Education and mental health trajectories in older age: the mediating role of wealth and physical activity

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Abstract

Objective. Financial conditions, such as low wealth, have been highlighted as a factor explaining why people with lower levels of educational attainment have poorer mental health than people with higher levels. However, whether behavioral factors can further explain this association remains unclear. Here, we examined the extent to which physical activity behavior mediates the effect of education on mental health trajectories in old age, independently of the financial condition pathway.

Methods. Data from 54,818 adults 50 years of age or older (55% women) included in the Survey of Health, Ageing and Retirement in Europe (SHARE) were analyzed using longitudinal mediation and growth curve models to estimate the mediating role of wealth and physical activity (initial status and change) in the association between education and mental health trajectories. Education, wealth, and physical activity were self-reported. Depressive symptoms and well-being were measured using validated scales.

Results. Lower education was associated with a lower level and steeper decrease in physical activity over time, which predicted more depressive symptoms and greater decrease in well-being. In other words, education affected mental health through both the level and trajectories of physical activity. Physical activity explained 30.5% of additional variance in depressive symptoms and 49.1% in well-being, relative to the model including wealth as the only mediator.

Conclusions. Physical activity may be at least as important as socioeconomic factors (e.g., wealth) in explaining the association between low education attainment and poor mental health trajectories in adults 50 years of age or older.

Keywords: Educational status, exercise, mental health, aging, longitudinal studies

Introduction

Mental health conditions are a leading cause of disability,[1 2] whose prevalence increases with age.[3] Promoting mental health and well-being is thus a public health priority, especially in older adults.[4] This promotion considers education as an important factor in mental health as lower levels of education have been found to be robustly associated with poor mental health in middle-aged and older adults.[5-12] Similarly, a meta-analysis showed a dose-response association between education and depression, with the log odds ratio of major depression decreasing by 3% for each additional year of education.[13]

Although empirical evidence remains scarce, social epidemiology often contends that the association between educational attainment and health, including mental health, is underlined by life course socioeconomic conditions such as wealth.[5 14 15] For example, a recent large-scale prospective cohort study conducted on Australians aged 45 or older suggested that wealth mediated the associations between lower educational attainment and higher psychological distress.[5] This result was consistent with those observed in young people.[14] However, in both studies, nearly half of the detrimental association between lower education and poorer mental health was not explained by employment status or wealth level. These findings highlight that, although socioeconomic factors are important mediators of the education–mental health association, a substantial amount of variance remains to be explained. Thus, other pathways through which education could influence mental health remain to be investigated.

Physical activity could be part of these pathways: First, existing literature has robustly demonstrated that higher levels of education are associated with higher levels of physical activity across the lifespan.[16-21] Second, numerous studies have shown that higher levels of physical activity are associated with a better mental health across aging,[22-25] with several psychosocial and biological mechanisms explaining this association.[26 27] However, to the best of our knowledge, no large-scale longitudinal studies have been conducted to examine whether, and to what extent, physical activity explains the association between educational attainment and mental health, while adjusting for the established socioeconomic pathways.

To address these knowledge gaps, the objective of the present study was to examine whether the initial level and the rate of change in physical activity mediate the association between educational attainment and mental health trajectories in adults 50 years of age or older. To extend the existing literature that exclusively focused on poor mental health, both depressive symptoms and well-being were investigated.[28 29] We hypothesized that both initial level and change in physical activity explain the association between lower educational attainment and steeper increase in depressive symptoms as well as steeper decrease in well-being across time, irrespective of the socioeconomic status.

Methods

Participants and study design

Data are from the Survey of Health, Ageing and Retirement in Europe (SHARE), a longitudinal, cross-national population-based study of adults 50 years of age or older.[30] In SHARE, data were collected every two years between 2004 and 2019, with a total of eight measurement waves using computer-assisted personal interviews (CAPI) in participants' homes. Educational attainment was measured when participants were first included in the study. Physical activity and mental health were assessed in all measurement waves except wave 3 (2008-2009). Here, educational level and at least one measure of physical activity and on measure of depressive symptoms were required for a participant to be included. Participants with suspected dementia at baseline, as indicated by a score above two on the time-orientation question, [31] as well as

participants who reported more than two limitations in activities of daily living (ADL) at baseline, were excluded. SHARE is approved by the relevant research ethics committees in the participating countries. All participants provided written informed consent.

