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Associations between grip strength of parents and their 4 year old children: findings from the Southampton Women's Survey

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Summary

Relationships between birthweight and grip strength throughout the lifecourse suggest that early influences on the growth and development of muscle are important for long-term muscle function. However, little is known about parental influences on children's grip strength. We have explored this in the Southampton Women's Survey, a prospective general population cohort study from before conception through childhood. Grip strength was measured using a Jamar handgrip dynamometer in the mother at 19 weeks' gestation and her partner, and in the child at age four years. Pre-pregnancy heights and weights were measured in the mothers; reported weights and measured heights were available for the fathers. Complete data on parents and children were available for 444 trios. In univariate analyses, both parents' grip strengths were significantly associated with that of the child ($r=0.17$, $p<0.001$ for mothers, $r=0.15$, $p=0.002$ for fathers). These correlations were similar to that between the grip strength of the mothers and the father ($r=0.17$, $P<0.001$). In the multivariate model, after adjustment for child's height and physical activity, the correlations with the child's grip strength were attenuated, being 0.10 ($P=0.02$) and 0.11 ($P=0.01$) for mothers' and fathers' grip strength respectively. The findings show that grip strength of both parents is associated with that of their child, indicating that heritable influences and the shared family environment influence the development of muscle strength. This contributes to our understanding of the role of heritable and environmental factors on early muscle growth and development, which are important for muscle function across the lifecourse.

Keywords

muscle; grip strength; growth and development; genetic and environmental influences; height

Introduction

Grip strength, a widely used measure of muscle strength, increases through childhood reaching a peak in early adulthood and declines from middle age.¹⁻³ Grip strength also

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appears to be a good marker of general health. For example lower grip strength in middle aged and older adults is associated with a subsequent increased risk of morbidity and mortality.⁴⁻¹³ Indeed, measurement of grip strength has been proposed as a useful screening tool on entry to hospital as a measure of frailty and as a guide to the provision of care.¹⁴

Birthweight is a predictor of adult grip strength¹⁵⁻¹⁹ and generally the association remains even after adjustment for current height, weight, and levels of physical activity. Findings from these studies indicate that a one kilogram increase in birthweight is associated with an increase of around two kilograms in grip strength.²⁰ This suggests that influences before birth act on muscle growth and development and have long term consequences for muscle strength.

Less is known about the relationships between birthweight and grip strength in childhood. In 9-year old children in Pune in India, grip strength was found to be strongly associated with birthweight.²¹ However, the relationship was attenuated after adjustment for height and weight. Similar findings have been found in preliminary analyses of data for 4 year old children in Southampton, UK.²²

The role of heritable influences in these associations is of interest. Twin studies have been widely used to explore the heritability of muscle strength and have concluded that there is a strong genetic component with heritability estimates ranging between one-third to one-half of the individual variation in muscle strength and power among older people.²³⁻²⁷ However, twin studies do not address the specific relationships between individual parents and their children. Familial aggregation in grip strength along with other assessments of muscle strength was explored in various studies in the 1980s^{28,29} and recently familial resemblance in changes in musculoskeletal fitness over time has been explored.³⁰ The results indicated a significant familial resemblance for all indicators of musculoskeletal fitness including grip strength.

A direct assessment of the associations between parental and child grip strength was performed recently in a study from three European countries.³¹ Correlations were obtained between the grip strength of parent-offspring pairs in which the parent was aged 90 years or older. Higher correlations were found between the children and their fathers than for their mothers. Due to the age of the parents, no data were available on trios of parents with the child, as in most families only one or other parent was still alive. No studies to date have considered the transgenerational influences on grip strength in children. We sought to explore the relationship between parents' grip strength and that of their children at the age of four years.

Methods

The study formed part of the Southampton Women's Survey,³² for which 12,583 women aged 20-34 years were recruited between 1998 and 2002. Between 1998 and 2007, some 3,159 of these women were followed through pregnancy, with fetal ultrasound scans at 11, 19, and 34 weeks, and delivered a live-born infant. From February 2002 onwards, at the 19 week ultrasound visit, the grip strength of the woman was measured. Her partner was encouraged to attend at the same time and his grip strength and height were measured. Reported weights of the fathers were also requested. The children were then followed-up at 6, 12, 24 and 36 months. At age 4 years, a sample of children was invited to attend for a body composition assessment using dual x-ray absorptiometry and at the same time the children's grip strength was measured, using a Jamar handgrip dynamometer (Promedics, Blackburn, UK). For the grip strength measurements of the parents and the children a standardised approach was used as described by Roberts *et al.*³³ Specifically, the

dynamometer was adjusted to fit the hand size of each individual and three measurements of each hand were taken with the maximum of all six measurements being used in the analysis. The dataset for this study comprises all children with a grip strength measurement at four years of age, and grip strength measurements for both parents. All phases of the Southampton Women's Survey were approved by the Southampton and South West Hampshire Local Research Ethics Committee.

