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Association of early- and adult-life socioeconomic circumstances with muscle strength in older age

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Abstract

Background: socioeconomic circumstances (SEC) during a person's lifespan influence a wide range of health outcomes. However, solid evidence of the association of early- and adult-life SEC with health trajectories in ageing is still lacking. This study assessed whether early-life SEC are associated with muscle strength in later life—a biomarker of health—and whether this relationship is caused by adult-life SEC and health behaviours.
Methods: we used data from the Survey of Health Ageing and Retirement in Europe, a 12-year population-based cohort study with repeated measurement in six waves (2004–15) and retrospective collection of life-course data. Participants' grip strength was assessed by using a handheld dynamometer. Confounder-adjusted logistic mixed-effect models were used to examine the associations of early- and adult-life SEC with the risk of low muscle strength (LMS) in older age.
Results: a total of 24,179 participants (96,375 observations) aged 50–96 living in 14 European countries were included in the analyses. Risk of LMS was increased with disadvantaged relative to advantaged early-life SEC. The association between risk of LMS and disadvantaged early-life SEC gradually decreased when adjusting for adult-life SEC for both sexes and with unhealthy behaviours for women. After adjusting for these factors, all associations between risk of LMS and early-life SEC remained significant for women.
Conclusion: early-life SEC are associated with muscle strength after adjusting for adult-life SEC and behavioural lifestyle factors, especially in women, which suggests that early life may represent a sensitive period for future health.

Keywords: *health, socioeconomic status, ageing, hand strength, older people*

Introduction

Socioeconomic circumstances (SEC) over a person's lifespan are associated with health risk factors [1, 2], morbidity [3, 4] and mortality [1, 2, 5]. However, how these SEC explain health differences is unclear. Early-life SEC are thought to influence adult health through three intertwined pathways: (i) socioeconomic and psychological; (ii) health

behaviours; and (iii) biological via a cumulative physiological wear-and-tear in response to chronic stress (e.g. the inflammatory system) [6]. However, previous studies relied on cross-sectional and/or short follow-up designs [7–9], which may have prevented effects related to chronological ageing and birth cohorts from being disentangled [10, 11]. Thus, evidence on the relationhsips between life-course SEC and the decline in health with ageing is relatively weak. Moreover, studies have generally used crude assessments of early-life SEC (i.e. based on a limited number of indicators) [12, 13], which may bias the estimated associations between early-life SEC and health indicators. As a result, solid evidence on the associations of early- and adult-life SEC with health in later life is still lacking.

Therefore, based on a 12-year European large cohort study, the present large-scale and longitudinal study investigated whether individuals who experienced disadvantaged early-life SEC show a higher risk of low muscle strength (LMS) in later life, an accurate biomarker of health [14], and whether adult-life SEC and health behaviours explained this association. Muscle strength declines in middle-aged and older adults [14, 15] and has been associated with a wide range of adverse health outcomes such as future disability [16, 17], morbidity [17, 18] and mortality [19, 20]. In addition, LMS is associated with inflammatory biomarkers [21], which are thought to underlie the mechanisms linking the social and biological pathways. We hypothesised that disadvantaged early-life SEC are associated with higher risk of LMS in older age and with a higher increased risk of LMS with ageing. We also hypothesised that the relationships between early-life SEC and LMS are partially due to adult-life SEC and unhealthy behaviours. We hypothesised a partial, but not full, explanation, because early-life SEC should also have a direct association with muscle strength as highlighted by the interrelated pathways described above.

Methods

Study design and participants

Data from individuals aged 50 years and over included in SHARE were used [22]. SHARE comprises six waves of data collected every 2 years between 2004 and 2016. During the third wave, retrospective life-course data related to early- and adult-life SEC were collected. We included data for participants aged 50–96 years who took part in the third wave and performed at least one grip strength measure. SHARE was approved by the relevant research ethics committees in the participating countries, and all participants provided written informed consent.

Measures

Early-life SEC

Early-life SEC were determined according to the Wahrendorf and Blane [23] measure of childhood circumstances. This measure was constructed as an index combining four binary indicators of adverse SEC at age 10, which were (i) the occupational position of the main breadwinner; (ii) the number of books at home; (iii) a measure of overcrowding; and (iv) housing quality. By combining the information for these four indicators, we computed a five-level categorical variable of 'most advantaged', 'advantaged', 'middle', 'disadvantaged' and 'most disadvantaged.'

Prior confounders

All analyses were adjusted for potential confounders: (i) birth cohort; (ii) welfare regimes of the country of residence; (iii) living with biological parents; and (iv) participant attrition.