Measures

Outcome variables. *Depressive symptoms* were assessed using the depression symptoms scale from the EURO-DEP consortium (EURO-D scale).[32 33] The EURO-D scale includes 12 items: depressed mood, pessimism, wishing death, guilt, sleep, interest, irritability, appetite, fatigue, concentration, enjoyment, and tearfulness. Each item was scored 0 (symptom absent) or 1 (symptom present), generating a score ranging from 0 to 12, with higher scores indicating higher depressive symptoms. *Quality of life and well-being* were assessed using a short version of the CASP-19 scale,[34 35] that includes 12 items assessing 4 conceptual domains of individuals' needs: control, autonomy, self-realization, and pleasure. Each item was scored 0 (often) to 3 (Never), generating a score ranging from 0 to 36, with higher score indicating higher quality of life and well-being.

Exposure variable. The level of education was based on the UNESCO's International Standard Classification of Education (ISCED).[36] The levels of academic education were primary (ISCED levels 0 and 1), secondary (ISCED levels 2 to 4), or tertiary (ISCED levels 5 and 6).[37] This measure was treated as continuous.

Mediators. *Physical activity* was derived from the following question: "How often do you engage in activities that require a low or moderate level of energy such as gardening, cleaning the car, or going for a walk?".[24 38-40] Participants responded on a four-point scale: 1 = more than once a week; 2 = once a week; 3 = one to three times a month; 4 = hardly ever or never. This measure was treated as continuous. *Wealth* was derived from the equalized household net wealth. Specifically, household non-pension net wealth includes financial, physical, and housing wealth after all debt has been subtracted. The estimated an equalized measure by dividing the household sum by the square root benefiting members. The score was then categorized into country-specific quartile (i.e., low, below medium, above medium, high wealth).[41 42]

Covariates. *Occupational position* was based on the skill classification of participants' main job over the life course according to the International Standard Classification of Occupations (ISCO). ISCO's 10 main occupational groups were reclassified according to their skill levels, whereby skill levels 1 and 2 were grouped into "low" and skill levels 3 and 4 were grouped into "high" main occupational position. Participants who have never had a paid work, were included in a third category ("never work"). This variable was expected to cause wealth and as such not to be in the causal pathway from wealth to mental health.[14] Yet, its adjustment allows to examine the unique effect of wealth on mental health, after accounting for the independent effect of participants' main occupational position. *Unhealthy behavior* was computed using an index combining binary indicators of unhealthy eating, smoking, and alcohol consumption across waves for each participant. This resulted in a continuous variable ranging from 0 (none of the 3 indicators) to 1 (all unhealthy indicators) (Sieber et al., 2019). This variable was included to capture the unique association between physical activity and mental health, after accounting for the effect of other health-related behaviors.[43] This variable was not included in the model testing the mediating role of wealth only.

Confounders. Consistent with existing literature,[14] the following potential confounders were identified: *parents' employment* (i.e., low skill vs. high skill), *long-term health conditions* (i.e.,

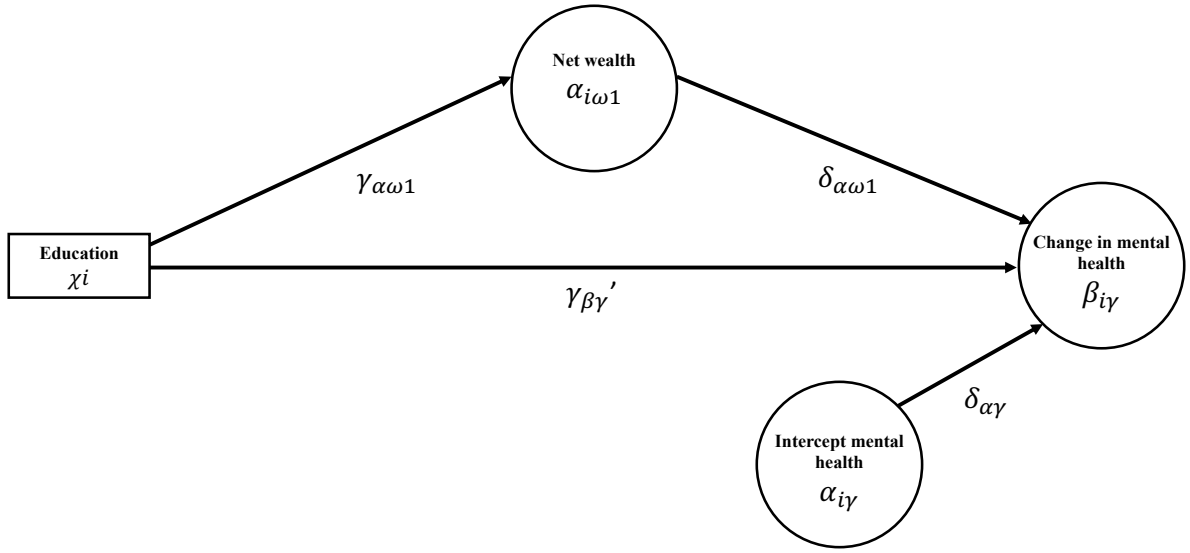
more or less than 2 chronic conditions), *age group* (50-64, 65-79, 80-96 years), *sex* (male, female), *household structure* (single vs. couple), and *country of residence*. All confounders were time-invariant.

