

**Developmental factors associated with decline in grip strength from midlife to old age: a
British birth cohort study**

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SUPPLEMENTARY MATERIAL

Supplementary Material

Model specification

Multilevel models were used to estimate the grip strength trajectory defined by the intercept (at age 53) and the slope, with measurements (level1) nested within individuals (level 2).

If $grip_{ij}$ denotes grip strength of individual j ($j=1, \dots, n$) on measurement occasion i ($i=1,2,3$) and age_{ij} the age (centred at 53 years) at which that measurement was recorded, the basic multilevel model can be written as:

$$grip_{ij} = \alpha + u_j + (\beta_1 + v_j)age_{ij} + e_{ij}$$

where the fixed parameter α is the mean intercept and the fixed parameter β the mean slope. The parameters u_j and v_j represent the deviation of the j th individual's intercept from the overall mean and slope, respectively. Finally, e_{ij} is the residual error term.

Covariates were then added to the model and could be associated with the intercept and the slope. Covariate by age interactions were assessed and included in models if $p < 0.1$.

For Table 3 in men, the first line of the table is from the model:

$$\begin{aligned} grip_{ij} = & \alpha + u_j + (\beta_1 + v_j)age_{ij} + \beta_2bwt_j \\ & + \beta_3htsize_j + \beta_4httempo_j + \beta_5htvelocity_j + \beta_6wtsize_j \\ & + \beta_7wttempo_j + \beta_8wtvelocity_j + \beta_9adultht_{ij} + e_{ij} \end{aligned}$$

Adjusting for BMI, for example, as a time-varying covariate which is associated with both intercept (β_{10}, β_{11}) and slope (γ_1), the model is:

$$\begin{aligned} grip_{ij} = & \alpha + u_j + (\beta_1 + v_j)age_{ij} + \beta_2bwt_j \\ & + \beta_3htsize_j + \beta_4httempo_j + \beta_5htvelocity_j + \beta_6wtsize_j \\ & + \beta_7wttempo_j + \beta_8wtvelocity_j + \beta_9adultht_{ij} + \beta_{10}BMI_{ij} + \beta_{11}BMI_{ij}^2 \\ & + \gamma_1BMI_{ij}.age_{ij} + e_{ij} \end{aligned}$$

Similarly, for Table 4 in men, the first line of the table where childhood cognition is associated with both intercept (β_2, β_3) and the slope (γ_1), the model is:

$$\begin{aligned} grip_{ij} = & \alpha + u_j + (\beta_1 + v_j)age_{ij} + \beta_2childcog_j + \beta_3childcog_j^2 \\ & + \gamma_1childcog_j.age_{ij} + \beta_4walking_j + \beta_5walking_j^2 + \gamma_2walking_j.age_{ij} \\ & + \beta_6adultht_{ij} + e_{ij} \end{aligned}$$

Adjusting for adult BMI:

$$\begin{aligned}
grip_{ij} = & \alpha + u_j + (\beta_1 + v_j)age_{ij} + \beta_2childcog_j + \beta_3childcog_j^2 \\
& + \gamma_1childcog_j \cdot age_{ij} + \beta_4walking_j + \beta_5walking_j^2 + \gamma_2walking_j \cdot age_{ij} \\
& + \beta_6adultht_{ij} + \beta_7BMI_{ij} + \beta_8BMI_{ij}^2 + \gamma_3BMI_{ij} \cdot age_{ij} + e_{ij}
\end{aligned}$$

For Table 5 in women, the first line is from the model:

$$\begin{aligned}
grip_{ij} = & \alpha + u_j + (\beta_1 + v_j)age_{ij} + \beta_2bwt_j + \gamma_1bwt_j \cdot age_{ij} \\
& + \beta_3childcog_j + \beta_4walking_j + \beta_5adultht_{ij} + e_{ij}
\end{aligned}$$

Adjusting for adult BMI:

$$\begin{aligned}
grip_{ij} = & \alpha + u_j + (\beta_1 + v_j)age_{ij} + \beta_2bwt_j + \gamma_1bwt_j \cdot age_{ij} \\
& + \beta_3childcog_j + \beta_4walking_j + \beta_5adultht_{ij} + \beta_6BMI_{ij} + \beta_7BMI_{ij}^2 \\
& + \gamma_2BMI_{ij} \cdot age_{ij} + e_{ij}
\end{aligned}$$

