



Education and grip strength among older Thai adults: A mediation analysis on health-related behaviours

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Abstract

Background: Previous studies have investigated the effect of differential educational attainment at younger ages on health disparities among older adults, but how such an effect can be attenuated remains understudied. This study examines the mediating effects of four health-related behaviours, namely smoking, alcohol drinking, healthy eating, and physical activity, on the relationship between older adults' education and grip strength.

Methods: The study used data from 7,064 individuals aged 60 years and older who participated in the 2009 National Health Examination Survey of Thailand. To examine the relationships among education, health behaviours, and grip strength, multivariate regressions were performed following Baron and Kenny's approach. Generalized Structural Equation Modelling (SEM) was utilized to quantify the mediating effects.

Results: All else being equal, education is positively associated with stronger grip for both genders. The mediation analyses demonstrate that health-related behaviour plays an important role in the relationship between education and grip strength; however, the extent to which it mediates the effect of education varies with the type of health behaviour and between genders. Not smoking and engaging in physical activity can partly explain the relationship between education and grip strength in older men. Meanwhile, the consumption of fruits and vegetables and participation in regular physical activity significantly mediate the effect of education on grip strength in older women.

Conclusion: Our study reaffirms the importance of educational opportunity in earlier life and recommends health-related behavioural modifications to improve health status in low-educated older adults.

1. Introduction

Grip strength is an objective health indicator that has been increasingly referred to as a biomarker of aging (Bohannon, 2019). It can be used to measure overall muscle strength (Cooper, Kuh, Hardy, & Mortality Review Group, 2010) and to predict mortality (Cooper et al., 2010; Leong et al., 2015), disability (Snih, Markides, Ottenbacher, & Raji, 2004), cognitive impairment (Alfaro-Acha et al., 2006), and cardiovascular disease (Leong et al., 2015) in older persons. To gain a better understanding of grip strength, health and social science research has begun to look at socioeconomic determinants, including educational attainment. Most of the existing research has found a positive association between education and grip strength (Alqahtani, Alenazi, Alshehri, Alqahtani, & Elnaggar, 2019; Carney & Benzeval, 2018). While there is considerable evidence of various possible channels through which

education may improve health outcomes (Lochner, 2011), our understanding of how older individuals with higher educational attainment have stronger grips remains unclear.

Health-related behaviour is an important lifestyle factor that has important independent associations with education and grip strength. There is good evidence showing that higher education significantly increases the consumption of healthy foods, such as fruits and vegetables (Satheanoppakao, Aekplakorn, & Pradipasen, 2009), and the likelihood of engaging in physical activity (Kaplan, Newsom, McFarland, & Lu, 2001; Shaw & Spokane, 2008) in older adults. For health-compromising behaviours, such as smoking and drinking alcohol, education has been indicated to have a protective effect in several studies (de Walque, 2007; Shankar, McMunn, & Steptoe, 2010), but not others (Kelfve, Agahi, Mattsson, & Lennartsson, 2017; Rossow & Træen, 2020). Previous studies have also reported various effects of

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health-related behaviours on grip strength among older persons. For example, Kim, Jeon, and Jeong (2019) and Kwon et al. (2017) found that drinking alcohol has a negative association with grip strength in older Koreans, whereas a positive association and no association were demonstrated, respectively, in studies by Huckle, You, and Casswell (2010) in New Zealand and Lenardt et al. (2014) in Brazil. Inconsistent findings have been observed for smoking as well. While the adverse effects of smoking on muscle strength have been commonly reported in the medical literature (Brunello, Fort, Schneeweis, & Winter-Ebmer, 2016), other studies conducted exclusively in older populations have demonstrated inconsistent findings, with smoking having a positive association (MohdHairi, Mackenbach, Andersen-Ranberg, & Avendano, 2010) or no association with grip strength (Kim et al., 2019; Lenardt et al., 2014).

Despite these two independent lines of research showing how education and health-related behaviours are individually associated with grip strength in older adults, it remains unclear whether, and to what extent, these factors are interrelated. Previous studies have shown evidence of a mediating effect of health-related behaviours on the relationship between education and health of older adults. Certain behaviours – i.e., smoking, drinking, consumption of healthy food and physical activity – have been commonly indicated as significant mediators (Brunello et al., 2016; Solis-Urra et al., 2020). However, the extent to which these behaviours contribute to or mediate the educational effect on health varies substantially across studies, which is due in large part to the differences in health outcomes examined (e.g., self-rated health and functional limitations) as well as the study design used to identify the mediator (Brunello et al., 2016). However, to our knowledge, no prior studies have examined the mediation effect of health-related behaviours on the association between education and grip strength.

Most research on the association between old-age grip strength and education or health-related behaviours has focused on more developed contexts, such as Europe and North America. In Asia, the majority of existing studies have been conducted in East and Middle East Asian contexts. However, this issue is of particular importance for developing countries, where socio-economic inequalities are a major issue, and where the populations are aging rapidly, with the great majority of older persons having little or no education. Even though overall health in developing countries has improved over the past decades – as reflected by various health indicators, including higher life expectancy (Ortiz-Ospina & Rose, 2016) – the experience of developed countries reveals that health gains tend to be concentrated in highly-educated people rather than in those with lower education levels (Zajacova & Lawrence, 2018). This trend is likely to widen existing socio-economic inequalities and health disparities.