Statistical analyses

We used a longitudinal mediation approach combined with growth curve models to estimate how the initial status (i.e., intercept) and change (i.e., slope) of the mediator (i.e., physical activity) could explain the associations between the exposure variable (i.e., education) and the change across time in the outcome variables (i.e., depressive symptoms and quality of life).[44] Specifically, the following mediating paths were defined and simultaneously entered in the model. A first path tested the intercept as mediator: Education (time-invariant exposure variable) predicted the initial status (intercept) of the mediator (*path 1a*) and the initial status of the mediator predicted the change (slope) in mental health (*path 1b*). A second path tested the slope as mediator. Education predicted the change (slope) in the mediator (*path 2a*) and the change in the mediator predicted the change in mental health (*path 2b*). Moreover, a direct effect from education to change in mental health was included (c'). To ensure that the estimation of the mediation would not be confounded by differences between subjects in the initial status in the dependent variable,[44-46] we included a path from initial status in mental health to change in mental health. Finally, the models were adjusted for the above-mentioned covariates and confounders.

Models 1 included only wealth as mediator (Figure 1). As wealth was a time-invariant mediator, only a mediation at the intercept level could be estimated. Models 2 added physical activity (i.e., level and change) as an independent mediator (Figure 2). Indirect effects were estimated using the maximum likelihood estimator and with Full Information Maximum Likelihood estimation for the missing values.[47] The proportion of the total effects explained by the mediating variables were calculated as follows: $\frac{\text{indirect effects}}{\text{total effects}}$. The analyses were performed with the lavaan R package.[48] The lavaan syntax, formal equations of the longitudinal mediation models, and the complete results of the models are in the supplemental material.

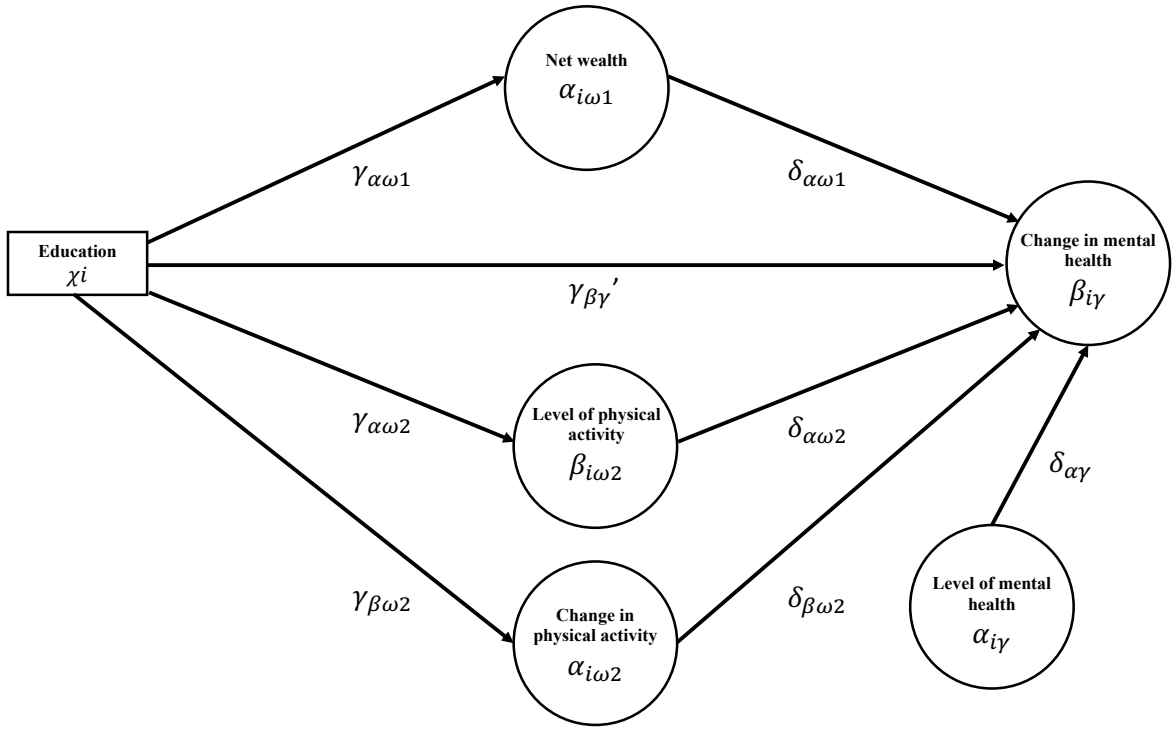
Figure 1. Longitudinal mediation model combined with growth curve models testing the mediating role of wealth on the association between education and mental health



Notes. Education is the independent variable. Wealth is the mediating variable. Mental health indicators (i.e., depressive symptoms and well-being) are the dependent variables. These

models allow to test whether the wealth explains the association between education and change in mental across time. The models tested included additional paths, as well as variance and covariances estimates. It also included covariates and confounders. These paths are not presented for the sake of clarity. The equations of the models are provided in supplemental material.

