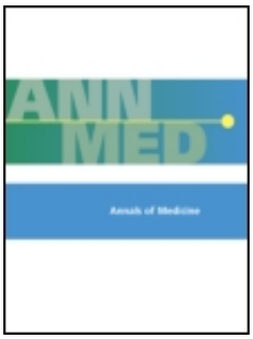

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ORIGINAL ARTICLE

Markers of biological fitness as predictors of all-cause mortality

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Introduction. **Within the Helsinki Birth Cohort, men who were tall when they were 7 years old lived for 5 years longer than men who were short. In the present analyses we examined two other influences known to be associated with lifespan: having children and educational attainment. We hypothesized that tall stature, the ability to have children, and high educational attainment reflect three aspects of biological fitness that are acquired during development.** ***Methods.*** **We examined all-cause mortality in 6975 men and 6370 women born in Helsinki during 1934–1944, whose childhood growth, number of children, and educational attainment were recorded.** ***Results.*** **In contrast to men, tall stature in childhood was not associated with longer lifespan among women. Men and women who had children lived for longer than those who had no children. Among women, having children was only associated with increased lifespan among those whose body mass index increased between 2 and 11 years. High educational attainment was associated with longer lifespan in both sexes. The trends of lower all-cause mortality with higher educational attainment were present in each socio-economic group. The men and women who had children, and attained upper tertiary education, lived for 16 years longer than those who had no children and only basic education.** ***Conclusion.*** **We suggest that the associations between having children, educational attainment, and lifespan reflect two different aspects of biological fitness that are acquired during early development.**

Key words: Biological fitness, child growth, educational attainment, fertility, lifespan

Key messages

- Tall stature in childhood is associated with longer lifespan in men but not among women.
- Men and women who had children, and attained higher education, lived for 16 years longer than those who had no children and only basic education.
- We suggest that the association between having children, educational attainment, and lifespan reflect different aspects of biological fitness acquired during early development.

Introduction

Within the Helsinki Birth Cohort, men who were tall when they were 7 years old, the age of school entry, lived for 5 years longer than men who were short (1,2). The tallest boys, with heights of more than 126 cm, lived for 5 years longer than the shortest, with heights of 114 cm or less. This is consistent with a body of evidence showing that tall adult stature is associated with lower all-cause mortality (3–9). In the present analyses we examine two other influences known to be associated with lifespan: having children (10) and educational attainment (11). We hypothesize that tall stature, the ability to have children, and high educational attainment reflect three aspects of biological fitness that are acquired during development. We use the term 'fitness' to define aspects of a phenotype that enable it to survive and reproduce.

Height is the product of two biological processes: an adequate supply of nutrients and the ability to grow. The ability to grow depends on hormonal signals and metabolic processes that are programmed during life *in utero* and in infancy (1). The tall stature of the boys who had long lives may therefore have reflected their physiological fitness. In all species, the ability to reproduce is a marker of biological fitness. In humans both biological and social influences must determine whether a man or woman has children. Children's performance on intelligence tests, one aspect of educational attainment, has been proposed as a reflection of general aspects of childhood fitness that are related to long-term health (12).

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Methods

The Helsinki Birth Cohort includes 6975 men and 6370 women who were born in Helsinki, Finland during 1934–1944, who went to child welfare clinics in the city, and who were still living in Finland in 1971. They were born in either the University Central Hospital or in the Maternity Hospital. Details of the birth records have been described (13). The weight and length of the baby were recorded. The child welfare clinics recorded growth from birth to 7 years. Each child had an average of 12 measurements of height and weight before the age of 7 years (14). On school entry, which in Finland occurs at 7 years, height and weight were again recorded.

Based on a classification from Statistics Finland, fathers were grouped into upper and lower middle class and manual workers (15). The men and women's own occupations, recorded at successive 5-year censuses from 1970 to 2000, were obtained from Statistics Finland, who grouped them into four categories (15). We used the highest category attained. The subject's educational attainment was also obtained from census data and grouped into upper tertiary, lower tertiary, upper secondary, basic, or unknown. Using the personal identification number assigned to each resident in Finland, we identified all deaths among the men and women during 1971 to 2007. All deaths in Finland are recorded in the national mortality register.