Supplementary Table 1. Estimates From Multilevel Models Showing Mean Differences in Grip Strength (kg) in 1,375 NSHD Men (3,111 Observations) and in 1,385 NSHD Women (3,266 Observations) for Mutually Adjusted Physical Growth Indicators. All Models Adjusted for Age Term and Adult height and Using Sample With Complete Childhood Data.

| | MEN | | | WOMEN | | |
|--------------------------|-------------|--------------|---------|-------------|--------------|---------|
| | Reg. Coeff. | 95% CI | P-value | Reg. Coeff. | 95% CI | P-value |
| Age (months) at sitting | 0.030 | -0.35,0.40 | 0.9 | -0.031 | -0.27,0.21 | 0.8 |
| Age (months) at standing | 0.14 | -0.23,0.46 | 0.6 | -0.29 | -0.53,-0.052 | 0.02 |
| Age (months) at walking | | | | | | |
| Walking | 1.72 | 0.33,3.1 | 0.01 | 0.11 | -0.093,0.32 | 0.3 |
| Walking ² | -0.075 | -0.12,-0.028 | 0.002 | N/A | | |
| | | | | | | |
| | | | | | | |

Supplementary Table 2. Estimates From Multilevel Models Showing Mean Differences in Grip Strength (kg) and Mean Differences in Grip Strength Change (kg/year) in 1,316 NSHD Men (2,983 Observations) for Mutually Adjusted Childhood Factors. All Models Adjusted for Age Term and Standardised Adult Height.

| | Adjusted for age term and height | | | Fully adjusted | | |
|-------------------------------------|----------------------------------|-------------|----------|----------------|-------------|----------|
| | Reg. Coeff. | 95% CI | P-value+ | Reg. Coeff. | 95% CI | P-value+ |
| BIRTHWEIGHT (kg) | 2.00 | 1.05,2.95 | <0.001 | 1.40 | 0.41,2.38 | 0.005 |
| GROWTH PARAMETERS | | | | | | |
| Height -size (cm) | -0.09 | -0.32,0.14 | 0.4 | -0.07 | -0.30,0.16 | 0.5 |
| Height-tempo (%) | 0.16 | 0.052,0.26 | 0.004 | 0.15 | 0.046,0.26 | 0.005 |
| Height-velocity (%) | -0.02 | -0.10,0.06 | 0.6 | -0.03 | -0.10,0.05 | 0.5 |
| Weight-size (kg) | 0.93 | 0.41,1.44 | <0.001 | 0.62 | 0.094,1.15 | 0.02 |
| Weight-tempo (%) | -0.07 | -0.13,0.00 | 0.051 | -0.05 | -0.12,0.02 | 0.1 |
| Weight-velocity (%) | -0.10 | -0.18,-0.02 | 0.011 | -6.16 | -14.11,1.79 | 0.1 |
| MOTOR DEVELOPMENT (months) | | | | | | |
| Age at walking | | | | | | |
| Walking | 1.35 | -0.073,2.78 | 0.06 | 1.30 | -0.11,2.72 | 0.07 |
| Walking ² | -0.057 | -0.10,-0.01 | 0.02 | -0.054 | -0.10,-0.01 | 0.02 |
| CHILDHOOD DEVELOPMENT (SD) | | | | | | |
| Cognition | -0.32 | -0.98,0.33 | 0.3 | -0.41 | -1.08,0.27 | 0.2 |
| Cognition ² | -0.78 | -1.25,-0.30 | 0.001 | -0.77 | -1.24,-0.30 | 0.001 |
| Cognition*age (year) | 0.07 | 0.021,0.11 | 0.004 | 0.067 | 0.02,0.11 | 0.003 |
| Cognition ² * age (year) | 0.03 | -0.01,0.06 | 0.09 | 0.024 | -0.01,0.06 | 0.2 |
| FATHER'S OCCUPATIONAL CLASS | | | | | | |
| I & II | REF | | 0.08 | REF | | 0.09 |
| III | -0.62 | -1.81,0.58 | | -0.77 | -1.99,0.44 | |
| IV and V | -1.55 | -2.91,-0.18 | | -1.63 | -3.08,-0.18 | |