Mediators

Adult-life SEC. A participant's highest educational attainment, main occupational position during adult life, and satisfaction with household income were added as potential mediators.

Unhealthy behaviour index. This index was constructed based on four binary indicators of key unhealthy behaviours, which were (i) physical inactivity; (ii) unhealthy eating; (iii) smoking; and (iv) alcohol consumption. By averaging the information for these four indicators, we computed a continuous variable ranging from 0, none of these four health-detrimental behaviours, to 1, all of these four health-detrimental behaviours.

Outcome

Muscle strength was determined using grip strength, which was measured with a handheld dynamometer (Smedley, S Dynamometer, TTM, Tokyo, 100 kg). At each wave of data collection, grip strength was measured for both hands twice, and the mean of the maximum values obtained for each hand was used for the outcome [19]. The cut-off for LMS was then computed according to the literature [24, 25] (see the Supplementary data available in *Age and Ageing online* for more details on all the measures).

Statistical analysis

Logistic mixed-effect models were used for the analyses. These models are a type of mixed model that accounts for the nested structure of the data (e.g. multiple observations within a single participant), thereby providing accurate parameter estimates with acceptable type I error rates [26]. Analyses were stratified by sex. Model 1 tested the association between early-life SEC and the probability of LMS, adjusting for prior confounders. Age was centred at the midpoint of the sample's age range (i.e. 73 years). To adjust for cohort effects, the models included birth cohort and an interaction term between birth cohort and age. In addition, an interaction term between early-life SEC and age was included to test whether early-life SEC moderated the association of age with LMS. Education (model 2), main occupational position (model 3), satisfaction with household income (model 4), unhealthy behaviour index (model 5), and their interactions with age, were sequentially added as potential mediators in the model. Finally, we performed the following five sensitivity analyses: (i) controlling for the physical demands of the main job; (ii) excluding participants

Table 1. Risk of low muscle strength in older age according to early- and adult-life socioeconomic circumstances (SEC) for women.