The current study aims to fill several gaps in the literature by examining the association between the education and grip strength of older persons and the mediating roles in this association of four different health-related behaviours, namely smoking, drinking alcohol, healthy eating and physical activity, using nationally representative data from Thailand. Thailand provides an appropriate setting for this study, as the country is among the very few developing countries in Asia that has collected information on biomarkers in a national-level survey. More importantly, the majority of the current cohort of Thai older persons have completed only basic primary education (Teerawichitchainan, Pothisiri, Knodel, & Prachuabmoh, 2019). Previous studies have found that lower-educated older Thai adults are more likely to experience ill health and faster aging than their counterparts with higher education (Loichinger & Pothisiri, 2018; Pothisiri, Prasitsiriphon, & Aekplakorn, 2020). Unlike other socioeconomic factors, education primarily occurs at a young age and does not change significantly over the middle and later life course. Therefore, the evidence of the mediating role of health-related behaviours in the association between education and grip strength obtained in this study is anticipated to provide valuable information for effective policy interventions to improve older persons'

health as well as the health of those in other age groups, and to reduce existing health disparities overall.

2. Material and methods

2.1. Data and sample

This study relies on data from the 2009 National Health Examination Survey (NHES), which was the fourth in a periodic series conducted by the Health Systems Research Institute, Ministry of Public Health, and preceded by three surveys, in 1991, 1997, and 2004. The 2009 NHES was the first survey in the series that incorporated objective assessments of physical performance, including grip strength. The sample is nationally representative and comprises 31,680 non-institutionalized individuals older than 1 year of age. The sampling design was multistage, first involving the selection of 22 provinces (including Bangkok), followed by 104 districts, and then 340 electoral units in municipal areas and 272 villages in non-municipal areas. Prior to data collection, the 2009 NHES was approved by the Ethical Review Committee for Research in Human Subjects of the Ministry of Public Health, Thailand. Further details about the survey's methodology can be read elsewhere (Thailand National Health Examination Survey Office, 2010).

In this analysis, we restricted the sample to individuals aged 60 years and older, the age range most commonly used when referring to older persons in Thailand (Teerawichitchainan et al., 2019). We further excluded cases with missing information on variables of interest – i.e., grip strength, education, and all other socio-demographic and health characteristics – using listwise deletion methods. Missing data were modest, ranging from 0.01% for hypertension to 9.6% for income. After applying all restrictions, the final analytical sample size was 7064 older adults, of whom 49.9% were men and 51.1% were women. To avoid any potential sample selection bias, we compared the distributions of all variables of interest in the total sample before excluding the missing values, and the final analytic sample. Our diagnostic results demonstrated no statistically significant differences in any of the variables between the two samples.

2.2. Variable measurements

2.2.1. Grip strength

Grip strength was measured using a handgrip dynamometer (model no. T.K.K5401 GRIP-D; Takei Scientific Instruments, Niigata, Japan). During the test, respondents were instructed to sit with their elbow at 90-degree flexion and their forearm and wrist in neutral position, and to squeeze the device as firmly as possible for 3 seconds. For each hand, two consecutive tests were performed, from which the mean value was derived and incorporated into the analysis as a continuous variable. Appendix Figure S.1 shows the distribution of grip strength for older men and women.

2.2.2. Education

Education was primarily derived from a question regarding the highest level of education attained. The respondents' answers were validated with their reported number of schooling years to minimize discrepancies resulting from recall bias and changes in the number of years required for primary education during Thailand's education reform between 1932 and 1977 (Loichinger & Pothisiri, 2018). The original responses were recoded into three categories, namely lower than primary education (including no education), primary education, and beyond primary education. Lower than primary education was used as the reference category in the regression analyses.

2.2.3. Health-related behaviours

Smoking was assessed through a single-item question asking whether the respondent had smoked any tobacco products – such as cigarettes, cigars, or bidis – at least once in the 12 months prior to the survey.

Possible responses were reverse-coded so that a positive response indicated that the respondent was a non-smoker.

Regular alcohol drinking was constructed based on the respondents' answer to two questions about whether, and how frequently, they had consumed any alcoholic beverages – including beer, wine, whisky, or any fermented alcoholic drinks – at least once in the 12 months prior to the survey. Possible responses ranging from the lowest frequency (i.e., only once a year) to the highest frequency (i.e., every day) were categorized and reverse-coded to signify whether the respondents were non-drinkers (i.e., never consumed any alcoholic beverages), irregular drinkers (i.e., consumed alcoholic beverages 1–2 days a week), or regular drinkers (i.e., consumed alcohol at least 3–4 days a week).

Healthy eating was assessed through questions regarding the frequency and serving size of fresh fruits and vegetables consumed during the day. Processed fruits and vegetables (e.g., canned, dried, juice) were not included. Those who reported consuming at least four servings of either fruits or vegetables per day were considered to have healthy eating habits (Miller et al., 2017).

Physical activity was derived from respondents' yes/no responses to two questions on whether they had undertaken moderate or heavy physical activities (e.g., sports, exercising, cycling) for at least 10 minutes during leisure time. Those who answered yes were considered to have moderate-to-vigorous physical activity.