Correlations between the grip strengths of each pair of family members were obtained, then univariate and stepwise multiple regression analyses were performed to relate the child's grip strength to characteristics of the mother, the father and the child respectively, including the parental grip strength measures. The grip strength measures were standardised to enable comparison of effect sizes and to provide results that could be interpreted as correlation coefficients for comparison with studies from elsewhere.

The maternal factors that were considered as possibly influencing the child's grip strength were: age at birth of the child, height, pre-pregnant weight, skinfold thicknesses, reported hours of strenuous exercise per week, smoking in pregnancy, education and social class. Less information was available about the fathers of children in the Southampton Women's Survey but the influence of height and social class was investigated. Factors specific to the child were: sex, height, weight, birthweight, and reported hours per day spent actively on the move and spent watching television. Height was measured with a portable stadiometer (Harpender; CMS Weighing Equipment Ltd, London, UK) to the nearest 0.1 cm with the head in the Frankfort plane. Weight was measured with calibrated electronic scales (Seca, Hamburg, Germany) to the nearest 0.1 kg. Birthweights were as recorded by midwives attending the birth, and the two variables summarising the activity levels of the child were obtained from questionnaires administered to the mother when the child was six years old. Variables were included in the model if their relationship with the child's grip strength was statistically significant at the 10% level. Separate models were also fitted for boys and girls.

Results

Grip strength measurements were available for 968 children born between July 2002 and January 2005. For 445 of these children, grip strength measurements were available for both parents. The data were excluded for one mother as her grip strength was particularly low due to rheumatoid arthritis, leaving 444 records with data on both parents and the child.

Characteristics of the 444 parent and child trios are presented in Table 1 and compared with the remaining 919 children in the Southampton Women's Survey born in the same time period. Notably, those with full grip strength measurements had mothers who were older and better educated than those without grip strength measurements. Differences between the fathers of those with and without grip strength measurements were less apparent, though fewer variables were available for analysis. The children who had grip strength measures were slightly heavier at birth, but among those measured at 4 years of age, there was no difference in height and weight between those with full grip strength measures and those without. The children's grip strengths were measured when they were between 4 and 4.4 years old.

The means and standard deviations of the grip strengths of the parents and children are given in Table 2, along with the correlation coefficients (equivalent to the regression of the standardised grip strength measurements on each other) between family members. The correlations between the grip strengths of each pair of family members were statistically significant and similar, but not very strong. Notably the correlation between the mothers' and fathers' grip strengths was of the same magnitude (0.17) as that for the mothers and

their children. The correlation between the fathers' grip strengths and those of their children was marginally weaker at 0.15.

The results of the regression analyses are given in Table 3. In univariate analyses, the child's grip strength was strongly associated with the heights and grip strengths of both parents. Additionally, there was a relationship, though less strong, with the mother's pre-pregnant weight. The child's grip strength was strongly positively associated with the child's own height and weight at the time of the grip strength measurement and there were weaker relationships, positively, with the child's birthweight, and, negatively, with the amount of time the child spent watching television each day.

Using a backwards stepwise modelling approach all the variables with a univariate relationship with the child's grip strength were considered. The final model is presented in Table 3. The strongest relationship was with the child's current height, but both parents' grip strengths remained in the model, as too did the amount of time the child spent watching television. This model explained 20% of the variance in the child's grip strength.

Table 4 shows the results of the same modelling process for boys and girls separately. There was a suggestion that the relationships were stronger for same sex pairings, such that the grip strength of mothers was more strongly correlated with girls' grip strength while for boys the relationship with the father's grip strength was the stronger. However, there was no significant interaction between parental grip strength and the sex of the child and so these differences must be interpreted with caution.

Discussion

Parental grip strength is associated with the grip strength of the child at 4 years of age. The relationships are modest, with an increase in parental grip strength of 1 standard deviation (SD) being associated with an increase of around 0.15SD in the child's grip strength. The univariate relationship between the child's grip strength and that of the mother was slightly stronger than with that of the father. The relationships between the child's grip strength and the grip strengths of both parents remained after adjustment for various confounding factors, though the child's height, in particular, attenuated the relationships. There was a suggestion that mothers' grip strength was more strongly associated with that of their female children while for boys a stronger relationship was seen with their fathers, but the interaction was not significant. The correlation between the grip strengths of the father and the mother was similar to that between each parent and the child.