	Women									
	(*n* = 13,477)									
	Model 1		Model 2		Model 3		Model 4		Model 5	
Variables	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
Age	1.07 (1.05–1.10)	<0.001	1.08 (1.06–1.11)	<0.001	1.08 (1.05–1.12)	<0.001	1.05 (1.02–1.09)	0.005	1.06 (1.02–1.10)	0.004
Welfare regimes										
Bismarckian	(ref)		(ref)		(ref)		(ref)		(ref)	
Irish	3.73 (2.20–6.31)	<0.001	4.27 (2.52–7.23)	<0.001	4.46 (2.63–7.56)	<0.001	3.67 (2.18–6.19)	<0.001	5.46 (3.23–9.23)	<0.001
Southern European	3.97 (3.28–4.81)	<0.001	3.80 (3.14–4.60)	<0.001	3.72 (3.08–4.50)	<0.001	2.49 (2.05–3.03)	<0.001	2.72 (2.24–3.31)	<0.001
Eastern European	1.35 (1.06–1.72)	0.016	1.27 (0.99–1.61)	0.056	1.28 (1.01–1.64)	0.043	0.89 (0.70–1.15)	0.375	1.00 (0.79–1.28)	0.976
Scandinavian	0.80 (0.63–1.02)	0.068	0.86 (0.67–1.08)	0.197	0.83 (0.65–1.05)	0.123	0.99 (0.79–1.26)	0.959	1.19 (0.94–1.50)	0.140
Birth cohort										
After 1945	(ref)		(ref)		(ref)		(ref)		(ref)	
1939–45	1.96 (1.38–2.79)	<0.001	1.70 (1.20–2.42)	0.003	1.57 (1.11–2.23)	0.011	1.74 (1.22–2.46)	0.002	1.88 (1.33–2.67)	<0.001
1929–38	2.82 (2.01–3.94)	<0.001	2.37 (1.69–3.31)	<0.001	2.16 (1.55–3.01)	<0.001	2.37 (1.70–3.30)	<0.001	2.37 (1.70–3.30)	<0.001
1919–28	2.13 (1.28–3.53)	0.003	1.37 (0.83–2.27)	0.218	1.01 (0.61–1.67)	0.973	1.27 (0.77–2.09)	0.002	1.59 (0.97–2.60)	0.067
Living with biological parents										
Both parents	(ref)		(ref)		(ref)		(ref)		(ref)	
One biological parent	1.21 (0.91–1.59)	0.188	1.19 (0.90–1.57)	0.221	1.12 (0.85–1.48)	0.411	1.14 (0.87–1.50)	0.327	0.88 (0.74–1.03)	0.116
No biological parent	1.24 (0.74–2.09)	0.408	1.15 (0.69–1.93)	0.592	1.14 (0.69–1.91)	0.605	1.25 (0.76–2.06)	0.381	1.23 (0.89–1.69)	0.213
Attrition										
No drop out	(ref)		(ref)		(ref)		(ref)		(ref)	
Drop out	1.06 (0.86–1.32)	0.570	1.06 (0.86–1.31)	0.569	1.04 (0.84–1.28)	0.731	1.00 (0.81–1.23)	0.998	1.10 (0.89–1.35)	0.377
Death	2.19 (1.61–2.96)	<0.001	2.22 (1.64–3.01)	<0.001	2.27 (1.68–3.06)	<0.001	2.11 (1.57–2.82)	<0.001	1.95 (1.46–2.60)	<0.001
Early-life SEC										
Most disadvantaged	(ref)		(ref)		(ref)		(ref)		(ref)	
Disadvantaged	0.67 (0.53–0.84)	0.001	0.68 (0.54–0.85)	0.001	0.69 (0.55–0.87)	0.002	0.78 (0.62–0.97)	0.028	0.79 (0.64–0.99)	0.043
Middle	0.48 (0.37–0.61)	<0.001	0.51 (0.40–0.65)	<0.001	0.53 (0.42–0.68)	<0.001	0.65 (0.51–0.83)	<0.001	0.69 (0.54–0.86)	0.001
Advantaged	0.36 (0.27–0.48)	<0.001	0.41 (0.31–0.55)	<0.001	0.47 (0.35–0.63)	<0.001	0.57 (0.43–0.76)	<0.001	0.58 (0.44–0.77)	<0.001
Most advantaged	0.33 (0.21–0.50)	<0.001	0.43 (0.28–0.68)	<0.001	0.49 (0.31–0.77)	0.002	0.61 (0.39–0.95)	0.029	0.67 (0.44–1.04)	0.075
Age × early-life SEC										
Age × most disadvantaged	(ref)		(ref)		(ref)		(ref)		(ref)	
Age × disadvantaged	1.01 (0.99–1.03)	0.445	1.01 (0.99–1.03)	0.477	1.02 (1.00–1.04)	0.128	1.01 (0.99–1.03)	0.220	1.01 (0.99–1.03)	0.274
Age × middle	1.01 (0.99–1.03)	0.557	1.00 (0.99–1.02)	0.640	1.01 (0.99–1.03)	0.246	1.01 (0.99–1.03)	0.190	1.01 (0.99–1.03)	0.219
Age × advantaged	0.99 (0.97–1.01)	0.356	0.99 (0.97–1.01)	0.316	1.00 (0.98–1.03)	0.903	1.00 (0.98–1.02)	0.989	1.00 (0.97–1.02)	0.735
Age × most advantaged	1.00 (0.96–1.03)	0.817	0.99 (0.96–1.03)	0.761	1.00 (0.97–1.04)	0.951	1.01 (0.97–1.04)	0.771	1.01 (0.97–1.04)	0.748
Age × birth cohort										
Age × after 1945	(ref)		(ref)		(ref)		(ref)		(ref)	
Age × 1939–45	1.06 (1.03–1.09)	<0.001	1.06 (1.03–1.09)	<0.001	1.05 (1.02–1.08)	0.001	1.06 (1.02–1.09)	<0.001	1.06 (1.03–1.10)	<0.001
Age × 1929–38	1.16 (1.13–1.19)	<0.001	1.15 (1.12–1.18)	<0.001	1.14 (1.11–1.17)	<0.001	1.15 (1.12–1.18)	<0.001	1.16 (1.13–1.19)	<0.001
Age × 1919–28	1.23 (1.19–1.28)	<0.001	1.24 (1.20–1.29)	<0.001	1.25 (1.20–1.30)	<0.001	1.25 (1.20–1.30)	<0.001	1.23 (1.18–1.27)	<0.001