+ P-values are given for the overall tests of associations

Supplementary Table 3. Estimates From Multilevel Models Showing Mean Differences in Grip Strength (kg) and Mean Differences in Grip Strength Change (kg/year) in 1,320 NSHD Women (3,069 observations) for Mutually Adjusted Childhood Factors. All Models Adjusted for Age Term and Standardised Adult Height.

| | Adjusted for age term and height | | | Adjusted for age term and height and all childhood factors | | |
|------------------------------------|----------------------------------|--------------|----------|--|-------------|----------|
| | Reg. Coeff. | 95% CI | P-value+ | Reg. Coeff. | 95% CI | P-value+ |
| BIRTHWEIGHT (kg) | | | | | | |
| Birthweight | 1.20 | 0.32,2.08 | .007 | 1.05 | 0.24,1.86 | 0.01 |
| Birthweight*age (year) | -0.07 | -0.13,-0.002 | .04 | -0.07 | -0.14,-0.01 | 0.03 |
| GROWTH PARAMETERS | | | | | | |
| Height -size (cm) | -0.14 | -0.28,0.01 | 0.07 | -0.15 | -0.30,0.01 | 0.06 |
| Height-tempo (%) | 0.02 | -0.041,0.08 | 0.6 | 0.02 | -0.04,0.09 | 0.3 |
| Height-velocity (%) | -0.01 | -0.05,0.037 | 0.7 | -0.01 | -0.05,0.04 | 0.9 |
| Weight-size (kg) | 0.36 | -0.02,0.75 | 0.06 | 0.25 | -0.15,0.65 | 0.2 |
| Weight-tempo (%) | 0.00 | -0.05,0.05 | 1.0 | 0.01 | -0.05,0.06 | 0.8 |
| Weight-velocity (%) | -0.05 | -0.11,0.07 | 0.08 | -0.03 | -0.91,0.26 | 0.3 |
| MOTOR DEVELOPMENT (months) | | | | | | |
| Age at standing | -0.16 | 2.50,3.39 | 0.03 | -0.14 | -0.29,0.00 | 0.06 |
| CHILDHOOD DEVELOPMENT (SD) | | | | | | |
| Cognition | 0.41 | 0.09,0.73 | .01 | 0.42 | 0.07,0.78 | 0.02 |
| FATHER'S OCCUPATIONAL CLASS | | | | | | |
| I & II | REF | | 0.2 | REF | | 0.2 |
| III | -0.59 | -1.65,0.47 | | -0.41 | -1.38,0.57 | |
| IV and V | 0.22 | -0.99,1.43 | | 0.59 | -0.55,1.72 | |
| III *age (year) | -0.02 | -0.10,0.06 | 0.2 | -0.02 | -0.10,0.05 | 0.1 |
| IV and V*age (year) | -0.08 | -0.17,0.01 | | -0.09 | -0.18,0.004 | |

+ P-values are given for the overall tests of associations

Supplementary Table 4 Estimates From Multilevel Models Showing Mean Differences in Grip Strength (kg) and Mean Differences in Grip Strength Change (kg/year) by Each Adult Factor. All Models Adjusted for Age Term and Standardised Adult Height.