Cournil *et al*³¹ explored relationships between the 290 pairs of parents (of either sex) and children where the parent was over the age of 90 years. They found a correlation of 0.16 between parents and children which is remarkably similar to the correlations we have observed between the children and their mothers (0.17) and their fathers (0.15). However, Cournil *et al*³¹ found a stronger correlation for father-child pairs ($r=0.26$) than for mothers and their children ($r=0.03$), in contrast to our findings that suggested same sex pairings of parent and child grip strength relationships. However, there are marked contrasts between this study and ours. Notably the age difference is extreme, with opposite ends of the age spectrum being considered in the two studies. Also, Cournil *et al*³¹ were unable to examine trios, as due to the extreme old age of the parents, only one parent tended to be alive. Neither study, however, has found very strong relationships between the generations, though at old ages the relationships between fathers and their children is stronger than for mothers, whereas we generally observed similar relationships between the grip strengths of both parents and those of their children.

Two other studies have examined relationships between the muscle strength of parents and children.²⁹⁻³⁰ Katzmarzyk *et al*³⁰ primarily focused on changes in musculoskeletal fitness over a seven year period, but, at baseline, they found strongly significant associations between parents' and children's grip strengths, though they did not quote the correlation coefficient. Perusse *et al*²⁹ assessed quadriceps muscle strength instead of grip strength and found a correlation between parents and children of 0.32. Neither study distinguished between relationships with fathers and mothers, nor conducted sex-specific analyses.

According to twin studies, up to 50% of the variation in grip strength is estimated as being due to genetic factors. However, whilst twin studies allow inferences to be made regarding the genetic and environmental contribution to childhood grip strength, they do not permit elucidation of the independent role of either parent. Our approach, along with that of the studies above, has attempted to explore these direct relationships between parents and children. Neither the study by Cournil *et al*³¹ nor our study showed very strong relationships between parents and their children with few correlation coefficients exceeding 0.2. Of note, the correlation between the grip strengths of the fathers and mothers was of the same magnitude as that of each parent with the child. While no genetic association would be expected between the two parents, assortative mating may provide an explanation. However, this is in contrast to the findings of Katzmarzyk *et al*³⁰ who found no relationship between the grip strength of spouses in their study.

Other cohort studies have examined the concordance between parents and children in relation to body composition measures. For example, in the Avon Longitudinal Study of Parents and Children, correlations between parents and children for body mass index were slightly greater than those found here for grip strength, but maternal-child and paternal-child correlations were similar, with no suggestion of sex-linked associations.³⁴ In the same cohort, associations between parental body mass index and child's bone mass were similar for both parents and the correlations were comparable to those seen here for grip strength.³⁵

A major strength of this study is that it comprises data on all three members of the parent-child trios drawn from the general population. Our children are young, when the impact of developmental influences is likely to be most apparent. The children were measured at the broadly the same age, so the impact of age on grip strength was negligible, though was slightly more evident among girls.

However, obtaining data on complete trios is challenging and we were constrained to collecting these data on families who attended clinics. The children with grip strength measurements tended to be born to older, more highly educated mothers, and they were slightly heavier at birth than those without these measurements. Additionally the fathers of the children with grip strength measurements were slightly older on average than those without. Clearly, there is scope for bias in that we have a selected population, though our data do represent the full spectrum of parental ages, birthweights and educational levels, and so we consider that our results are likely to be internally valid.

Measuring grip strength in young children is harder than in adults but the children were willing and able to cooperate at this young age, and the appropriateness of using this method for pre-school children has been shown elsewhere.³⁶ Measurement error may nonetheless have diluted the relationships between the children's grip strengths and those of their parents, but the strong relationships observed between the children's grip strength and their height does indicate that the grip strength is measured in a reasonably robust way in children of this age.

Similar correlations between mothers and children and between fathers and children can be interpreted in a number of ways. They may be due to fixed genetic variation, inherited from

both parents or they may indicate shared parental environmental influences, which may operate *in utero* or postnatally. The similarity of the correlation between the two parents to that between either parent and the child points towards shared environmental influences, but assortative mating may be part of the explanation. Disentangling the genetic and environmental influences is not possible in these data but our findings contribute to our understanding of the role of heritable and environmental factors on early muscle growth and development, which are increasingly recognised to be important for muscle function across the lifecourse.

Parent-child relationships in relation to grip strength have now been explored in detail at the extreme ends of the age distribution, and more data on such relationships in trios in the middle age range would be informative. Within the Southampton Women's Survey, as the children become older, their grip strengths will be measured at ages 6 and 8 years, enabling influences on change in grip strength to be observed across childhood. This will provide greater insights into the developmental and genetic influences on grip strength through the childhood years.

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Table 1
Comparison of those having full grip strength measurements with all other eligible Southampton Women's Survey children and their parents.