Continued

Table 1. Continued

	Women									
	(*n* = 13,477)									
	Model 1		Model 2		Model 3		Model 4		Model 5	
Variables	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
Level of education										
High education			(ref)		(ref)		(ref)		(ref)	
Low education			2.13 (1.59–2.78)	<0.001	1.56 (1.15–2.13)	0.005	1.38 (1.02–1.85)	0.037	1.43 (1.06–1.92)	0.020
Age × education										
Age × high education			(ref)		(ref)		(ref)		(ref)	
Age × low education			1.01 (0.99–1.03)	0.407	1.00 (0.97–1.02)	0.886	1.00 (0.98–1.02)	0.976	1.00 (0.97–1.02)	0.866
Main occupation class										
Advantaged					(ref)		(ref)		(ref)	
Disadvantaged					1.75 (1.31–2.35)	<0.001	1.66 (1.24–2.22)	0.001	1.65 (1.24–2.19)	0.001
Age × main occupation class										
Age × advantaged					(ref)		(ref)		(ref)	
Age × disadvantaged					1.00 (0.97–1.02)	0.917	1.00 (0.97–1.02)	0.811	1.00 (0.98–1.03)	0.753
Satisfaction with household income ('make ends meet')										
Very easily							(ref)		(ref)	
Fairly easily							1.72 (1.40–2.11)	<0.001	1.68 (1.37–2.05)	<0.001
With some difficulty							3.06 (2.41–3.88)	<0.001	2.99 (2.36–3.78)	<0.001
With great difficulty							6.88 (5.09–9.31)	<0.001	6.64 (4.93–8.93)	<0.001
Age × satisfaction with household income										
Age × very easily							(ref)		(ref)	
Age × fairly easily							1.02 (1.00–1.04)	0.021	1.02 (1.00–1.03)	0.052
Age × with some difficulty							1.03 (1.01–1.05)	0.003	1.02 (1.00–1.04)	0.046
Age × with great difficulty							1.03 (1.01–1.06)	0.004	1.02 (1.00–1.04)	0.076
Unhealthy behaviour index									7.14 (5.0.-10.0)	<0.001
Age × unhealthy behaviour index									1.00 (0.98–1.03)	0.783

OR, odds ratio; 95% CI, 95% confidence interval.

older than 90 because the descriptive statistics showed few observations above this age; (iii) excluding participants who died during the survey; (iv) excluding participants who dropped out; and (v) excluding participants with at least one of the following chronic conditions: self-reported heart attack, high blood pressure, stroke, diabetes, chronic lung disease, Parkinson's disease or cancer.

Results

Descriptive results

The data set stratified by sex and early-life SEC is described in Supplementary Table S1 (available in *Age and Ageing* online). The total sample included 24,179 participants (96,375 observations; 13,477 women) living in 14 European countries (Supplementary Figure S1, available in *Age and Ageing online*). Results revealed an increased prevalence of LMS in those with disadvantaged early-life SEC for both sexes.

Association of early-life SEC with LMS (model 1)

The risk of LMS was significantly increased with ageing for all cohorts (*P*-values < 0.001). For women at the midpoint of the age range, disadvantaged, middle, advantaged, and most advantaged early-life SEC were associated with a decreased risk of LMS, compared with most disadvantaged early-life SEC [odds ratios (ORs) = 0.67, 0.48, 0.36 and 0.33, respectively; Table 1, and Figure 1].

For men at the midpoint of the age range, disadvantaged, middle and advantaged early-life SEC were associated with a decreased risk of LMS, compared with most disadvantaged early-life SEC (ORs = 0.59, 0.57 and 0.53, respectively; Table 1, Figure 1). In contrast, no significant difference was observed between most advantaged and most disadvantaged early-life SEC. However, because of the low number of observations within the most advantaged early-life SEC, this result should be interpreted cautiously. Additionally, the adverse associations between ageing and risk of LMS were significantly less pronounced in the advantaged compared with the most disadvantaged early-life SEC in men only (OR = 0.97; interaction between age and advantaged early-life SEC).

Association of adult-life SEC and unhealthy behaviours with LMS (models 2–5)

For women, the associations between early-life SEC and LMS were gradually attenuated but remained significant with the addition of education (model 2), main occupation (model 3), satisfaction with household income (model 4), and unhealthy behaviour index (model 5) (Supplementary Figure S2 available in *Age and Ageing* online). Low education (OR = 2.13; model 2), disadvantaged occupational position (OR = 1.75; model 3), low satisfaction with household income (OR = 6.88; model 4) and number of unhealthy behaviours (OR = 7.14; model 5) were associated with an increased risk of LMS. Additionally, the adverse relationships between ageing and LMS were significantly more pronounced in women with a lower compared with a higher level of satisfaction with household income (interaction between age and satisfaction with household income;