2.2.4. Socio-demographic and health covariates

Several socio-demographic and health covariates, which potentially affect older persons' grip strength and the four health-related behaviours, were incorporated into the analyses. These included age, height, weight, marital status, area of residence, last year's work status, income level, functional limitations, diabetes and hypertension. Marital status and area of residence were incorporated owing to evidence of the effect of marital status on health (Ejechi & Ogege, 2020), and urban–rural differentials in grip strength and health-related behaviours (Arokiasamy & Selvamani, 2018). Prior studies have reported that economic conditions significantly affect old-age muscle strength and various health-related practices (Ejechi & Ogege, 2020; Mohd Hairi et al., 2010); these were assessed in the present study through two measures: last year's employment status and income level. The level of income was constructed based on the reported average monthly income from all sources and converted into terciles indicating whether the respondent was a low-, middle-, or high-income earner. Measures of health conditions – i.e., functional limitations, diabetes and hypertension – commonly reported to be negatively associated with grip strength were also included (Kim et al., 2019; Syddall et al., 2018). A functional limitation was defined as having difficulty in at least one of three physical functional activities, namely lifting a heavy load, climbing ten stairs without resting, and walking 400 meters. Cronbach's alpha demonstrates that the three components of functional limitation had good reliability ($\alpha = 0.7369$). Respondents were considered to have diabetes when their fasting plasma glucose level (FPG) was greater than or equal to 126 mg/dl, and they reported having been diagnosed with diabetes by a health professional or were prescribed glucose-lowering medications by a health professional within the past 12 months. Blood pressure was measured three times by a general practitioner or health professional using an automatic monitor. Hypertension was identified based on one of the following conditions: a systolic blood pressure of 140 mmHg or above, a diastolic pressure of 90 mmHg or above, or current use of antihypertensive medications (Kim et al., 2019). Table 1 summarizes the measurement of these variables.

2.3. Analysis

We employed both descriptive and inferential analyses. Descriptive statistics were utilized first to describe the distributions of all analytical variables across education groups. One-way ANOVA and Chi-square tests were used for continuous variables and categorical variables,

Table 1
Measurement of sociodemographic and health covariates.

Variable	Measurement
Age	Continuous
Height	Continuous
Weight	Continuous
Marital status	Dichotomous: 0 = not currently married, 1 = currently married
Area of residence	Dichotomous: 0 = rural, 1 = urban
Last year's work status	Dichotomous: 0 = did not work, 1 = worked
Income level	Categorical: Men: Low = 0–2000 THB (US\$ 0–66), Middle = 2001–5000 THB (US\$ 67–166), High = 5001 THB (US\$ 167) and over Women: Low = 0–1500 THB (US\$ 0–50), Middle = 1501–3000 THB (US\$ 51–100), High = 3001 THB (US\$ 167) and over
Functional limitation	Dichotomous: 0 = can do by oneself, 1 = cannot do at all or can do only with assistance
Diabetes	Dichotomous: 0 = no, 1 = yes
Hypertension	Dichotomous: 0 = no, 1 = yes

Notes: THB = Thai Baht currency; US\$ = US Dollar; 1 US\$ is equivalent to approximately 30 THB.

respectively, to analyse differences among education groups. Binary and multinomial logistic regressions and Ordinary Least Squares (OLS) were then used to examine the mediation effect of four health-related behaviours on the relationship between grip strength and education, following Baron and Kenny's approach (Baron & Kenny, 1986). Binary logistic regression was used when the dependent variable was coded as a dichotomous variable, whereas multinomial logistic regression was used when the dependent variable had more than two categories. Meanwhile, OLS regression models were fitted for the analysis when the dependent variable was treated as a continuous variable and had a normal distribution.

According to Baron and Kenny's approach, the following analytical steps were performed. Statistical significance was considered for $p < 0.05$.

- (1) Logistic regressions of education as the independent variable and each potential mediator as the dependent variable. For non-smoking, healthy eating and physical activity, the binary logistic regression equation takes the following form (Models 1A, 1C, 1D in Table 3 and Models 4A, 4C, 4D in Table 4):

$$\ln \frac{P(HB_{k,i} = 1)}{1 - P(HB_{k,i} = 1)} = \alpha_0 + \alpha_1 Edu_i + x_i^T \zeta + e_i \quad (1)$$

in which $HB_{k,i}$ denotes the potential mediator k of each individual i . Edu_i refers to the education level of each individual i ; x_i represents the set of socio-demographic and health covariates; α_0 is the intercept, α_1 is the coefficient of education to be estimated; ζ contains the coefficients of the covariates in x_i ; and e_i is the error term.

For regular alcohol drinking, the multinomial regression is performed based on two simultaneous equations (Model 1B in Table 3 and Model 4B in Table 4):

$$\ln \frac{P(Non - drinking_i = 1)}{P(Regular drinking = 0)} = \beta_0 + \beta_1 Edu_i + x_i^T \eta + u_i \quad (2.1)$$

$$\ln \frac{P(Irregular drinking_i = 2)}{P(Regular drinking_i = 0)} = \gamma_0 + \gamma_1 Edu_i + x_i^T \theta + v_i \quad (2.2)$$

in which β_0 and γ_0 are the intercept; β_1 and γ_1 denote the coefficients of education, while η and θ represent the coefficients of the covariates in x_i ; u_i and v_i are the error terms.

- (2) Regression of grip strength as the dependent variable and education as the independent variable. Based on the continuous

Table 2
Descriptive statistics of analytic variables by education, men and women aged 60 years and older, Thailand.