Statistical methods

The end-point for our survival analysis was death. We analysed men and women separately. People were censored in the analysis when they migrated from Finland or survived to the end of 2007. We used a Cox proportional hazards model to calculate the hazard ratios for death stratified by year of birth. To determine the statistical significance of trends, measurements were analysed as continuous variables although they are presented in the tables as groups. We estimated height, weight, and body mass index (weight/height^2) for each child at 6 months and birthdays from age 1 to 11 years. At any age we interpolated between the standard deviation score of measurements made immediately before and after that age. One measurement had to have been recorded within 2 years of the particular age. Usually it was within a few months. We divided postnatal growth into infant growth (birth to 2 years) and childhood growth (2 to 11 years). We examined, in sequence, trends in all-cause mortality with growth, number of children, and educational attainment. We next examined trends with educational attainment within categories of numbers of children. We examined whether growth interacted with number of children or educational attainment. Finally we examined whether the trends were influenced by adjustment for the father's occupation.

Results

There were 1570 deaths from all causes among men, and 658 deaths among women. The mean age at death was 54 years (range 27–73) among men and 57 (range 31 to 74) among women. Table I shows the causes of death.

Height and mortality

Among men, body size at birth, including weight and length at birth, was not related to all-cause mortality. The association between tall stature and reduced all-cause mortality was present at 6 months and at all birthdays from age 1 to 11 years ($P = 0.04$ at 6 months and 0.008 at 2 years). Among women, body size at birth and childhood height were not related to mortality.

Number of children

Table II shows that all-cause mortality was related to the number of children that the men and women had had. Men with no children had higher all-cause mortality compared to men who had one or more children. Among those who did have children there was no trend in mortality as the number of children increased. Among women there was progressively lower mortality as the number of children increased. The difference between men and women in the trends in mortality among those who had one or more children formed a statistically significant interaction (P for interaction = 0.008). Of the men with no children 46% were married, compared with 99% of those who had children. The comparable figures for women were 46% and 98%. In both men and women, being married was associated with lower all-cause mortality independently of having children. The lowest mortality was in people who were married and had children. Among men, when compared to those who were married and had children, the hazard ratios were 1.8 (95% CI 1.5–2.1) in those who were married but childless, 1.7 (1.0–3.1) in those who were unmarried but had children, and 2.6 (2.3–3.0) in those who were unmarried and childless. The corresponding figures for women were 1.3 (1.0–1.7), 2.2 (1.3–3.7), and 2.4 (1.9–2.9).

Table I. Numbers of deaths by cause.

		Men ($n = 6975$)		Women ($n = 6370$)	
	ICD codes (9th; 10th rev)	Number of deaths	%	Number of deaths	%
All causes		1570	100	658	100
Cardiovascular	390–459; I00–I99	520	33	143	22
Coronary heart disease	410–414; I21–I25	315	20	61	9
Stroke	430–438; I60–I69	83	5	46	7
Non-cardiovascular disease		1050	67	515	78
Cancer	140–209; C00–C99	337	21	256	39
Lung cancer	161–162; C32–C34	99	6	32	5
GI system cancer	150–157; C15–C26	104	7	68	10
Breast cancer	174; C50	0	0	64	10
Prostate cancer	185; C61	13	1	0	0
Respiratory disease	460–519; J00–J99	64	4	38	6
GI disease	520–579; K00–K99	151	10	39	6
Non-natural causes	800–999; W00–X99	84	5	40	6

Table II. Hazard ratios for all-cause mortality in men and women according to the number of their children.

	Men			Women		
	Deaths /men	Hazard ratio	95% CI	Deaths /women	Hazard ratio	95% CI
Number of children						
0	466/1432	2.4	2.1–2.7	183/1433	2.1	1.7–2.5
1	320/1452	1.3	1.1–1.5	149/1229	1.5	1.2–1.8
2	472/2596	1.0	baseline	212/2381	1.0	baseline
3	221/1064	1.1	1.0–1.3	87/973	1.0	0.8–1.2
4 or more	91/431	1.2	0.9–1.5	27/354	0.8	0.5–1.1
Total	1570/6975			658/6370		
Hazard ratio per child		0.78	0.75–0.82		0.76	0.71–0.81
P for trend		< 0.001			< 0.001	
P for trend in those with any children		0.4			< 0.001	
P for interaction		0.008				

CI = confidence interval.