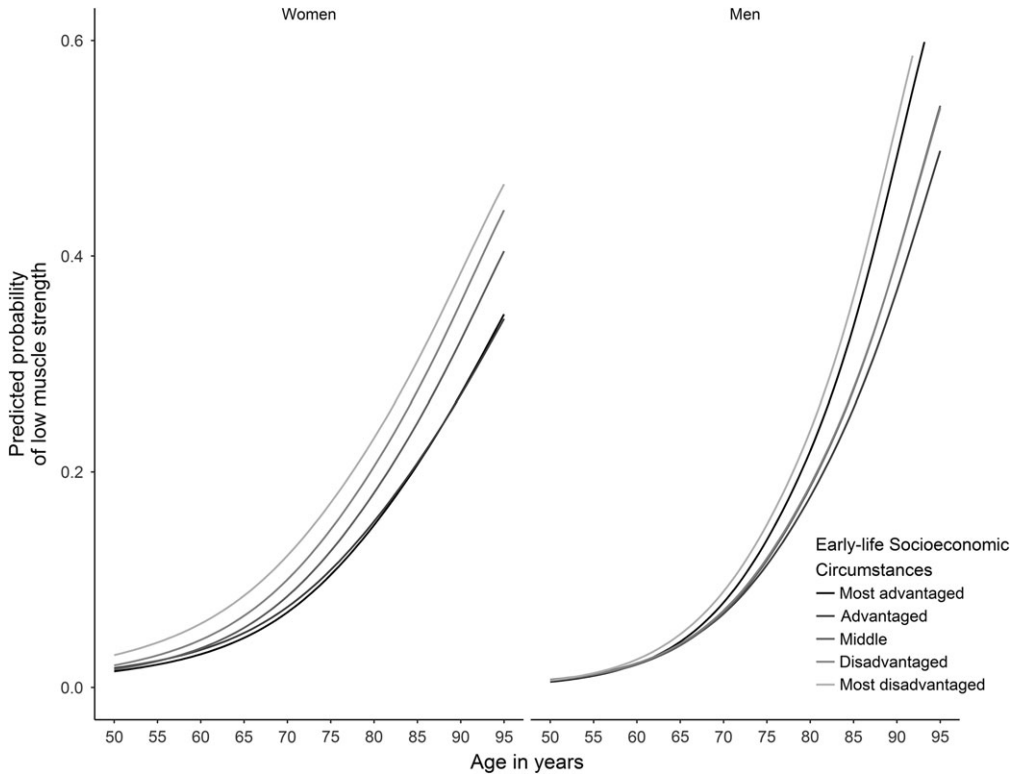

Figure 1. Predicted probability of low muscle strength across age by early-life socioeconomic circumstances (SEC).

Table 2. Risk of low muscle strength in older age according to early- and adult-life socioeconomic circumstances (SEC) for men.