Variable	All	Men			P-value ^a	All	Women			P-value ^a
		Lower than primary	Completed primary	Beyond primary			Lower than primary	Completed primary	Beyond primary	
Grip strength, mean (SD)	26.4 (6.7)	23.4 (6.4)	26.4 (6.6)	29.1 (6.3)	<0.001	17.7 (4.3)	16.6 (4.3)	17.9 (4.3)	19.0 (4.0)	<0.001
Age, mean (SD)	69.3 (6.8)	72.2 (7.2)	68.3 (6.3)	66.3 (6.1)	<0.001	69.0 (6.8)	71.8 (7.3)	68.3 (6.3)	66.3 (6.1)	<0.001
Height, mean (SD)	161.4 (6.0)	160.0 (5.9)	161.2 (5.9)	163.2 (6.0)	<0.001	150.4 (5.6)	149.5 (5.7)	150.7 (5.6)	151.5 (5.0)	<0.001
Weight, mean (SD)	58.6 (11.3)	54.5 (10.5)	58.2 (11.3)	63.3 (10.5)	<0.001	54.6 (11.7)	51.8 (11.8)	55.4 (11.6)	57.0 (10.4)	<0.001
Currently married, %	2931 (83.1)	390 (76.9)	1977 (82.8)	564 (89.2)	<0.001	1717 (48.5)	391 (40.6)	1161 (51.0)	165 (54.8)	<0.001
Urban, %	1801 (51.1)	208 (41.0)	1111 (46.5)	482 (76.3)	<0.001	1940 (54.8)	474 (49.3)	1205 (53.0)	261 (86.7)	<0.001
Worked last year, %	1761 (49.9)	221 (43.6)	1297 (54.3)	243 (38.5)	<0.001	1177 (33.3)	265 (27.6)	836 (36.8)	76 (25.3)	<0.001
Income level, %					<0.001					<0.001
Low	1502 (42.6)	320 (63.1)	1075 (45.0)	107 (16.9)		1302 (36.8)	490 (50.9)	788 (34.6)	24 (8.0)	
Middle	1057 (30.0)	132 (26.0)	800 (33.5)	125 (19.8)		1050 (29.7)	275 (28.6)	720 (31.7)	55 (18.3)	
High	967 (27.4)	55 (10.9)	512 (21.5)	400 (63.3)		1186 (33.5)	197 (20.5)	767 (33.7)	222 (73.8)	
Functional limitation, %	362 (10.3)	92 (18.2)	246 (10.3)	24 (3.8)	<0.001	659 (18.6)	249 (25.9)	380 (16.7)	30 (10.0)	<0.001
Diabetes, %	510 (14.5)	60 (11.8)	314 (13.2)	136 (21.5)	<0.001	649 (18.3)	169 (17.6)	427 (18.8)	53 (17.6)	0.680
Hypertension, %	1715 (48.6)	239 (47.1)	1116 (46.8)	360 (57.0)	<0.001	1840 (52.0)	494 (51.4)	1181 (51.9)	165 (54.8)	0.569
Potential mediator										
Non-smoking, %	2261 (64.1)	280 (55.2)	1485 (62.2)	496 (78.5)	<0.001	3357 (94.9)	879 (91.4)	2180 (95.8)	298 (99.0)	<0.001
Non-drinking, %	2025 (57.4)	323 (63.7)	1378 (57.7)	324 (51.3)	0.001	3026 (85.5)	831 (86.4)	1935 (85.1)	260 (86.4)	0.773
Irregular drinking, %	1026 (29.1)	127 (25.1)	690 (28.9)	209 (33.1)		429 (12.1)	107 (11.1)	288 (12.7)	34 (11.3)	
Regular drinking, %	475 (13.5)	57 (11.2)	319 (13.4)	99 (15.7)		83 (2.4)	24 (2.5)	52 (2.3)	7 (2.3)	
Healthy eating %	799 (22.7)	86 (17.0)	523 (21.9)	190 (30.1)	<0.001	830 (23.5)	188 (19.5)	536 (23.6)	106 (35.2)	<0.001
Physically active, %	1645 (46.7)	161 (31.8)	1093 (45.8)	391 (61.9)	<0.001	1270 (35.9)	262 (27.2)	845 (37.1)	163 (54.2)	<0.001
Number of observations	3526	507	2387	632		3538	962	2275	301	

Source: The 2009 NHES.

Notes: ^a Chi-square test and ANOVA were used to compare differences between the three education groups for categorical and continuous variables, respectively.

Table 3
Mediation effect of each health-related behaviour on the association between education and grip strength, men aged 60 years and older, Thailand.