Educational attainment

Higher educational attainment was associated with lower all-cause mortality in both men and women. In Table III the men and women are divided according to the level of education they achieved and whether or not they had any children. At any level of education mortality was higher among men and women who had no children, while the lowest mortality was in those who had children and high educational achievement. Among men, in a simultaneous regression, short stature at 7, having no children, and poor educational attainment were each statistically significantly associated with higher mortality. Among women, in a simultaneous regression, having few children and poor educational attainment were each associated with higher mortality. Men who had children and attained upper tertiary education lived for 16.8 years longer than men who had no children and only basic education. The equivalent figure for women was 16.5 years.

Table IV shows the findings for deaths from cardiovascular disease and deaths from non-cardiovascular causes. For both groups of causes, higher educational attainment was associated with lower mortality. Again, at any level of education, mortality was higher among men and women who had no children, while the lowest mortality was in those who had children and high educational attainment.

Occupational status

Men and women who themselves had high occupational status had lower all-cause mortality ($P < 0.001$ for both). Men and women whose fathers had higher occupational status also had lower all-cause mortality ($P < 0.001$ in men, $P = 0.002$ in women). We analysed the effect of father's occupational status in a simultaneous regression with height among men. The association between tall stature from the age of 6 months onwards and lower mortality were little changed. The trends with numbers of children among men and women (Table II) were little changed by adjustment for father's occupation. Among men the hazard ratio per child changed from 0.78 to 0.79, while among women it remained at 0.76. In Table V the men and women are divided according to their educational attainment and their father's occupational status. The trends of lower all-cause mortality with higher educational attainment were present in each occupational group. In any educational group the hazard ratios were similar across each occupational group.

Body size

We examined whether the effects of having no children, the number of children, and educational attainment interacted with body size at any age. Among men there were no such interactions. Among women there were no interactions with having no children or educational attainment, but Table VI shows that the trend of lower mortality with greater numbers of children was confined to women whose *z*-score for body mass index increased during childhood, that is between the ages of 2 and 11 years. This was a statistically significant interaction. There was no similar interaction with change in height between 2 and 11.

Discussion

Men and women who had children lived for longer than those who had no children. The more children women had, the longer they lived, but this association was confined to women whose

Table III. Hazard ratios for all-cause mortality in men and women according to their educational attainment and whether or not they had children.

Educational attainment	No children			Children		
	Deaths/subjects	Hazard ratio	95% CI	Deaths/subjects	Hazard ratio	95% CI
Men						
Basic or less	265/582	4.8	3.8–6.2	519/1990	2.4	1.9–3.0
Upper secondary	117/318	3.8	2.9–5.1	296/1385	1.9	1.5–2.5
Lower tertiary	50/182	1.8	2.7–1.9	189/1282	1.3	1.0–1.6
Upper tertiary	13/82	1.5	0.9–2.7	87/752	1.0	baseline
P for trend	< 0.001			< 0.001		
Women						
Basic or less	105/454	5.7	3.3–9.6	262/2229	2.5	1.5–4.2
Upper secondary	34/222	3.7	2.0–6.7	110/1149	2.1	1.2–3.5
Lower tertiary	19/231	1.8	0.9–3.4	80/1058	1.6	1.0–2.8
Upper tertiary	13/125	2.5	1.2–5.1	16/348	1.0	baseline
P for trend	< 0.001			< 0.001		

CI = confidence interval.

Table IV. Hazard ratios for cardiovascular and non-cardiovascular mortality in men and women according to their educational attainment and whether or not they had children.

