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Household and schooling rather than diet offset the adverse associations of height with school competence and emotional disturbance among Taiwanese girls

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Abstract

Objective: Short stature may reflect health in early life and be an enduring disability. How birth weight, gender, household, elementary schooling and diet play a role in associations between stature and overall school competence (OSC) have been assessed.

Design: The 2001–2002 Nutrition and Health Survey in Taiwan (NAHSIT) for elementary schoolchildren (*n* 2274, 52·1 % boys) was linked to birth records. It provided sociodemographic, dietary quality, body compositional and school performance (as Scale for Assessing Emotional Disturbance, SAED; OSC as an SAED subscale) data. Lower birth weight was ≤15th percentile: 2850 g for boys and 2700 g for girls, and stature as *z*-scores for Taiwanese. Multivariable linear regression was used for relationships between OSC and stature. Trends in OSC by stature and school grade were assessed.

Setting: The 2001–2002 NAHSIT for elementary schoolchildren.

Participants: Totally, 2274 schoolchildren aged 6–13 years.

Results: Compared to normal height ($-2<$ height for age *z*-score (HAZ) <2), shorter girls (HAZ ≤ -2) had a lower OSC (8·87 *v.* 10·5, $P<0{\cdot}05$) and taller girls (HAZ ≥ 2) had a better OSC (12·3 *v.* 10·5, $P<0{\cdot}001$). Maternal education and household income each contributed more than 5 % of OSC variance. OSC and HAZ among girls were positively associated and emotional disturbance negatively associated. Shortness-associated lower OSC underwent remediation with advancing school grade. Stature and OSC were not evidently related in boys.

Conclusions: Shorter stature can compromise OSC among school girls. The major determinants in shorter girls are less household income and limited parental education.

Keywords
Birth weight
Dietary pattern
Parental education
School grade
Gender

Height is a perennial concern among individuals, their parents, sociologists and health workers. Its determinants are generally regarded as genetic(1,2), environmental (especially through hygiene)(3,4), societal(4), economic(3), gestational (intrauterine fetal growth restriction, IUGR)(5), dietary(6,7) and consequent on episodic illness. Insofar as height outcomes are concerned, the most worrisome have been those to do with how shortness might be associated with compromised educability along with social, mental and physical functionality. Global programmes like Scaling Up Nutrition (SUN) are promoted on evidence that the first 1000 d of life from conception affect height and health relationships(8). These may offer a window for prevention and remediation of impaired development, reflected in part by linear growth and manifest as 'stunting'(9,10). In this vein, efforts are made to enable infants and children to grow faster and taller. However, whether height itself or its associated determinants are responsible for the various height-associated dysfunctions is by no means settled. That 'healthy shortness' is not only possible, but common is a reality.

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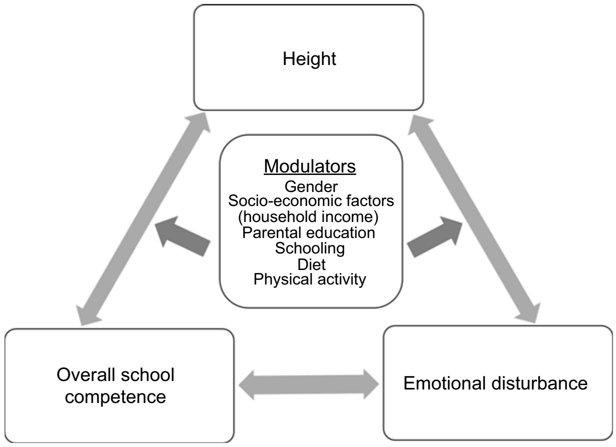

Fig. 1 Hypothetical associations and pathways for height and school performance

The present population-based and representative study of children, with documented birth weight, from elementary school in a relatively socio-economically advanced country, Taiwan, seeks to understand the associations between growth and 'overall school competence (OSC)' in children of dominantly Chinese, but also indigenous, ancestry. We hypothesised that shorter children may be more vulnerable to socio-environmental risk factors, including household income and parental education, insofar as school performance is concerned (Fig. 1).