| | n | Men | | | n | Women | | |
|--|-------|-------------|---------------|---------|-------|-------------|---------------|---------|
| | | Reg. Coeff. | 95% CI | P-value | | Reg. Coeff. | 95% CI | P-value |
| a. BMI (per SD) ^a | 1,528 | | | | 1,524 | | | |
| BMI | | 1.66 | 0.93,2.38 | <0.001 | | -0.18 | -0.42,0.049 | 0.1 |
| BMI ² | | -0.49 | -0.80,-0.18 | 0.002 | | n/a | | |
| BMI*age | | -0.057 | -0.11,-0.0056 | 0.03 | | n/a | | |
| b. Health conditions at 53y | 1,415 | | | | 1,441 | | | |
| Health conditions | | -0.84 | -1.70,0.19 | 0.05 | | -1.42 | -1.89,-0.94 | <0.001 |
| Health conditions ² | | -0.055 | -0.12,0.0057 | 0.08 | | 0.030 | -0.0066,0.066 | 0.1 |
| c. Smoker v. non-smoker ^a | 1,516 | -1.28 | -2.38,-0.18 | 0.02 | 1,520 | -0.17 | -0.90,0.55 | 0.6 |
| d. Leisure time physical activity ^a | 1,521 | | | | 1522 | | | |
| Inactive | | REF | | 0.003 | | REF | | 0.005 |
| Intermediate | | 1.52 | 0.54,2.51 | | | 0.85 | 0.21,1.48 | |
| Active | | 1.04 | 0.23,1.84 | | | 0.71 | 0.18,1.24 | |
| e. Verbal memory ^a | 1,489 | | | | 1,508 | | | |
| Verbal memory | | -0.67 | -1.24,-0.093 | 0.02 | | 0.070 | -0.31,0.45 | 0.7 |
| Verbal memory*age | | 0.10 | 0.061,0.15 | <0.001 | | 0.032 | 0.0020,0.063 | 0.04 |
| f. Qualifications (per step) | 1,445 | 0.17 | -0.13,0.48 | 0.3 | 1,444 | 0.38 | 0.16,0.59 | 0.001 |
| g. Own social class at 53y ^b | 1,511 | | | | 1,518 | | | |
| I and II | | REF | | 0.001 | | REF | | 0.001 |
| III | | 0.83 | -0.50,2.15 | | | -1.02 | -1.63,-0.41 | |
| IV & V | | -3.20 | -5.25,-1.15 | | | -1.11 | -1.89,-0.33 | |
| III *age | | -0.16 | -0.25,-0.066 | 0.001 | | N/A | | |
| IV & V * age | | 0.50 | -0.097,0.20 | | | N/A | | |

^aincluded as time varying covariates; ^b illustrated in Web Figure 1.

P-values for sex interactions: BMI (intercept) $P < 0.001$; BMI (quadratic) $P = 0.004$; BMI (slope) $P = 0.01$; health conditions (slope) $P = 0.05$; smoker $P = 0.08$; sex*age*occupational class $P = 0.001$

Supplementary Table 5. Estimates From Multilevel Models Showing Mean Differences in Grip Strength (kg) by age at First Walking (in 1161men, 2515 observations) and Age at First Standing (in 1211women, 2709 observations) Adjusted for Age Term, Standardised Adult Height, and Then Additionally Adjusted for Each Set of Adult Factors in Turn

| | Men: Age at walking (linear) | | | Men: Age at walking (quadratic) | | | Women: Age at standing | | |
|---|------------------------------|------------|---------|---------------------------------|---------------|---------|------------------------|-------------|---------|
| | Reg. Coeff. | 95% CI | P-value | Reg. Coeff | 95% CI | P-value | Reg. Coeff | 95% CI | P-value |
| Adjusted for age, adult height | 0.96 ^b | -0.62,2.54 | 0.2 | -0.042 ^b | -0.096,0.011 | 0.1 | -0.16 ^{b,c} | -0.31,-0.12 | 0.03 |
| Additional adjustments | | | | | | | | | |
| BMI ^a , BMI ² , BMI*age | 1.02 | -0.55,2.60 | 0.2 | -0.044 | -0.097,0.0095 | 0.1 | -0.17 | -0.32,-0.02 | 0.03 |
| Health conditions 53y, Health conditions*age | 0.99 | -0.58,2.57 | 0.2 | -0.044 | -0.097,0.0094 | 0.1 | -0.18 | -0.33,-0.04 | 0.01 |
| Educational qualifications | 0.88 | -0.70,2.46 | 0.3 | -0.040 | 0.094,0.013 | 0.1 | -0.18 | -0.33,-0.03 | 0.03 |
| Verbal memory ^a , Verbal memory*age | 0.96 | -0.62,2.54 | 0.2 | -0.042 | -0.095,0.011 | 0.1 | -0.16 | -0.31,-0.01 | 0.03 |
| Own social class 53y, Own social class*age | 1.05 | -0.53,2.63 | 0.2 | -0.046 | -0.099,0.0072 | 0.09 | -0.16 | -0.31,-0.02 | 0.03 |
| Smoking and exercise ^a | 0.90 | -0.67,2.47 | 0.3 | -0.041 | -0.094,0.012 | 0.1 | -0.17 | -0.32,-0.23 | 0.02 |

^atime varying covariates; ^b also adjusted for childhood cognition; ^c also adjusted for birthweight