Characteristic	Without grip strength		With grip strength		P-value
	N		N		
<i>Mother</i>					
Mother's age at child's birth (y) (mean(SD))	919	30.5 (3.9)	444	31.3 (3.6)	0.0002
Mother's height (cm) (mean(SD))	914	163.2 (6.4)	442	163.8 (6.3)	0.1
Mother's pre-pregnant BMI (kg/m ²) (median(IQR))	907	24.3 (21.8-27.7)	441	24.3 (22.2-27.2)	0.7
Mother's educational attainment (n(%))	917		441		
None		25 (2.7)		4 (0.9)	
CSE		100 (10.9)		31 (7.0)	
O levels		273 (29.8)		125 (28.3)	
A levels		287 (31.3)		135 (30.6)	
HND		53 (5.8)		29 (6.6)	
Degree		179 (19.5)		117 (26.5)	0.0002
<i>Father</i>					
Father's age at child's birth (y) (mean(SD))	718	32.9 (5.6)	393	33.6 (4.6)	0.05
Father's height (cm) (mean(SD))	751	177.9 (6.9)	440	177.9 (6.8)	0.99
Father's BMI (kg/m ²) (median(IQR))	734	26.0 (23.9-28.4)	433	26.0 (24.0-28.1)	0.8
<i>Child</i>					
Sex (n(%))	918		444		
Male		490 (53.4)		215 (48.4)	
Female		428 (46.6)		229 (51.6)	0.09
Birthweight (kg) (mean(SD))	905	3.44 (0.54)	442	3.50 (0.51)	0.03
Gestational age (weeks) (mean(SD))	919	39.7 (1.9)	444	39.9 (1.6)	0.2
Child's height at 4 year visit (cm) (mean(SD))	111	103.7 (4.2)	443	104.1 (3.9)	0.3
Child's weight at 4 year visit (kg) (median(IQR))	113	16.5 (15.3-18.3)	443	17.1 (15.8-18.5)	0.1

Table 2
Means and standard deviations of grip strength measurements and correlation coefficients for grip strength between family members

	Mean	SD	Correlation with:	
			Mother's grip	Father's grip
Mother's grip strength (kg)	33.2	5.8		
Father's grip strength (kg)	55.3	8.6	0.17[0.07, 0.26] ^a	
Child's grip strength (kg)	8.7	1.6	0.17 [0.08, 0.27] ^a	0.15 [0.06, 0.24] ^b

^aP<0.001

^bP=0.002

Table 3
Regression analysis of child's grip strength at 4 years of age (SD scores) in relation to characteristics of the mother, father and the child: univariate relationships and final regression model.

	Beta	95% CI	P-value
<i>Univariate relationships:</i>			
Mother			
Height (cm)	0.03	[0.01, 0.04]	0.0001
Pre-pregnant weight (kg)	0.01	[0.00, 0.02]	0.02
Grip strength (SD)	0.17	[0.08, 0.27]	0.0002
Father			
Height (cm)	0.02	[0.01, 0.04]	0.002
Grip strength (SD)	0.15	[0.06, 0.24]	0.002
Child			
Height at age 4 years (cm)	0.11	[0.08, 0.13]	< 0.0001
Weight at age 4 years (kg)	0.16	[0.12, 0.20]	< 0.0001
Child's hours per day spent watching TV at age 4 years	-0.11	[-0.22, -0.01]	0.03
Child's birthweight (kg)	0.20	[0.02, 0.39]	0.03
<i>Final multiple regression model:</i>			
Child's height at age 4 years (cm)	0.10	[0.08, 0.12]	< 0.0001
Child's hours per day spent watching TV at age 4 years	-0.09	[-0.19, 0.00]	0.05
Mother's grip strength (SD)	0.10	[0.02, 0.19]	0.02
Father's grip strength (SD)	0.11	[0.02, 0.19]	0.01

Table 4
Final multiple regression analyses of child's grip strength at 4 years of age (SD scores) in relation to parental and child risk factors, by sex.

Independent variables	Beta	95% CI	P-value
Boys (N = 214)			
Mother's grip strength (SD)	0.12	[-0.02, 0.26]	0.08
Father's grip strength (SD)	0.15	[0.03, 0.27]	0.02
Child's height at age 4 years (cm)	0.1	[0.07, 0.13]	< 0.0001
Hours per day child actively on the move	0.09	[0.00, 0.17]	0.04
Girls (N = 229)			
Child's age (years)	1.84	[-0.10, 3.78]	0.06
Child's height at age 4 years (cm)	0.1	[0.07, 0.13]	< 0.0001
Mother's grip strength (SD)	0.11	[0.00, 0.22]	0.04