Materials and methods

Study design and participants

The present study was cross-sectional in design. Participants were schoolchildren aged 6–13 years who enrolled in the Nutrition and Health Survey in Taiwan (NAHSIT) 2001–2002[11–13]. All 359 townships and districts were grouped into 13 strata by regional dietary pattern, urbanisation, and geographical characteristics. The probability proportional to population size method was used to select 2407 children from 104 elementary schools (8 schools from each stratum) randomly. Questionnaires, by face-to-face household interview, and physical examinations allowed children's demographic and anthropometric information to be obtained, along with food intake and physical activity. NAHSIT was linked to birth registration for birth weight. After taking account of missing data, 2274 children (52·1 % boys) were eligible for analysis.

Height

We calculated gender- and age-specific z-scores for height (HAZ) in this population representative sample of Taiwanese schoolchildren to identify height status. HAZ ≤ -2 was classified as 'stunted', ≥ 2 was 'tall' and between > -2 and < 2 was 'normal height'[10,14].

The Scale for Assessing Emotional Disturbance

The Chinese version used in Taiwan of the Scale for Assessing Emotional Disturbance (SAED) questionnaires was originally developed by Epstein and Cullinan[15–17]. It has a validity of 0·76 and reliability of 0·92[18]. This was the basis of our assessment of overall school performance (OSC) and emotional disturbance by the student's Class Mentor teacher, as previously described[12,13,18–20]. The SAED has seven subscales: Inability to Learn (IL), Relationship Problems (RP), Inappropriate Behaviour (IB), Unhappiness or Depression (UD), Physical Symptoms or Fears (PF), Social Maladjustment (SM) and OSC. The standardised SAED scores had a mean of 10 and a SD of 3. Children with higher SAED subscales are considered to have more serious emotional and behavioural disorders, whereas a higher OSC indicates a favourable school performance[15,16,18–20].

Covariates

Covariates were derived by questionnaire or physical measurement. Potential covariates for the associations between height and either OSC or other SAED subscales included gender, school grade, living region, maternal education (primary and below, junior high school, senior high school, university and above), household income (0–30 000, 30 000–50 000, 50 000–80 000, ≥80 000 NTD/month), dietary quality (The Youth Healthy Eating Index-Taiwan, YHEI-TW), lower birth weight (≤ 15th percentile, 2850 g for boys and 2700 g for girls), BMI (classified as underweight, normal, overweight or obese for Taiwanese children)[13,21] and physical activity (0, 0–30, 30–60, ≥60 min/d). We adjusted for all thirteen regions, since there are known differences in many variables, including the food and health systems, school ecology, ethnicity and natural environment from coastal to mountainous[22]. Ethnicity in Taiwan is highly correlated with region and, therefore, by inclusion of region as a covariate, we largely take account of it. YHEI-TW (0–90) was used to assess dietary quality[12,23,24]. To avoid multicollinearity, paternal education has not been included because it was highly correlated with both maternal education and household income.

Statistical analysis

The distributions of basic characteristics among schoolchildren according to HAZ (≤ -2, $-2 <$ HAZ < 2 and ≥ 2) were assessed by chi-square and ANOVA tests. On the basis of previous studies in this population[12,13,22], gender-specific multivariable linear regression was used to evaluate the relationships between OSC, emotional disturbance and height adjusted for covariates. Linear trends in OSC by height and school grade were assessed by multivariable linear regression. Statistical analyses were performed using SAS for Windows version 9.4 and SUDAAN 11.0.3. To obtain unbiased weighted estimates of standard errors, SUDAAN was used to adjust for the design effects of cluster sampling as well as to ensure representativeness[25].

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Results

Table 1 shows basic characteristics of schoolchildren based on HAZ categories. There were 2274 schoolchildren who were representative of 1 806 919 in total in Taiwan at that time. Stunting was evident in 1·98 % (representing 35 772) of the children in this study (57·4 % boys). Children living in mountainous areas, principally indigenous, had a higher stunting rate (3·97 %) than any other region ($P = 0{\cdot}001$). Stunted children more often had parents with less education (55·1 % of mothers had a primary education level or less, as did 30·8 % of fathers) and came from households with lower incomes ($P = 0{\cdot}006$). Some 16·2 % of stunted children had lower birth weights ($P < 0{\cdot}001$) and 34·4 % were underweight ($P < 0{\cdot}001$). Compared with taller children (21·7 %), only 3·87 % of stunted children exercised more than 1 h a day ($P = 0{\cdot}013$). The YHEI-TW scores were not significantly different among HAZ groups. In terms of dietary intakes, stunted children had lower carbohydrate and higher fat nutrient densities than did taller children (129 *v.* 147, and 37·6 *v.* 29·9 g/1000 kcal). Among HAZ groups, shorter children had the highest LDL-cholesterol (116 mmol/l) and the taller had the highest serum uric acid (6·89 mmol/l).