Figure 2. Independent longitudinal mediation model combined with growth curve models



Notes. Education is the independent variable. Wealth and physical activity are the mediating variables. Mental health indicators (i.e., depressive symptoms and well-being) are the dependent variables. The models tested included additional paths, as well as variance and covariances estimates. It also included covariates and confounders. These paths are not presented for the sake of clarity. The equations of the models are provided in supplemental material.

Sensitivity analyses

To satisfy the temporal precedence between the slope of physical activity and the slope of mental health, piecewise growth curve models were used. Specifically, we created a time lag between physical activity (i.e., the mediator) and depressive symptoms and well-being (i.e., the outcomes). Accordingly, the slope of the physical activity was estimated before the slope of mental health, thereby satisfying the causal condition of temporal precedence between the mediator and the dependent variable.[49 50]

Results

Descriptive results and growth curves models

Descriptive. A total of 54,818 participants (55% women) were included in the sample. Table 1 describes the sample stratified by educational level. Simple association tests showed that participants with higher levels of education had lower depressive symptoms as well as higher well-being and physical activity levels, were younger, and more likely to be a man, to be in couple, to have a high-skilled main occupational position, and were less likely to have two or more chronic conditions (*ps* < .001).

Table 1. Baseline characteristics of the participants across the level of education

N = 54,818	Primary level of education (N = 12,026)	Secondary level of education (N = 30,619)	Tertiary level of education (N = 12,173)	*p*-value
Outcomes:				
Depressive symptoms, mean ± SD	2.6 ± 2.3	2.2 ± 2.1	1.8 ± 1.8	<.001
Well-being, mean ± SD	35.3 ± 6.3	37.8 ± 5.6	39.5 ± 5.1	<.001
Mediators:				
Wealth, n (%)				
Q1	3,359 (27.9)	5,714 (18.6)	1,271 (10.4)	
Q2	3,611 (30.1)	7,720 (25.2)	2,124 (17.5)	
Q3	3,108 (25.8)	8,976 (29.3)	3,185 (26.2)	
Q4	1,948 (16.2)	8,209 (26.8)	5,593 (45.9)	<.001
Physical activity, mean ± SD	2.3 ± 1.06	2.5 ± 0.9	2.6 ± 0.8	<.001
Covariates				
Age, n (%)				
50-64	5,053 (42.0)	19,907 (65.1)	8,197 (67.3)	
65-79	5,921 (49.2)	9,604 (31.4)	3,604 (29.6)	
80-96	1,052 (8.8)	1,108 (3.6)	372 (3.1)	<.001
Gender				
Women, n (%)	7,216 (60.0)	16,846 (55.0)	6,129 (50.3)	
Men, n (%)	4,810 (40.0)	13,773 (45.0)	6,044 (49.7)	<.001
Marital status				
Alone, n (%)	3,268 (27.2)	7,539 (24.6)	2,854 (23.4)	
In couple, n (%)	8,758 (72.8)	23,080 (75.4)	9,319 (76.6)	<.001
Main occupational position				
Low skill, n (%)	11,210 (93.2)	25,369 (82.8)	7,675 (63.0)	
High skill, n (%)	816 (6.8)	5,250 (17.2)	4,498 (37.0)	
Unhealthy behaviors	0.24 ± 0.29	0.30 ± 0.30	0.27 ± 0.27	<.001
Chronic conditions				
2 or more, n (%)	6,442 (53.6)	12,318 (40.2)	4,153 (34.1)	
Less than 2, n (%)	5,584 (46.4)	18,301 (59.8)	8,020 (65.9)	<.001

Notes. Baseline = first measurement for each participant; SD = standard deviation; *p*-values are based on the analysis of variance and chi-square tests for continuous and categorical variables, respectively, testing the effect of education. The descriptive statistics (with the exception for descriptive statistics on well-being) are estimated using the larger sample (i.e., from depressive symptoms).