Dependent variable	Independent variable	Completed primary			Beyond primary			Potential mediator			
		β	S.E.	CI	β	S.E.	CI	β	S.E.	CI	
Step 1: Models 1A–1D											
1A	Non-smoking	Education (Lower than primary = ref)	0.39	0.11	0.18, 0.61	0.83	0.19	0.45, 1.21	–	–	–
1B*	Non-drinking	Education (Lower than primary = ref)	–0.12	0.20	–0.51, 0.27	–0.26	0.28	–0.81, 0.30	–	–	–
	Irregular drinking	Education (Lower than primary = ref)	–0.11	0.24	–0.58, 0.36	0.13	0.33	–0.53, 0.78	–	–	–
1C	Healthy eating	Education (Lower than primary = ref)	0.28	0.19	–0.10, 0.65	0.63	0.19	0.25, 1.01	–	–	–
1D	Physically active	Education (Lower than primary = ref)	0.60	0.13	0.35, 0.85	1.07	0.18	0.72, 1.42	–	–	–
Step 2: Model 2A											
2A	Grip strength	Education (Lower than primary = ref)	1.05	0.37	0.32, 1.79	2.23	0.47	1.30, 3.17	–	–	–
Step 3: Models 3A–3D											
3A	Grip strength	Education (Lower than primary = ref)	1.15	0.37	0.43, 1.87	2.42	0.48	1.49, 3.36	–1.10	0.34	–1.77, –0.42
		Non-smoking (Smoking = ref)									
3B	Grip strength	Education (Lower than primary = ref)	1.05	0.37	0.32, 1.77	2.14	0.46	1.23, 3.05	–0.93	0.31	–1.55, –0.32
		Non-drinking (Regular drinking = ref)									
		Irregular drinking (Regular drinking = ref)							0.37	0.37	–0.34, 1.09
3C	Grip strength	Education (Lower than primary = ref)	1.05	0.37	0.32, 1.79	2.23	0.47	1.30, 3.16	0.04	0.30	–0.54, 0.62
		Healthy eating (Unhealthy eating = ref)									
3D	Grip strength	Education (Lower than primary = ref)	0.98	0.98	0.24, 1.73	2.10	0.47	1.17, 3.03	0.54	0.21	0.13, 0.96
		Physically active (Inactive = ref)									

Source: The 2009 NHES.

Notes: * The reference category for this multinomial regression is ‘regular drinking’.

a. β = Coefficient; S.E. = Cluster-robust Standard Error; CI = 95% Confidence Interval. β significant at 0.05 or beyond is shown in bold face.

b. All models are adjusted for age, height, weight, marital status, area of residence, work status, income, functional limitation, diabetes and hypertension.

Table 4
Mediation effect of each health-related behaviour on the association between education and grip strength, women aged 60 years and older, Thailand.

Dependent variable	Independent variable	Completed primary			Beyond primary			Potential mediator			
		β	S.E.	CI	β	S.E.	CI	β	S.E.	CI	
Step 1: Models 4A–4D											
4A	Non-smoking	Education (Lower than primary = ref)	0.42	0.22	–0.01, 0.85	1.94	0.67	0.63, 3.24	–	–	–
4B*	Non-drinking	Education (Lower than primary = ref)	0.30	0.30	–0.29, 0.88	0.27	0.62	–0.95, 1.49	–	–	–
	Irregular drinking	Education (Lower than primary = ref)	0.39	0.32	–0.24, 1.02	0.38	0.68	–0.95, 1.71	–	–	–
4C	Healthy eating	Education (Lower than primary = ref)	0.14	0.12	–0.09, 0.37	0.70	0.20	0.30, 1.10	–	–	–
4D	Physically active	Education (Lower than primary = ref)	0.35	0.15	0.05, 0.65	0.71	0.20	0.31, 1.11	–	–	–
Step 2: Model 5A											
5A	Grip strength	Education (Lower than primary = ref)	0.52	0.20	0.13, 0.91	0.79	0.32	0.16, 1.41	–	–	–
Step 3: Models 6A–6D											
6A	Grip strength	Education (Lower than primary = ref)	0.54	0.20	0.15, 0.93	0.82	0.32	0.19, 1.45	–0.72	0.41	–1.53, 0.08
		Non-smoking (Smoking = ref)									
6B	Grip strength	Education (Lower than primary = ref)	0.52	1.99	0.13, 0.91	0.79	0.32	0.17, 1.41	–0.84	0.49	–1.81, 0.13
		Non-drinking (Regular drinking = ref)									
		Irregular drinking (Regular drinking = ref)							–0.47	0.55	–1.55, 0.61
6C	Grip strength	Education (Lower than primary = ref)	0.51	0.20	0.12, 0.90	0.72	0.32	0.10, 1.34	0.54	0.18	0.18, 0.89
		Healthy eating (Unhealthy eating = ref)									
6D	Grip strength	Education (Lower than primary = ref)	0.46	0.46	0.08, 0.85	0.66	0.32	0.03, 1.30	0.79	0.17	0.46, 1.13
		Physically active (Inactive = ref)									

Source: The 2009 NHES.

Notes: * The reference category for this multinomial regression is ‘regular drinking’.

a. β = Coefficient; S.E. = Cluster-robust Standard Error; CI = 95% Confidence Interval. β significant at 0.05 or beyond is shown in bold face.

b. All models are adjusted for age, height, weight, marital status, area of residence, work status, income, functional limitation, diabetes and hypertension.

nature of the dependent variable, i.e. grip strength, the OLS model takes the following form (Model 2A in Table 3 and Model 5A in Table 4):

$$GS_i = \delta_0 + \delta_1 Edu_i + x_i^T \vartheta + w_i \tag{3}$$

in which GS_i represents grip strength of each individual i . Edu_i and Vector x_i are defined similarly to Eq.(1); δ_0 is the intercept. δ_1 is the coefficient of education and ϑ contains the coefficients of covariates in x_i , respectively; and w_i is the error term.

(3) Regressions of grip strength as the dependent variable, and education and the potential mediators as independent variables. In this final step, each potential mediator was considered in the model separately, and the OLS regression equation is given by (Model 3A – 3D in Table 3 and Model 6A – 6D in Table 4):

$$GS_i = \varepsilon_0 + \varepsilon_1 Edu_i + \varepsilon_2 HB_{k,i} + x_i^T \mathbf{1} + z_i \tag{4}$$

in which ε_0 is the intercept; ε_1 is the coefficients of education, while $\mathbf{1}$ contains the coefficients of the covariates in x_i ; and z_i is the error term.