Shorter girls ($HAZ \leq -2$) had lower OSC scores compared with those of normal height ($-2 < HAZ < 2$) (8·87 *v.* 10·5, $P < 0{\cdot}05$), and taller girls ($HAZ \geq 2$) had better scores (12·3, *v.* 10·5, $P < 0{\cdot}001$). Except for SM, all SAED subscales were lower among taller girls (IL, 8·30, $P < 0{\cdot}001$; RP, 8·48, $P < 0{\cdot}001$; IB, 8·47, $P < 0{\cdot}001$; UD, 8·83, $P < 0{\cdot}01$; and PF, 8·76, $P < 0{\cdot}001$) compared to normal height (Table 2). There were no evident differences in any SAED score for boys among HAZ groups.

Table 3 shows the multivariable linear regression for OSC and HAZ. There was a significant positive association between OSC and children's HAZ, especially in girls ($P_{\text{for trend}} < 0{\cdot}001$). Among shorter girls, after adjustment for school grade and region (Model 1), HAZ was negatively associated with OSC ($\beta = -1{\cdot}688$, $P < 0{\cdot}01$), but the significance was lost when adjusted for mother's education (Model 2, $\beta = -0{\cdot}60$, $P > 0{\cdot}05$). Further adjustments with other covariates did not alter this finding. However, taller girls had significantly higher OSC scores than normal height girls regardless of adjustments. There were no apparent associations for boys (data not shown).

The multivariable linear regression for the contribution of HAZ to SAED components in girls are shown in Table 4. There was no justification for similar analysis for boys given the negativity of findings in Table 2. Taller girls had lower IL ($\beta = -1{\cdot}03$, $P < 0{\cdot}05$), RP ($\beta = -0{\cdot}96$, $P < 0{\cdot}001$), IB ($\beta = -0{\cdot}80$, $P < 0{\cdot}01$), UD ($\beta = -0{\cdot}83$, $P < 0{\cdot}05$) and total SAED ($\beta = -1{\cdot}07$, $P < 0{\cdot}01$) scores. Compared with normal height girls, taller girls had a lower PF in Model 2 (adjusted for grade, region and mother's education, $\beta = -0{\cdot}79$, $P < 0{\cdot}05$), but the significance was lost in Model 3 (household income was adjusted).

Figure 2 shows the correlations between OSC and HAZ by school grade and gender, adjusted for potential covariates, though there was no significance interaction between gender and grade ($P = 0{\cdot}604$) on OSC. However, the basic rationale for grade stratification is to explore the persistence or otherwise of the association between stature and school performance with educational advancement. For girls in grades 3 and 4, there was a positive association between OSC and HAZ ($P_{\text{for trend}} = 0{\cdot}003$). However, this relationship of shortness with OSC undergoes progressive remediation with the advance to school grades 5 and 6. This was not evident for boys.

Discussion

Childhood height and overall school competence

At a time when international nutrition policy and action is focused on stunting, there remains controversy about whether height itself is a health problem or a composite indicator of associated health risks. This is particularly the case for stunting as a consequence of malnutrition, infection or social deprivation, any one of which might be the fundamental or actual problem. The outcomes of so-called stunting of greatest concern are those to do with cognitive and mental health, reflected in successful learning[26].

In this Taiwanese study, shorter children, notably girls, are more vulnerable to less good school performance compared with their normal height and taller counterparts. Compared with normal height children, short children's IQ scores have been found normal, although scholastic attainment, especially reading, may be less good[27].

Taller Taiwanese elementary school girls have an OSC and emotional advantage, not evident in boys. This is consistent with studies which have found that children with a greater HAZ have better mathematics scores[28–30].

