Participation in weekly MVPA at each time point (%), according to baseline health

472 literacy

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493 APPENDIX

494 Health Literacy Assessment

MEDCO TABLET

INDICATIONS: Headaches, muscle pains, rheumatic pains, toothaches, earaches.

RELIEVES COMMON COLD SYMPTOMS

DOSAGE: ORAL. 1 or 2 tablets every 6 hours, preferably accompanied by food, for not longer than 7 days. Store in a cool, dry place.

CAUTION: Do not use for gastritis or peptic ulcer. Do not use if taking anticoagulant drugs. Do not use for serious liver illness or bronchial asthma. If taken in large doses and for an extended period, may cause harm to kidneys. Before using this medication for chicken pox or influenza in children, consult with a doctor about Reyes Syndrome, a rare but serious illness. During lactation and pregnancy, consult with a doctor before using this product, especially in the last trimester of pregnancy. If symptoms persist, or in the case of an accidental overdose, consult a doctor. Keep out of reach of children.

INGREDIENTS: Each tablet contains
500 mg acetylsalicylic acid.

Excipient c.b.p 1 tablet

Reg. No. 88246

Made in Canada by STERLING PRODUCTS, INC
1600 Industrial Blvd. Montreal, Quebec H9J 3P1

495

496 **Instructions Read Out by the Interviewer**

497 The final task in this section is about comprehension. This is a made-up medicine label and does
498 not refer to a real medicine. It is often difficult to read and understand instructions on medicine
499 labels. In a moment, I will ask you to read the card quietly to yourself. I will then ask you some
500 questions about what it says. You do not have to memorise the card, as you will be able to look
501 at it while answering the questions.

- 502 1. What is the maximum number of days you may take this medicine?
503 *(Correct answer 7. If responds with 'one week', interviewer may probe for number of*
504 *days. Other answers incorrect.)*
505
- 506 2. List three situations for which you should consult a doctor.
507 *(Respondent should mention at least three of the following: (Before giving medication to*
508 *children with) chicken pox; (Before giving medication to children with) influenza, Reyes*
509 *syndrome, (During) lactation, (During) pregnancy, If symptoms persist, (Accidental)*
510 *overdose. Incorrect answer: any other response.)*
511
- 512 3. List one condition for which you might take the Medco tablet.
513 *(Correct if answered one of: Headaches, Muscle Pains, Rheumatic pains, Toothache,*
514 *Earache, Common cold. Other answers incorrect.)*
515
- 516 4. List one condition for which you should not take the Medco tablet.
517 *(Correct if respondent mentions at least one of the following as conditions for which you*
518 *should not take the tablet: Gastritis, Peptic ulcer, Serious liver illness, Bronchial asthma.*
519 *Incorrect answer: any other response.)*
520

521 Scoring: 1 point per complete correct response.

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526 **Physical Activity Example Show Card**

P3096

HEACTA/HEACTB/HEACTC

CARD C25**Vigorous***For example:*

Running or jogging

Swimming

Cycling

Aerobics or gym workout

Tennis

Digging with a spade or shovel

Moderate*For example:*

Gardening

Cleaning the car

Walking at a moderate pace

Dancing

Floor or stretching exercises

Mild*For example:*

Vacuuming

Laundry

Home repairs

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Appendix Table. Reverse associations between baseline MVPA and change in memory, verbal fluency, and health literacy over the follow-up, England, 2004-13, n=4345			
MVPA	Health literacy decline of ≥ 1 point (Yes vs. No)	Memory decline of >1 point (Yes vs. No)	Verbal fluency decline of >1 point (Yes vs. No)
	OR (95% CI)	OR (95% CI)	OR (95% CI)
Weekly MVPA at baseline			
No	1.00 (ref)	1.00 (ref)	1.00 (ref)
Yes	0.93 (0.73, 1.17)	0.93 (0.76, 1.13)	0.99 (0.82, 1.20)

531 Note: All ORs adjusted for age, sex, ethnicity, education, net non-pension wealth, self-rated health, limiting long-
532 standing illness, and IADL limitations, and are population-weighted