To illustrate the role of mediators in the pathway between education and grip strength, a generalized structural equation modelling (SEM) approach was utilized in which the independent variable (education), statistically significant mediators, covariates, and the dependent variable (grip strength) were all incorporated together. In the analyses, linear and logit transformation functions were employed simultaneously in the model. A linear link was used, since grip strength was treated as a continuous variable and had a normal distribution. Meanwhile, the logit links were fitted for education and the statistically significant mediators. Since education was measured as a categorical variable, the direct, indirect, and total effects in SEM were estimated following the approach

Table 5

Magnitude of attenuation in the association between grip strength and education by individual mediators and all mediators combined.

	Completed primary		Beyond primary	
	β (CI)	% Attenuation	β (CI)	% Attenuation
Men				
Model 2A (without mediator)	1.05 (0.32, 1.79)		2.23 (1.30, 3.17)	
Models 3A & 3D (with each mediator)				
Non-smoking	1.15 (0.43, 1.87)	-9.52	2.42 (1.49, 3.36)	-8.52
Physically active	0.98 (0.24, 1.73)	6.67	2.10 (1.17, 3.03)	5.83
Full Model (with all mediators)	1.08 (0.35, 1.81)	-2.86	2.28 (1.34, 3.22)	-2.24
Women				
Model 5A (without mediator)	0.52 (0.13, 0.91)		0.79 (0.16, 1.41)	
Model 6C & 6D (with each mediator)				
Healthy eating	0.51 (0.12, 0.90)	1.92	0.72 (0.10, 1.34)	8.86
Physically active	0.46 (0.08, 0.85)	11.54	0.66 (0.03, 1.30)	16.46
Full Model (with all mediators)	0.46 (0.07, 0.84)	11.54	0.61 (-0.20, 1.23)	22.78

Source: The 2009 NHES.

Notes: ^a β = Coefficient; CI = 95% Confidence Interval.^b All models are adjusted for age, height, weight, marital status, area of residence, work status, income, functional limitation, diabetes, hypertension.**Table 6**

Estimates of direct, indirect, and total effects of education and mediators on grip strength among older men and women aged 60 years and older, Thailand.

Composition of effect	Standardized β	CI
Men		
Direct effect	3.36	1.84, 4.88
Total indirect effect	-0.53	-1.95, 0.89
Indirect effect: non-smoking	-1.51	-2.70, -0.33
Indirect effect: physically active	0.98	0.22, 1.75
Total effect (= direct effect + total indirect effect)	2.83	0.85, 4.81
Proportion of total effect that is mediated	-18.74%	
Women		
Direct effect	1.07	0.18, 1.95
Total indirect effect	1.21	0.49, 1.93
Indirect effect: healthy eating	0.41	-0.01, 0.83
Indirect effect: physically active	0.80	0.23, 1.36
Total effect (= direct effect + total indirect effect)	2.28	1.18, 3.37
Proportion of total effect that is mediated	53.22%	

Source: The 2009 NHES.

Notes: ^a β = Coefficient; CI = 95% Confidence Interval.

proposed by Hayes and Preacher (2014).

Prior to the analyses, several diagnostic tests were performed to check the analytic assumptions. Correlations of education and socio-demographic and health covariates are shown in Appendix Tables S1 and S2. The variance inflation factor (VIF) was also used to detect the potential for multi-collinearity among these variables. None of these variables demonstrated VIFs of greater than five, suggesting that the multi-collinearity in the present study was negligible (James, Witten, Hastie, & Tibshirani, 2013). The heteroskedasticity of errors was diagnosed through the Breusch-Pagan test, in which the statistical significance of chi-squares indicated the presence of heteroskedasticity in the regression models (Cook & Weisberg, 1983). To simultaneously account for the cluster effect of the survey's sampling design and heteroskedasticity, the cluster-robust standard errors were applied for all regression analyses (Cameron & Miller, 2015).

All statistical analyses were performed on older men and women separately due to their significant differences in most of the analytic variables (results shown in Table S3) and adjusted for covariates using STATA version 13.0. To account for the complex survey design, all analyses were weighted by the sample weights to obtain nationally representative estimates.

3. Results

3.1. Sample description

Mean values, standard deviations, and percentage distributions for all analytical variables by gender and education are presented in Table 2. In both the men's and women's samples, those with higher education levels were significantly more likely to have stronger grips than their counterparts with lower education levels. They also tended to be younger, taller, heavier, and currently married, and to dwell in urban areas. In terms of economic conditions, while older persons with beyond primary education were less likely to continue working, they were significantly more likely to report earning a higher income than their counterparts. With respect to health conditions, both older men and women with more education were less likely to experience functional limitations; however, they were more likely to have diabetes and hypertension. Overall, while it was more typical for older women than older men to not smoke or drink alcohol, the prevalence of physical activity was higher among older men than women. In older men, those with more education were significantly less likely to smoke, but more likely to drink alcoholic beverages, consume a healthy diet, and engage in physical activity compared to their counterparts with lower education

levels. For older women, a similar educational gradient was observed for smoking, healthy eating, and engaging in physical activity. The drinking pattern did not significantly differ across the three education groups.