Growth curves models. Results of the growth curves models showed a positive latent slope for depressive symptoms across time, which was steeper in the older age categories (b = 0.011, 95% confidence interval [95% CI] = 0.005–0.016, $p < .001$, for age 50-64; b = 0.153, 95% CI = 0.144–0.161, $p < .001$, for age 65-79; b = 0.173, 95% CI = 0.148–0.199, $p < .001$, for age 80-96). In addition, results showed a positive slope for well-being across time in the youngest age category (b = 0.047, 95% CI = 0.032–0.062, $p < .001$, for age 50-64), but a negative slope in the middle age category (b = -0.284, 95% CI = -0.306–-0.262, $p < .001$, for age 65-79), which was more pronounced in the oldest age category (b = -0.460, 95% CI = -0.532–-0.387 $p < .001$, for age 80-96). These results suggested that mental health deteriorates with age, but that the decline in well-being occurs later than the increase in depressive symptoms. Finally, we observed a negative latent slope for physical activity across time, which was stronger in the

older age categories (b = -0.014, 95% confidence interval [95% CI] = -0.017–-0.011, $p < .001$, for age 50-64; b = -0.068, 95% CI = -0.072–-0.064, $p < .001$, for age 65-79; b = -0.117, 95% CI = -0.129–-0.106, $p < .001$, for age 80-96).

Longitudinal mediation analyses

Tables 2 and 3 show the results of the longitudinal mediation analyses combined with growth curve models for the test of wealth and physical activity as mediators of the education–mental health association.

Table 2. Results of longitudinal mediation analyses combined with growth curve models examining the mediating role of net wealth and physical activity on the education – depressive symptoms association

Depressive symptoms	**Model 1: Wealth only**		**Model 2: Wealth and physical activity**	
	b (CI)	***p***	**b (95% CI)**	***p***
Slope depressive symptoms (β_{iv})				
Education ($\gamma_{\beta_{,,\prime}}$)	0.017 (0.011; 0.024)	<.001	0.006 (-0.001; 0.013)	.062
Wealth ($\delta_{\alpha\omega 1}$)	0.014 (0.011; 0.017)	<.001	0.008 (0.004; 0.012)	<.001
Intercept physical activity ($\delta_{\alpha\omega 2}$)			-0.057 (-0.071; -0.043)	<.001
Slope physical activity ($\delta_{\beta\omega 2}$)			-1.034 (-1.113; -0.955)	<.001
Wealth ($\alpha_{i\omega 1}$)				
Education ($y_{\alpha\omega 1}$)	1.046 (1.038; 1.055)	<.001	1.046 (1.038; 1.055)	<.001
Intercept physical activity ($\alpha_{i\omega 2}$)				
Education ($y_{\alpha\omega 2}$)			-0.077 (-0.096; -0.059)	<.001
Slope physical activity ($\beta_{i\omega 2}$)				
Education ($y_{\beta\omega 2}$)			-0.011 (-0.015; -0.007)	<.001
Total effect	0.032 (0.015; 0.027)	<.001	0.031 (0.024; 0.038)	<.001
Indirect effects				
Wealth				
Indirect effect (intercept) ($y_{\alpha\omega 1} \times \delta_{\alpha\omega 1}$)	0.015 (0.011; 0.018)	<.001	0.008 (0.005; 0.012)	<.001
Physical activity				
Indirect effect (intercept) ($y_{\alpha\omega 2} \times \delta_{\alpha\omega 2}$)			0.004 (0.003; 0.006)	<.001
Indirect effect (slope) ($y_{\beta\omega 2} \times \delta_{\beta\omega 2}$)			0.012 (0.007; 0.016)	<.001
Total indirect effect			0.024 (0.019; 0.029)	<.001
Percentage of mediated effect				
By wealth	46.9%		25.8%	
By physical activity			51.6%	
By both wealth and physical activity			77.4%	

Notes. 95% CI = confidence interval at 95%. The models were adjusted for parents' employment (i.e., low skill vs. high skill), long-term health conditions (i.e., more or less than 2 chronic conditions), age group (50-64, 65-79, 80-96 years), sex (male, female), household structure (alone vs. in couple), and main occupational position (low skill vs. high skill vs. never work). Unfavorable behaviors (smoking, alcohol consumption, unhealthy eating, and country of residence were adjusted in the model 2.

Depressive symptoms. Model 1. Low (vs. high) education was associated with a lower wealth ($y_{\alpha\omega 1}$ = 1.046, 95% confidence interval [95% CI] = 1.038–1.055, $p < .001$), which was associated with a steeper increase in depressive symptoms ($\delta_{\alpha\omega 1}$ = 0.014, 95% CI = 0.011–0.017, $p < .001$). In other words, the level of wealth mediated the association between education

and changes in depressive symptoms, as confirmed by a significant indirect effect (0.015, 95% CI = 0.011–0.018, $p < .001$). 46.9% of the total effect of education on depressive symptoms was mediated by wealth. The direct effect of education on depressive symptoms remained significant ($\gamma_{\beta_{y'}}$ = 0.017, 95% CI = 0.011–0.024, $p < .001$) (Table 2 and Figure 1).