Educational attainment	No children			Children		
	Deaths	Hazard ratio	95% CI	Deaths	Hazard ratio	95% CI
Cardiovascular:						
Men						
Basic or less	81	4.1	2.9–5.8	199	2.6	1.9–3.5
Upper secondary	34	3.2	2.1–4.9	98	1.8	1.3–2.5
Lower tertiary	15	2.2	1.2–3.9	53	1.0	baseline
Upper tertiary	3	1.0	0.3–3.2	32	1.0	0.7–1.6
P for trend	< 0.001			< 0.001		
Women						
Basic or less	25	3.4	1.9–6.1	61	1.5	0.9–2.5
Upper secondary	7	1.9	0.8–4.6	21	1.0	0.6–1.9
Lower tertiary	4	1.0	0.3–2.9	19	1.0	baseline
Upper tertiary	3	1.5	0.4–4.9	1	0.2	0.0–1.2
P for trend	0.004			0.02		
Non-cardiovascular:						
Men						
Basic or less	184	3.7	2.9–4.6	320	1.6	1.3–2.0
Upper secondary	83	2.9	2.2–3.9	198	1.4	1.1–1.7
Lower tertiary	35	2.0	1.4–3.0	136	1.0	baseline
Upper tertiary	10	1.3	0.7–2.4	55	0.7	0.5–0.9
P for trend	< 0.001			< 0.001		
Women						
Basic or less	80	3.5	2.5–4.9	201	1.6	1.2–2.1
Upper secondary	27	2.3	1.5–3.7	89	1.4	1.0–1.9
Lower tertiary	15	1.1	0.6–2.0	61	1.0	baseline
Upper tertiary	10	1.5	0.8–3.0	15	0.7	0.4–1.3
P for trend	< 0.001			< 0.001		

CI = confidence interval.

body mass index increased during childhood. High educational attainment was associated with longer lifespan in both sexes. The men and women who had children and upper tertiary education lived for 16 years longer than those who had no children and only basic education. They had lower mortality from cardiovascular and non-cardiovascular causes. These large differences in lifespan may be compared with those linked to the range of socio-economic status in adult life which, in our data, is associated with 8-year differences (1). Men who were tall at 6 months of age, and at all ages thereafter, had longer lives. Among men, having no children, poor educational attainment, and short stature in childhood were each independently associated with higher mortality. Among women, tall stature was not associated with longer lifespan, but having few children and poor educational attainment were independently associated with higher mortality.

Numbers of children

An association between having children and reduced all-cause mortality has been shown before (10). Both biological and social influences must determine whether a man or woman has children. One such influence is marriage, and we found that being married was associated with reduced mortality independently of the effect of having children. Studies in the UK and Finland showed that men who had low birth weight are less likely to marry (16). In the UK study, the odds ratio for being married was 1.51 (95% confidence interval 1.08–2.12) for each kilogram increase in birth weight; the corresponding figure in Finland was 1.42 (1.11–1.81). These findings suggest that getting married is a demonstration of some aspect of fitness that is programmed *in utero* (16).

Lower mortality with greater numbers of children was only apparent in women whose body mass index at 11 years was greater than their body mass index at 2 years. In Finland at the time

Table V. Hazard ratios for all-cause mortality in men and women according to their educational attainment and father's socio-economic status.

Educational attainment	Father's socio-economic status								
	Lower			Lower middle			Upper middle		
	Deaths/subjects	Hazard ratio	95% CI	Deaths/subjects	Hazard ratio	95% CI	Deaths/subjects	Hazard ratio	95% CI
Men									
Basic or less	544/1729	2.7	2.0–3.7	155/520	2.6	1.9–3.6	65/252	2.2	1.5–3.2
Upper secondary	283/1113	2.1	1.5–2.9	85/345	2.1	1.4–3.0	39/203	1.7	1.1–2.6
Lower tertiary	114/648	1.4	1.0–2.0	65/437	1.2	0.8–1.7	57/354	1.3	0.9–1.9
Upper tertiary	29/228	1.0	0.6–1.6	26/242	0.8	0.5–1.4	44/355	1.0	baseline
P for trend	< 0.001			< 0.001			< 0.001		
Women									
Basic or less	250/1831	2.8	1.4–5.4	76/540	3.0	1.5–5.9	28/221	2.8	1.3–5.9
Upper secondary	94/845	2.3	1.2–4.5	31/298	2.2	1.0–4.6	14/189	1.6	0.7–3.2
Lower tertiary	40/508	1.6	0.8–3.3	36/416	1.7	0.8–3.5	20/333	1.2	0.6–2.7
Upper tertiary	15/146	2.2	1.0–5.1	5/134	0.7	0.2–2.2	9/188	1.0	baseline
P for trend	0.002			< 0.001			0.002		

CI = confidence interval.