	Men									
	(*n* = 10,702)									
	Model 1		Model 2		Model 3		Model 4		Model 5	
Variables	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
Age	1.18 (1.14–1.22)	<0.001	1.17 (1.13–1.21)	<0.001	1.16 (1.11–1.21)	<0.001	1.19 (1.13–1.24)	<0.001	1.19 (1.14–1.25)	<0.001
Welfare regimes										
Bismarckian	(ref)		(ref)		(ref)		(ref)		(ref)	
Irish	3.24 (1.70–6.20)	<0.001	3.57 (1.86–6.84)	<0.001	3.39 (1.77–6.50)	<0.001	2.66 (1.38–5.12)	0.003	3.90 (2.04–7.45)	<0.001
Southern European	4.79 (3.79–6.04)	<0.001	4.76 (3.77–6.01)	<0.001	4.51 (3.57–5.69)	<0.001	3.45 (2.71–4.40)	<0.001	3.52 (2.76–4.48)	<0.001
Eastern European	1.34 (0.98–1.83)	0.067	1.33 (0.97–1.81)	0.075	1.30 (0.96–1.78)	0.094	1.01 (0.74–1.39)	0.936	1.06 (0.77–1.46)	0.710
Scandinavian	0.56 (0.42–0.76)	<0.001	0.56 (0.41–0.76)	<0.001	0.58 (0.43–0.78)	<0.001	0.54 (0.40–0.73)	<0.001	0.66 (0.49–0.89)	0.007
Birth cohort										
After 1945	(ref)		(ref)		(ref)		(ref)		(ref)	
1939–45	0.97 (0.63–1.52)	0.908	1.02 (0.65–1.59)	0.935	1.00 (0.64–1.55)	0.996	0.99 (0.64–1.53)	0.959	0.90 (0.58–1.40)	0.635
1929–38	0.99 (0.64–1.51)	0.952	1.03 (0.67–1.57)	0.904	1.00 (0.65–1.54)	0.99	0.73 (0.48–1.12)	0.153	0.83 (0.54–1.27)	0.390
1919–28	0.58 (0.31–1.10)	0.095	0.61 (0.32–1.15)	0.125	0.59 (0.31–1.10)	0.097	0.47 (0.25–0.88)	0.019	0.45 (0.24–0.84)	0.012
Living with biological parents										
Both parents	(ref)				(ref)		(ref)		(ref)	
One biological parent	1.14 (0.88–1.49)	0.324	0.96 (0.67–1.36)	0.800	0.98 (0.69–1.39)	0.918	0.97 (0.69–1.36)	0.845	0.97 (0.69–1.36)	0.839
No biological parent	1.24 (0.76–2.04)	0.390	1.19 (0.60–2.35)	0.611	1.17 (0.59–2.31)	0.648	1.14 (0.58–2.21)	0.705	1.12 (0.57–2.17)	0.747
Attrition										
No drop out	(ref)				(ref)		(ref)		(ref)	
Drop out	1.55 (1.19–2.02)	0.001	1.52 (1.17–1.99)	0.002	1.50 (1.15–1.95)	0.003	1.43 (1.10–1.85)	0.008	1.53 (1.17–1.98)	0.002
Death	3.92 (2.89–5.34)	<0.001	3.84 (2.82–5.22)	<0.001	3.79 (2.79–5.13)	<0.001	3.83 (2.84–5.17)	<0.001	3.58 (2.66–4.82)	<0.001
Early-life SEC										
Most disadvantaged	(ref)				(ref)		(ref)		(ref)	
Disadvantaged	0.59 (0.45–0.78)	<0.001	0.61 (0.46–0.80)	<0.001	0.63 (0.48–0.83)	0.001	0.68 (0.52–0.89)	0.005	0.67 (0.51–0.88)	0.004
Middle	0.57 (0.43–0.75)	<0.001	0.61 (0.46–0.82)	0.001	0.67 (0.50–0.89)	0.006	0.79 (0.60–1.05)	0.109	0.74 (0.56–0.98)	0.036
Advantaged	0.53 (0.38–0.75)	<0.001	0.60 (0.42–0.85)	0.004	0.69 (0.49–0.98)	0.039	0.90 (0.64–1.28)	0.566	0.78 (0.55–1.10)	0.158
Most advantaged	0.77 (0.48–1.25)	0.291	0.97 (0.59–1.59)	0.899	1.10 (0.67–1.81)	0.707	1.14 (0.70–1.87)	0.591	1.25 (0.77–2.04)	0.365
Age × early-life SEC										
Age × most disadvantaged	(ref)				(ref)		(ref)		(ref)	
Age × disadvantaged	0.98 (0.95–1.00)	0.092	0.98 (0.96–1.01)	0.194	0.99 (0.96–1.01)	0.396	0.99 (0.97–1.02)	0.481	0.99 (0.96–1.02)	0.420
Age × middle	0.98 (0.96–1.01)	0.136	0.99 (0.96–1.02)	0.461	1.00 (0.97–1.02)	0.804	0.99 (0.97–1.02)	0.587	0.99 (0.97–1.02)	0.559
Age × advantaged	0.97 (0.94–1.00)	0.043	0.97 (0.95–1.01)	0.105	0.98 (0.95–1.01)	0.288	0.99 (0.95–1.02)	0.349	0.98 (0.95–1.01)	0.179
Age × most advantaged	1.00 (0.96–1.05)	0.924	1.01 (0.97–1.06)	0.605	1.01 (0.96–1.06)	0.714	1.01 (0.96–1.05)	0.829	1.01 (0.96–1.05)	0.803
Age × birth cohort										
Age × after 1945	(ref)				(ref)		(ref)		(ref)	
Age × 1939–45	1.06 (1.02–1.10)	0.005	1.06 (1.02–1.10)	0.003	1.06 (1.02–1.10)	0.004	1.06 (1.02–1.10)	0.005	1.05 (1.01–1.09)	0.018
Age × 1929–38	1.15 (1.11–1.19)	<0.001	1.16 (1.11–1.20)	<0.001	1.15 (1.11–1.19)	<0.001	1.14 (1.10–1.18)	<0.001	1.14 (1.10–1.18)	<0.001
Age × 1919–28	1.26 (1.20–1.32)	<0.001	1.26 (1.20–1.32)	<0.001	1.26 (1.20–1.32)	<0.001	1.23 (1.17–1.29)	<0.001	1.23 (1.17–1.29)	<0.001
Level of education							1.03 (0.79–1.36)	0.811	1.02 (0.77–1.34)	0.915
High education			(ref)		(ref)		(ref)		(ref)	
Low education			1.32 (1.02–1.72)	0.038	1.01 (0.99–1.04)	0.939	0.97 (0.74–1.27)	0.811	0.98 (0.75–1.30)	0.915