Adjustments for various confounders show that parental and household factors play an important role in the height–OSC associations. Voss et al have shown that short children with a low socio-economic status are underachievers[27].

Height, overall school competence, grade and gender

Taller girls exhibit less social and emotional problems than their normal height counterparts. Aside from gender, these findings are consistent with other studies of growth and development. In this and other studies, interpretative problems are encountered with confounders and directionality of cause and effect[31–34]. Thus, is it that growth and development in girls more than boys is more likely to affect OSC, both favourably and unfavourably? Or is it that OSC can affect growth and development in accordance with gender? Insofar as poorer OSC in girls is concerned, its association with height is most evident in school grades 3–4 but is not

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Table 1 Basic characteristics of schoolchildren by HAZ categories (*n* 2274)

	HAZ								
	Total		≤−2		−2 < HAZ < 2		≥ 2		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*P* value
Number (%*)									
n	2274		61		2167		46		
%	100		1·98		95·9		2·16		
Gender									0·418
Boys	52·1		57·4		52·1		43·5		
Girls	47·9		42·6		47·9		56·5		
Age (years)	8·48	0·02	8·26	0·33	8·49	0·02	8·59	0·22	0·439
Region (%)									0·001
Hakka	9·62		10·7		9·77		2·09		
Mountain areas	0·76		3·97		0·71		0·28		
Eastern	2·30		1·63		2·33		1·55		
Penghu	0·35		0·83		0·35		0·25		
Northern 1	14·7		10·3		14·7		21·3		
Northern 2	13·8		16·3		13·8		11·9		
Northern 3	8·16		15·1		7·97		9·97		
Central 1	9·60		11·0		9·40		17·1		
Central 2	10·1		10·3		10·2		7·59		
Central 3	4·50		3·36		4·45		7·58		
Southern 1	7·60		2·19		7·75		5·75		
Southern 2	6·57		2·01		6·58		9·98		
Southern 3	11·9		12·3		12·1		4·65		
Father's ethnicity (%)									0·505
Fukienese	75·7		69·0		75·8		75·5		
Hakka	13·2		13·3		13·2		9·40		
Mainlander	9·18		11·0		9·03		14·0		
Indigenes	2·00		6·83		1·92		1·06		
Mother's education (%)					0·050				
Primary and below	7·60		10·5		7·41		13·5		
Junior high school	22·3		44·6		21·9		24·3		
Senior high school	55·3		33·0		50·7		45·0		
University and above	19·7		11·9		19·9		17·2		
Father's education (%)									0·773
Primary and below	6·16		6·48		6·14		6·72		
Junior high school	23·9		24·3		23·7		29·8		
Senior high school	41·0		50·6		41·0		32·4		
University and above	29·0		18·6		29·2		31·1		
Household income (%)									0·006
0–30 000 NTD/month	11·4		20·7		11·4		3·39		
30 000–50 000	27·4		38·8		26·5		50·5		
50 000–80 000	36·4		20·5		37·1		20·7		
≥80 000	24·9		20·1		24·9		25·5		
Lower birth weight (%)					<0·001				
Yes	4·96		16·2		4·84		0·00		
No	95·0		83·9		95·2		100		
BMI (%)									<0·001
Underweight	13·2		34·4		13·0		0·00		
Normal weight	57·0		65·4		57·2		39·7		
Overweight or obese	29·9		0·27		29·8		60·3		
Physical activity (%)									0·013
0 min/d	6·11		7·86		5·99		10·1		
<30 min/d	58·8		59·2		58·8		56·8		
<60 min/d	23·6		29·1		23·8		11·4		
≥60 min/d	11·5		3·87		11·4		21·7		
YHEI-TW									
Boys	46·8	0·37	45·8	1·49	46·9	0·37	46·7	2·59	0·729
Girls	46·6	0·31	45·6	1·55	46·5	0·31	48·4	1·70	0·254
Daily energy intake and nutrient densities									
Energy (kcal/d)	2003	34·0	1851	131	2005	34·6	2069	29·0	0·256
Carbohydrate (g/1000 kcal)†	134	0·95	129	3·81	134	0·96	147	4·14	<0·001
Fat (g/1000 kcal)†	34·3	0·36	37·6	1·94	34·3	0·37	29·9	1·86	0·004
Protein (g/1000 kcal)	39·4	0·37	37·9	1·70	39·5	0·37	36·5	2·11	0·573
Vitamin A (mg/1000 kcal)	2754	111	3030	852	2722	105	3933	1369	0·546
Vitamin D (μg/1000 kcal)	2·06	0·08	1·87	0·33	2·08	0·08	1·18	0·21	0·103
Ca (mg/1000 kcal)	267	5·05	232	22·7	268	5·18	246	20·5	0·694