3.2. Mediation effect of health-related behaviours

The results of the mediation test for older men and women are presented in [Tables 3 and 4](#), respectively. In these tables, we report coefficients indicating the size of the effect, cluster-robust standard errors, % confidence intervals, and the statistical significance of each education category and potential mediator on grip strength relative to the reference category. For older men, when all other covariates were adjusted in the model, those with a higher education level demonstrated relatively better health-related behaviours in terms of not smoking, healthy eating, and engaging in physical activity. The potential mediators of not smoking, eating a healthy diet, and being physically active were each statistically associated with education at $p < 0.05$ (Models 1A, 1C, 1D). Model 2A shows that when all other covariates were considered, education had a statistically significant effect on grip strength. Models 3A, 3B and 3D reveal that not smoking, alcohol drinking, and being physically active each had a significant association with grip strength when education and the other covariates were all controlled for. However, since alcohol drinking did not exhibit a significant association with education in Model 1B, it did not qualify as a mediator. Model 3A indicates the somewhat unexpected result that non-smoking is statistically and negatively correlated with grip strength.

Based on these results, we further calculated the extent to which mediators, individually and collectively, attenuated the association between education and grip strength. In doing so, we compared the coefficients of each education category from Model 2A, in which none of the mediators were included, to those from Models 3A and 3D, in which each mediator was incorporated, and those in which all mediators were presented. [Table 5](#) demonstrates that, for the completed primary education group, non-smoking attenuated -9.5% of the effect of education on grip strength, whereas the attenuation effects were 6.7% for being physically active and -2.9% when both mediators were combined. For the beyond primary education group, the pattern of mediation was generally similar to the completed primary education group. The attenuation effect when both mediators were combined was -2.2% .

[Table 4](#) presents the regression results for older women. Models 4A, 4C and 4D indicate that, all else being equal, older women with a higher education level were significantly more likely not to smoke, to consume a healthy diet and to engage in physical activity. Meanwhile, Model 5A shows that education was significantly and positively associated with older women's grip strength. Models 6C–6D show that healthy eating and being physically active each had a significant association with grip strength when education and other covariates were all controlled for. The conversion of mediating effect into a percentage ([Table 5](#)) shows that for the completed primary group, health eating attenuated only 1.9% of the educational effect on grip strength, while engaging in physical activity substantially diminished the effect of education, by 11.5% . For the beyond primary education group, adjusting for the two health-related behaviours individually resulted in greater attenuation: 8.9% for healthy eating and 16.5% for engaging in physical activity. When both mediators were adjusted simultaneously, the mediating effect accounted for 22.8% of grip strength.

[Table 6](#) presents results from the generalized SEM analyses by sex and the composition of the effects. Among older men, non-smoking accounted for a larger proportion of the total indirect effect as compared to engaging in physical activity. When both mediators were combined, -18.7% of the total effect of education on grip strength was mediated. In older women, practicing healthy eating explained a third of the total indirect effect, while engaging in physical activity accounted for the remainder. Taken together, both mediators attenuated 53.2% of the educational effect on grip strength.

4. Discussion

The current study has examined the association between education and grip strength and has investigated four different health-related behaviours, namely smoking, drinking alcohol, healthy eating and physical activity, that likely contribute to or mediate this association, using a large sample of older persons in a nationally representative health examination survey in Thailand. While some previous studies have shown no association between educational attainment and grip strength ([Mohd Hairi et al., 2010](#); [Ong et al., 2017](#)), our study finds that when all socio-economic and health covariates are adjusted for, education is positively and statistically associated with stronger grips in both older men and women. This finding is consistent with previous research conducted exclusively with older persons in both developed and developing nations ([Alqahtani et al., 2019](#); [Kim et al., 2019](#)).

In addition, this study shows varying evidence of educational gradients across the four examined health-related behaviours, either consistent with or contradictory to earlier findings (Models 1A–1D & 4A–4D). We have found that when all socio-demographic and health covariates are held constant, higher education is associated with a greater likelihood of not smoking, consuming a healthy diet and engaging in physical activity. These observations are true for both older men and women and consistent with a number of previous studies ([Chad et al., 2005](#); [Kaplan et al., 2001](#); [Sathannoppakao et al., 2009](#); [Shaw & Spokane, 2008](#)). On the other hand, the coefficients for drinking patterns show mixed results for older men and women. Being better educated, particularly having completed primary education, is associated with higher likelihoods of not drinking and drinking irregularly in older women. The inverse associations are broadly observed for older men. However, neither is statistically significant in this study.

The mediation analysis results demonstrate the importance of all of the health-related behaviours examined – with the exception of drinking habits – in the association between education and grip strength. The extent to which each behaviour mediates the effect of education, however, varies with the type of health behaviour examined and between genders. Our study suggests that physical activity is the primary mediator of the association between education and grip strength for both older men and women, as reflected by the magnitude of its mediating effect. The mediation effect indicates that higher education contributes to stronger grips because higher-educated older adults participate more in physical activity, and those who are physically active are more likely to have higher grip strength ([Syddall et al., 2018](#)).