Age × education								
Age × high education	(ref)		(ref)		(ref)		(ref)	
Age × low education	1.00 (0.98–1.03)	0.995	1.00 (0.97–1.03)	0.945	1.06 (1.02–1.10)	0.005	1.00 (0.97–1.03)	0.955
Main occupation class								
Advantaged			(ref)		(ref)		(ref)	
Disadvantaged			1.94 (1.51–2.50)	<0.001	2.01 (1.57–2.58)	<0.001	1.76 (1.38–2.26)	<0.001
Age × main occupation class								
Age × advantaged			(ref)		(ref)		(ref)	
Age × disadvantaged			1.00 (0.98–1.03)	0.751	1.00 (0.98–1.03)	0.701	1.00 (0.98–1.03)	0.887
Satisfaction with household income ('make ends meet')								
Very easily					(ref)		(ref)	
Fairly easily					1.20 (0.95–1.53)	0.132	1.31 (1.03–1.66)	0.028
With some difficulty					1.67 (1.26–2.23)	<0.001	1.96 (1.47–2.61)	<0.001
With great difficulty					2.58 (1.75–3.81)	<0.001	3.15 (2.13–4.65)	<0.001
Age × satisfaction with household income								
Age × very easily					(ref)		(ref)	
Age × fairly easily					1.02 (0.99–1.04)	0.195	1.02 (1.00–1.04)	0.113
Age × with some difficulty					1.00 (0.98–1.03)	0.998	1.00 (0.98–1.03)	0.998
Age × with great difficulty					0.99 (0.96–1.03)	0.682	0.99 (0.95–1.02)	0.383
Unhealthy behaviour index							5.26 (3.57–7.69)	<0.001
Age × unhealthy behaviour index							1.04 (1.01–1.07)	0.024

OR, odds ratio; 95% CI, 95% confidence interval.

model 4). In the fully adjusted model (model 5), the addition of the adult-life SEC indicators and the unhealthy behaviour index to model 1 reduced the associations of the disadvantaged, middle, advantaged and most advantaged early-life SEC with LMS by 43, 49, 47 and 65%, respectively. Similar to early-life SEC, the associations between education and LMS (model 2) were gradually attenuated with the addition of main occupation, satisfaction with household income, and the unhealthy behaviour index but remained significant. The attenuation of these associations was stronger for satisfaction with household income, compared with the other adult-life mediators (Table 1).

For men, the associations between early-life SEC and LMS were gradually attenuated with the addition of education (model 2), main occupational position (model 3) and satisfaction with household income (model 4) to become non-significant except for the disadvantaged early-life SEC (Supplementary Figure S2 available in *Age and Ageing* online).). In particular, low education (OR = 1.32; model 2), disadvantaged occupation (OR = 1.94; model 3), low satisfaction with household income (OR = 2.58; model 4) and number of unhealthy behaviours (OR = 5.26; model 5) were associated with an increased risk of LMS. Additionally, the adverse relationships between ageing and LMS were significantly more pronounced for men with a high number of unhealthy behaviours (OR = 1.04; interaction between age and unhealthy behaviours). In the model adjusted for adult-life SEC (model 5), the addition of the adult-life SEC indicators to model 1 reduced the associations of the disadvantaged, middle and advantaged early-life SEC with LMS by 26, 60 and 84%, respectively. Similar to early-life SEC, the associations between education and LMS (model 2) were gradually attenuated with the addition of main occupation, satisfaction with household income, and unhealthy behaviour index but remained significant. The attenuation of these associations was stronger for satisfaction with household income, compared with the other adult-life mediators (Table 2).

Sensitivity analysis

Overall, the results of the sensitivity analyses were consistent with those of the main analyses, with the association between early-life SEC and risk of LMS remaining unchanged for both sexes, except for the interaction effect of the advantaged early-life SEC with ageing in men, which became marginal or non-significant in some sensitivity analyses. Additionally, the associations were gradually attenuated with the addition of adult-life SEC and unhealthy behaviour index, with some of the associations remaining significant, especially for women. Moreover, the effect of the association of adult-life SEC and the unhealthy behaviour index on risk of LMS remained unchanged.

Discussion

Main findings

This large-scale longitudinal study investigated whether early-life SEC are associated with muscle strength in later life—a

biomarker of health—and, if so, whether adult-life SEC and health behaviours explained this association. Using a 12-year population-based cohort study of 24,179 individuals, we found that the risk of LMS was increased for individuals with disadvantaged early-life SEC for both sexes, especially in women. Advantaged early-life SEC were also associated with a decreased risk of LMS with ageing for men. However, this effect on the evolution of LMS with ageing was inconsistent across the sensitivity analyses, indicating that it was less robust.