Model 2. Compared to model 1, the indirect effect of education on changes in depressive symptoms through wealth was reduced by about half when physical activity was included as a potential mediator, but remained significant (indirect effect = 0.008, 95% CI = 0.005–0.012, $p < .001$). Low (vs. high) education was associated with a lower initial level of physical activity ($y_{\alpha\omega 2}$ = -0.077, 95% CI = -0.096–0.059, $p < .001$), which was associated with a steeper increase in depressive symptoms ($\delta_{\alpha\omega 2}$ = -0.057, 95% CI = -0.071–0.043, $p < .001$). In addition, low (vs. high) education was associated with a steeper decline in physical activity ($y_{\beta\omega 2}$ = -0.011, 95% CI = -0.015–-0.007, $p < .001$), which was associated with a stepper increase in depressive symptoms ($\delta_{\beta\omega 2}$ = -1.034, 95% CI = -1.113–-0.955, $p < .001$). In other words, both the initial level and changes in physical activity mediated the association between education and changes in depressive symptoms, as confirmed by indirect effects (intercept level = 0.004, 95% CI = 0.003–0.006, $p < .001$; slope level = 0.012, 95% CI = 0.007–0.016, $p < .001$). The direct effect of education on depressive symptoms was no longer significant when physical activity was included as a potential mediator ($\gamma_{\beta_{y'}}$ = 0.006, 95% CI = -0.001–0.013, $p = .062$). 77.4% of the total effect of education on depressive symptoms was explained (25.8% by wealth and 51.6% by physical activity). Adding physical activity explained 30.5% of additional variance in depressive symptom changes relative to the model including wealth as the only mediator (Table 2 and Figure 2).

Well-being. *Model 1.* Low (vs. high) education was associated with a lower wealth ($y_{\alpha\omega 1}$ = 1.048, 95% CI = 1.040–1.050, $p < .001$), which was associated with a steeper decrease in well-being ($\delta_{\alpha\omega 1}$ = -0.035, 95% CI = -0.045–-0.025, $p < .001$). In other words, the level of wealth mediated the association between education and changes in well-being, as confirmed by a significant indirect effect (-0.037, 95% CI = -0.047–-0.027, $p < .001$). 49.3% of the total effect of education on well-being was mediated by wealth. The direct effect of education on well-being remained significant ($\gamma_{\beta_{y'}}$ = -0.038, 95% CI = -0.055–-0.021, $p < .001$) (Table 2 and Figure 1).

Model 2. Compared to model 1, the indirect effect of education on change in well-being through wealth was reduced by about three times when physical activity was included as a potential mediator, and was no longer significant (indirect effect = -0.012, 95% CI = -0.023–0.001, although $p = .051$). Low (vs. high) education was associated with a lower initial level of physical activity ($y_{\alpha\omega 2}$ = -0.079, 95% CI = -0.099–0.059, $p < .001$), which was associated with a steeper decrease in well-being across time ($\delta_{\alpha\omega 2}$ = 0.155, 95% CI = 0.111–0.199, $p < .001$). In addition, low (vs. high) education was associated with a steeper decline in physical activity ($y_{\beta\omega 2}$ = -0.011, 95% CI = -0.015–-0.006, $p < .001$), which was associated with a steeper decrease in well-being ($\delta_{\beta\omega 2}$ = 3.429, 95% CI = 3.188–3.670, $p < .001$). In other words, both the initial level and changes in physical activity mediated the association between education and changes in well-being, as confirmed by indirect effects (at the intercept level = -0.012, 95% CI = -0.017–-0.008, $p < .001$; at the slope level = -0.036, 95% CI = -0.051–-0.021, $p < .001$). The direct effect of education on well-being was no longer significant when physical activity was included as a potential mediator ($\gamma_{\beta_{y'}}$ = -0.001, 95% CI = -0.021–0.018, $p = .885$). 98.4% of the total effect of education on well-being was explained (19.7% by wealth and 78.7% by physical activity). Adding physical activity explained 49.1% of additional variance in well-being changes relative to the model including wealth as the only mediator (Table 2 and Figure 2).