Table VI. Hazard ratios for all-cause mortality in women according to the number of their children and whether their *z*-score for body mass index (BMI) decreased or increased between age 2 and 11 years.

	BMI decreased			BMI increased		
	Deaths/women	Hazard ratio	95% CI	Deaths /women	Hazard ratio	95% CI
Number of children						
0	50/453	1.4	1.0–2.0	74/478	2.2	1.6–3.0
1	50/472	1.1	0.8–1.6	63/445	1.6	1.2–2.2
2	86/909	1.0	baseline	80/846	1.0	baseline
3	40/373	1.1	0.8–1.6	25/324	0.8	0.5–1.2
4 or more	14/141	0.9	0.5–1.7	4/101	0.4	0.1–1.1
Total	240/2348			246/2194		
Hazard ratio per child		0.91	0.81–1.02		0.69	0.61–0.77
P for trend	0.11			<0.001		
P for interaction	<0.001					

CI = confidence interval.

when these girls were growing up childhood obesity was rare, and gain in body mass index would have reflected normal physiology rather than pathology. Deposition of body fat is a feature of girls' pre-pubertal growth (17). We suggest that having many children demonstrated physiological fitness, and having adequate fat stores protected women from negative consequences of repeated pregnancies. Girls whose body mass index at 11 years was lower than it was at 2 years will not have increased their body fat. Repeated pregnancies did not increase their lifespan, which suggests that they had adverse effects. We suggest that they incurred these costs because they were thin, though we have no direct evidence of this.

Educational attainment

The association between lower intellectual performance in childhood or youth and increased mortality has been extensively replicated (18–20). Poor educational attainment may result from poor cognitive ability or from other mental impairments, such as inability to sustain attention. Altered autonomic nervous system activity is thought to underlie attention deficit disorder (21). High attainment was associated with greater lifespan in each socio-economic group, as defined by the father's occupation (Table V). Access to schooling is free in Finland, and educational attainment may be less closely linked to socio-economic status than in other Western countries. Whalley and Deary have proposed that performance in intelligence tests reflects general aspects of childhood fitness related to long-term health (12). In addition, greater intelligence and higher levels of education may be associated with healthier behaviour in adult life (22,23).

Height

Length at birth was not associated with lifespan in either sex. The association between tall stature and longer lifespan among men was apparent at 6 months of age and all ages thereafter. An interpretation of this is that, *in utero*, their programmed ability to grow was constrained by the mother to permit birth, but became displayed immediately after birth. The lack of an association between stature and lifespan among women may reflect the lower biological priority of tallness among women, compared to the higher priority of acquisition of fat.

Limitation of the study

Our study was restricted to people who had attended child welfare clinics. Although the majority of children attended these clinics, which were free, attendance was voluntary. Therefore, the people in our study may not be representative of all people now living in Helsinki. At birth, the distribution of social class, as indicated by father's occupation, was similar to that in the city as a whole, where at that time 60% of men were employed as manual workers, and 40% of families lived in homes with only one room. There were food shortages in Finland before and during the Second World War, and some families were malnourished. Some children were sent to Sweden during the Second World War so that they could be properly fed. These circumstances, which are unusual for most families in the contemporary Western setting, may limit the generalizability of our results.

Conclusion

Men and women who had children lived for longer than those who had no children. The more children women had the longer they lived, but only if their body mass index increased between 2 years of age and puberty. High educational attainment was associated with longer lifespan in both sexes. We suggest that the associations between having children, educational attainment, and lifespan reflect two different aspects of biological fitness that are acquired during early development and prolong life. The association between tall stature and prolonged lifespan among men was apparent at 6 months of age and all ages thereafter. While in boys the developmental origins of fitness are associated with growth in height, in girls they are linked to the acquisition of fat.

Declaration of interest: The authors report no conflicts of interest.

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