Another significant finding is the negative mediating role of not smoking in older men's education–grip strength association. As previously mentioned, while our finding shows that higher education is associated with a greater likelihood of not smoking, the mediation model shows that non-smoking men had a significantly lower grip strength ([Gunzler, Chen, Wu, & Zhang, 2013](#); [VanderWeele, 2016](#)). The latter finding is contradictory to most of the earlier findings indicating that smoking reduces muscle mass and strength ([Nandi, Glymour, & Subramanian, 2014](#); [Schrijvers, Stronks, van de Mheen, & Mackenbach, 1999](#)), aggravating age-related muscle decline and loss of muscle strength, and leading to increased incidences of sarcopenia and falls among older persons ([Rom, Kaisari, Aizenbud, & Reznick, 2012](#)). However, this finding is consistent with a study conducted among European older adults by [MohdHairi et al. \(2010\)](#) who explained that current smoking behaviour may be correlated with previous health status. As such, there is a possibility that some older persons may have stopped smoking because of previous health problems, which could explain why non-smokers had a lower grip strength than smokers. As previous research has shown various results on the effect of smoking on grip strength – including no effect ([Kim et al., 2019](#); [Lenardt et al., 2014](#)) – this warrants further investigation to confirm whether smoking is associated with grip strength ([Kim et al., 2019](#)).

Our study demonstrates a small but significant mediating effect of consuming fruits and vegetables on the relationship between education

and grip strength in older women. The positive association between grip strength and fruit and vegetable intake, particularly among older women, is in line with prior research (Robinson et al., 2008; Saito et al., 2011). Because nutrients such as β -carotene and selenium are beneficial to muscle function in older adults, and because vitamin C amplifies muscle function, particularly in older women, the intake of their nutritional sources – such as fruits and vegetables – has been found to be positively related to higher grip strength (Robinson et al., 2008).

Finally, even though our study did not perform a statistical test on the difference between men and women, it is apparent that the magnitude of the effect of higher educational attainment, particularly beyond primary education, on grip strength is larger for men than for women. This observation is consistent with recent studies in developing Asia – such as Saudi Arabia (Alqahtani et al., 2019), India (Arokiasamy & Selvamani, 2018) and Indonesia (Pengpid & Peltzer, 2018) – as well as elsewhere (Carney & Benzeval, 2018). Despite the lack of a clear explanation for this gender difference in our study, it has been reported in the literature that the difference may be due in part to the larger proportion of older men than women in the relatively small pool of higher-educated respondents (Pengpid & Peltzer, 2018).

Health is an important component of old-age well-being. This study provides evidence of significant mediators which preventive health policies can target to promote healthier behaviours – e.g., regular physical activities and sufficient consumption of fruits and vegetables – in lower-educated older persons in order to improve their health as well as to reduce existing health disparities overall. Our results lend further support to previous research showing the effects of education attained at younger ages on health in older ages (Lochner, 2011), underscoring the importance of continuing to invest in education for the current cohort of young people. While the effect of education on health in older ages can vary from one country to another, this study exemplifies why it is crucial for other developing countries characterised by an aging population and health disparities to begin paying attention to the casual link between education and health.

4.1. Limitations and strengths

This study has certain limitations. First, all of the health-related behaviours were self-reported and are therefore subject to response bias. Due to the tendency to underreport unhealthy behaviours, possibly in line with social norms (Jarvandi, Yan, & Schootman, 2012), the mediating effect of healthy behaviours might be underestimated in this study. Second, given the cross-sectional nature of the 2009 NHES, health-related behaviours were only measured at a single point in time. Because health-related behaviours can change over time – although recent studies suggest that they are relatively stable across different stages of life (Skogen, Øverland, & Knudsen, 2016) – our findings need to be verified in future studies with repeated measurements. This shortcoming also stresses the need for longitudinal data to more clearly examine the mediating effect of health-related behaviours, and to attain a better understanding of the mechanisms through which education and grip strength are linked. Finally, our analyses did not include certain variables that could potentially affect the role of health-related behaviours, including intrapersonal factors such as knowledge and attitudes, and interpersonal factors such as formal and informal social networks. Despite these limitations, the strengths of this study include the large sample size used and the utilization of an objective health indicator – i. e., grip strength – for health status. Our study is further strengthened by the study design, which considered several potentially confounding socio-demographic and health factors, and by the utilization of SEM, in addition to Baron and Kenny's approach, to quantify the indirect effects.

4.2. Conclusion

Understanding the mediating effects of smoking, drinking alcohol, healthy eating and physical activity between education inequalities and

health (i.e. grip strength) among older Thai adults is of utmost importance. Our findings indicate that education in earlier life is positively associated with stronger grips for both older men and women, and that health-related behaviour has a mediating effect on such a relationship. The extent of the mediating effect differs across the types of health behaviours examined and between genders. In older men, not smoking and engaging in physical activity can partly explain the relationship between education and grip strength, while in older women the consumption of fruits and vegetables and participation in regular physical activity significantly mediate the effect of education on grip strength. These findings can be used to guide the design and implementation of interventions to reduce health disparities among older persons. Future work is needed to repeat our measurements with longitudinal data.

Author statement

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Ethical statement

All individual level data used in the research article is secondary data. Access to data would be granted upon request and subject to an assessment by the research team and certain agreement provisions of the Human Research Ethics Committee, Faculty of Medicine Ramathibodi Hospital, Mahidol University, Thailand. For further inquiries, please contact us at raec.mahidol@gmail.com.

The authors declare no competing interests or have any financial declarations to make.

Declaration of completing interest

The authors have no affiliations or involvement with any organisations or individuals that may bias or influence the conclusions of this work.

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Appendix A. Supplementary data

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