Table 3. Results of longitudinal mediation analyses combined with growth curve models examining the mediating role of net wealth and physical activity on the education – well-being association

Well-being	Model 1: Wealth only		Model 2: Wealth and physical activity	
	b (CI)	*p*	b (95% CI)	*p*
Slope well-being (β_{iv})				
Education ($\gamma_{\beta_{v,v'}}$)	-0.038 (-0.055; -0.021)	<.001	-0.001 (-0.021; 0.018)	.885
Wealth ($\delta_{\alpha\omega 1}$)	-0.035 (-0.045; -0.025)	<.001	-0.011 (-0.022; 0.001)	.051
Intercept physical activity ($\delta_{\alpha\omega 2}$)			0.155 (0.111; 0.199)	<.001
Slope physical activity ($\delta_{\beta\omega 2}$)			3.429 (3.188; 3.670)	<.001
Wealth ($\alpha_{i\omega 1}$)				
Education ($y_{\alpha\omega 1}$)	1.048 (1.040; 1.057)	<.001	1.048 (1.040; 1.057)	<.001
Intercept physical activity ($\alpha_{i\omega 2}$)				
Education ($y_{\alpha\omega 2}$)			-0.079 (-0.099; -0.059)	<.001
Slope physical activity ($\beta_{i\omega 2}$)				
Education ($y_{\beta\omega 2}$)			-0.011 (-0.015; -0.006)	<.001
Total effect	-0.075 (-0.047; -0.027)	<.001	-0.061 (-0.082; -0.041)	<.001
Indirect effects				
Wealth				
Indirect effect (intercept) ($y_{\alpha\omega 1} \times \delta_{\alpha\omega 1}$)	-0.037 (-0.047; -0.027)	<.001	-0.012 (-0.023; 0.001)	.051
Physical activity				
Indirect effect (intercept) ($y_{\alpha\omega 2} \times \delta_{\alpha\omega 2}$)			-0.012 (-0.017; -0.008)	<.001
Indirect effect (slope) ($y_{\beta\omega 2} \times \delta_{\beta\omega 2}$)			-0.036 (-0.051; -0.021)	<.001
Total indirect effect			-0.060 (-0.076; -0.044)	<.001
Percentage of mediated effect				
By wealth	49.3%		19.7%	
By physical activity			78.7%	
By both wealth and physical activity			98.4%	

Notes. 95% CI = confidence interval at 95%. The models were adjusted for parents' employment (i.e., low skill vs. high skill), long-term health conditions (i.e., more or less than 2 chronic conditions), age group (50-64, 65-79, 80-96 years), sex (male, female), household structure (alone vs. in couple), and main occupational position (low skill vs. high skill vs. never work). Unfavorable behaviors (smoking, alcohol consumption, unhealthy eating, and country of residence) were adjusted in the model 2.

Sensitivity analyses

Results of the sensitivity analyses (N = 39,467 for depressive symptoms and N = 39,089 for well-being) were consistent with those of the main analyses (see supplemental materials). Specifically, for both indicators of mental health, models 1 showed significant indirect effects of education on mental health trajectories through wealth. Wealth explained 28.3% of the association between education and changes in depressive symptoms and 52% of the association between education and changes in well-being. Moreover, results of models 2 showed significant indirect effects of education on changes in mental health through both the level and changes in physical activity (though the indirect effect via the level of physical for well-being was not significant, p = .067), while the indirect effects via wealth were reduced. Models 2 explained 55.8% of the association between education and changes in depressive symptoms and 88.6% of the association between education and changes in well-being.

Discussion

Main findings

This cross-national and large-scale longitudinal study showed that the association between educational attainment and mental health trajectories in old age was explained by physical activity. Specifically, low education was associated with a lower initial level and a steeper decline in physical activity across time, which were associated with a steeper decline in mental health and well-being. These results were obtained while adjusting for the socioeconomic pathway (i.e., here indicated by wealth) and for multiple covariates (i.e., occupational position, health behaviors) and potential confounders (i.e., parents' employment, long-term health conditions, age group, sex, household structure, and country of residence). Adding physical activity level as a mediator explained 30.5% of additional variance in depressive symptoms (77.4 vs. 46.9%) and 49.1% in well-being (98.4 vs. 49.3%) relative to the model with wealth as sole mediator. Finally, education was no longer significantly associated with the mental health outcomes when physical activity was added to the model.

Comparison with previous studies

Our results showed that wealth, as an indicator of the socioeconomic status, mediated about half of the association between education and mental health – 46.9% and 49.3% for depressive symptoms and well-being, respectively. These results are consistent with the existing literature showing that fairly less than half of the detrimental effect of low education on mental health may be explained by the socioeconomic factors.[5 14] However, our study complements the literature by using longitudinal data that allowed to examine mental health trajectories among older adults, while previous studies examined the level of mental health only but disregarded its change across time. Likewise, while previous studies exclusively focused on indicators of poor mental health, our study is the first to also investigate an indicator of well-being. Interestingly, we observed that the results were overall consistent for both depressive symptoms and well-being, thereby suggesting that the mechanisms linking education to mental health could be similar for ill-being and well-being indicators.