These associations between early-life SEC and risk of LMS were explained by the three indicators of adult-life SEC (education, main occupational position and satisfaction with household income) for both sexes, and with the unhealthy behaviour index for women. Despite adjusting for adult-life SEC, the associations between early-life SEC and LMS remained significant, especially in women, for whom the associations were only slightly attenuated. These results suggest that early-life SEC were both directly and indirectly associated with LMS in older age. Finally, the risk of LMS with ageing was associated with low level of satisfaction with household income for women and high number of unhealthy behaviours for men, so adult-life SEC influenced not only the risk of LMS but also its evolution with age.

Comparison with other studies

Our findings support previous cross-sectional or short longitudinal studies that investigated the effect of life-course SEC on muscle strength trajectories in the ageing population [8, 9]. They showed that early-life SEC are associated with muscle strength even after adjusting for adult-life SEC and behavioural lifestyle factors. This partial explanation supports our hypothesis that early-life SEC could be associated with adult health outcomes through three different pathways: two indirect pathways (socioeconomic and behavioural) and one direct biological pathway. Furthermore, the important role played by satisfaction with household income in the process is in line with the biological pathway hypothesis, suggesting that factors associated with chronic stress have a cumulative physiological wear-and-tear effect, and are thus likely to have a detrimental effect on health-related outcomes such as muscle strength. Indeed, low satisfaction with household income is associated with higher levels of chronic psychosocial stress [27] compared with the other adult-life indicators. Chronic stress is associated with the lack of ability to purchase goods and services, acting in a way that extends life and eroding the capacity to cope [28]. Finally, results showed that early-life SEC are associated with the risk of LMS, but not with its trajectory across ageing, whereas adult-life SEC and behaviour lifestyle factors are associated with both. These findings support the concept of sensitive periods and social pathways linking early life and adult diseases [29]. More precisely, exposure to disadvantaged SEC at the sensitive age of 10 may affect adult health and/or channel individuals into future disadvantaged life trajectories.

Strengths and limitations

The strengths of our study include a large sample size, a 12-year follow-up with repeated measurements every 2 years and the use of an accurate biomarker of healthy ageing. However, one limitation is that early- and adult-life SEC information was extracted from self-reported retrospective life-course data and may therefore be subject to recall bias or social desirability bias. Regardless, previous research suggested a satisfactory validity of recall measures of socioeconomic status. Secondly, the early-life SEC score used in the current study combined different indicators of childhood circumstances. The construction of this score is recommended [23] but examining how each SEC indicator is related to LMS could also be interesting. Thirdly, this score reflects specific remembered conditions at the age of 10, which do not necessarily reflect the whole of childhood. Fourthly, attrition is an issue in longitudinal studies and may lead to a potential selection bias in the remaining sample. We dealt with this limitation by adjusting analyses for attrition and conducting sensitivity analyses excluding participants who dropped out or died. Fifthly, the unhealthy behaviours index may feature some misclassification bias because the index was computed by using the mean of four unhealthy behaviours. However, data were missing due to changes in some questions asked during the successive waves, and thus this bias should be non-differential and only reduce the association toward the null hypothesis. The strength of the observed associations supports the validity of this index.

Conclusion and public health implications

Our findings showed that early-life SEC is associated with a biomarker of healthy ageing—muscle strength—especially in women. This association was gradually attenuated with the addition of adult-life SEC and unhealthy behaviours. However, early-life SEC remained associated with muscle strength after adjusting for these factors, which supports the idea that early-life SEC represents a sensitive period that could be associated with health in later-life through both direct and indirect pathways. The direct and indirect effects of early-life SEC demonstrated here strengthen the evidence supporting public policies intervening in childhood to promote better health in later life.

Key points

- Early-life socioeconomic circumstances represents a sensitive period for health in later life, especially in women.
- Early-life socioeconomic circumstances are associated with muscle strength after adjusting for adult socioeconomic circumstances and behavioural lifestyle factors.
- Policy interventions during childhood may help to promote better health in later life.

Supplementary data

Supplementary data mentioned in the text are available to subscribers in *Age and Ageing* online.

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Conflict of interest

The authors declare no conflict of interests.

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Ethical approval

This study was part of the SHARE study, approved by the relevant research ethics committees in the participating countries, and all participants provided written informed consent.

Data sharing

This SHARE data set is available at http://www.share-project.org/data-access.html

Transparency

The lead author affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

Contributors

B.C, S.C., and M.P.B. designed the analyses. B.C. and S.C. analysed the data. B.C. and M.P.B. drafted the manuscript. All authors wrote the manuscript.

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