We found that the adverse associations between low education and change in mental health and well-being among older adults were explained not only by the initial level of physical activity, but also by its change across time – low education was associated with a lower initial level and stronger decline of physical activity across time, which in turn strengthen the increase in depressive symptoms and decreases in well-being across time. A result in line with the existing literature. Indeed, on the one hand, studies have shown that low education was associated with lower physical activity across the life course,[16-21] and, on the other hand, that lower physical activity was associated with weaker mental health across aging.[22-25] In sum, we demonstrate, for the first time, that physical activity could explain the association between low education and poorer mental in older age after accounting for the role of the socioeconomic pathway (i.e., here indicated by a measure related to the wealth).

Concerning the extent to which physical activity reduced the association between low education on mental health, we observed that adding physical activity explained 30.5% of additional variance in depressive symptoms and 49.1% in well-being relative to the model including wealth as the only mediator. In total, this model testing conjointly the socioeconomic and behavioral pathways explained 77.4% of the detrimental association between education and depressive symptoms and 98.4% for well-being. Crucially, for both indicators of mental health, the direct effect of education was no longer significant when physical activity was included as a potential mediator. These findings therefore suggest that most of the effect of low education

on mental health among older adults may be explained by a combination of socioeconomic (i.e., wealth) and behavioral (i.e., physical activity) factors.

When physical activity was included as a potential mediator, the indirect effect of education on mental health through wealth was reduced by about half for depressive symptoms and by about three times for well-being. Importantly, whether the indirect effect via wealth remained significant for depressive symptoms, this was no longer the case for well-being. In other words, the role of wealth in explaining the adverse association between low education and mental health was reduced when physical activity is accounted for. Specifically, the percentage mediated by wealth reduced from 46.9% to 25.8% for depressive symptoms and from 49.3% to 19.7% for well-being. Thus, once the behavioral pathway is considered in the model, the ability of the socioeconomic pathway to explain the detrimental effect of low education and mental health was reduced. Overall, these findings may suggest that a substantial part of the mediating role previously attributed to wealth (i.e., about 50%) on the link between education and mental health could have been overestimated in previous studies.

Limitations and strengths

The study includes features that limit the conclusion that can be drawn. First, though longitudinal, the correlational nature of the data cannot exclude reverse causality, thereby preventing from inferring causal links between education, wealth, physical activity, and mental health trajectories. However, to minimize the risk of a reverse causation bias, in the sensitivity analyses we introduced a time lag between physical activity and mental health to respect the temporal precedence. Results of these analyses yield similar results to those obtained in the main analysis. Second, the usual level of physical activity was measured using a self-reported questionnaire, which may not accurately reflect the actual level of physical activity.[51] Likewise, as our main outcomes were also measured using self-reported scales, a common method variance bias cannot be excluded. Accordingly, the high percentage of the effects of education on the mental health outcomes mediated by physical activity needs to be interpreted in this regard. Measuring physical activity using devices-based measures should be used in future studies. Third, the socioeconomic pathway was assessed using an indicator related to participants' wealth, representing an indicators of economic reserve.[52] Yet, this variable is not a comprehensive measure of the different features that underlie the socioeconomic advantages and disadvantages, along with income and occupation.[53] Assessing additional socioeconomic indicators is therefore warranted to better estimate the weight of the socioeconomic pathways in explaining the detrimental effects of education on mental health. Finally, additional pathways linking education to health have been suggested, including stress increase, lack of social support, and poorer decision making and cognitive functioning.[54-58] Future studies simultaneously controlling for these multiple channels are required to examine their unique role in explaining the association between low education and poor mental health.

However, these limitations are offset by several strengths. First, we use a large-scale (> 50'000), longitudinal (15-year follow-up), and multinational cohort (29 countries). Second, this is the first study to directly examine whether the behavioral pathway (i.e., physical activity) can explain the detrimental effects of low education on mental health trajectories among adults 50 years of age or older, and this after accounting for the socioeconomic pathway (i.e., wealth). Third, we adopted a statistical approach that allowed to test not only the mediating role of the level of physical activity but also its rate of change across time. Fourth, the mental health outcomes were based on validated scales with good reliability and validity. Finally, unlike previous literature that mostly focused on indicators of poor mental health (e.g., depression), the study also investigated an indicator of optimal mental functioning.

Conclusion

This study provides the first empirical support for the hypothesized indirect pathway between education and mental health trajectories in old age through physical activity. Both the initial level of physical activity and its change over the years explained a large part of the association between education and mental health trajectories, beyond the part explained by the level of wealth in adults 50 years of age or older.

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