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Table 1 *Continued*

	HAZ								
	Total		≤–2		–2 < HAZ < 2		≥ 2		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*P* value
Food intakes (servings/d)									
Vegetables†	1·61	0·06	1·32	0·23	1·60	0·06	2·30	0·38	0·112
Fruits	0·87	0·05	0·62	0·17	0·88	0·05	0·79	0·19	0·337
Eggs, beans, fish and meats	3·25	0·07	3·24	0·21	3·26	0·07	3·12	0·22	0·824
Fish	0·90	0·04	0·96	0·24	0·90	0·04	0·82	0·13	0·790
Eggs	0·62	0·01	0·68	0·10	0·62	0·02	0·66	0·06	0·673
Beans	1·19	0·03	1·19	0·15	1·19	0·03	1·00	0·12	0·286
Grains	2·97	0·04	2·83	0·15	2·97	0·04	3·05	0·14	0·517
Milk and dairy products	0·86	0·03	0·82	0·18	0·86	0·03	0·91	0·12	0·917
Plasma metabolic analytes									
Fasting glucose (mmol/l)	96·1	0·35	94·4	1·69	96·1	0·36	97·2	1·49	0·189
Total cholesterol (mmol/l)	177	1·13	183	6·76	177	1·11	169	6·51	0·103
TAG (mmol/l)	72·5	1·09	71·6	4·43	72·5	1·10	72·9	5·04	0·868
LDL-cholesterol (mmol/l)†	108	1·34	116	6·13	108	1·33	98·2	5·90	0·041
HDL-cholesterol (mmol/l)	59·2	0·41	62·5	2·74	59·2	0·43	56·5	2·66	0·094
Uric acid (mmol/l)†	5·88	0·06	5·99	0·24	5·86	0·06	6·89	0·25	0·019

HAZ, height for age *z*-score; YHEI-TW, The Youth Healthy Eating Index-Taiwan.
Values expressed as means ± SE or numbers (percentage).
Test of the distributions across height *z*-score groups by chi-square tests and ANOVA.
*Percentages are weighted by SUDAAN to reflect their representativeness in the population.
†*P* < 0·05 for difference between shorter and taller by *t* test where this superscript is shown.

Table 2 Scale for Assessing Emotional Disturbance (SAED) *z*-scores† by gender and HAZ groups

	HAZ					
	≤ –2		–2 < HAZ < 2		≥2	
	Mean	SD	Mean	SD	Mean	SD
Boys						
Overall school competence	8·85	0·80	9·55	0·10 ref.	8·70	0·66
Inability to learn	10·4	0·66	10·4	0·13 ref.	10·6	0·75
Relationship problems	10·7	0·75	10·3	0·12 ref.	9·50	0·49
Inappropriate behaviour	10·5	0·60	10·8	0·14 ref.	9·89	0·51
Unhappiness or depression	10·2	0·69	10·2	0·12 ref.	9·18	0·49
Physical symptoms or fears	10·4	0·47	10·1	0·13 ref.	9·79	0·86
Socially maladjusted	10·3	0·49	10·4	0·14 ref.	9·75	0·47
Girls						
Overall school competence	8·87	0·62*	10·5	0·14 ref.	12·3	0·42***
Inability to learn	9·90	0·64	9·54	0·11 ref.	8·30	0·30***
Relationship problems	9·32	0·48	9·68	0·11 ref.	8·48	0.·16***
Inappropriate behaviour	8·80	0·31	9·22	0·10 ref.	8·47	0·12***
Unhappiness or depression	9·70	0·65	9·87	0·13 ref.	8·83	0·29**
Physical symptoms or fears	9·63	0·69	9·94	0·12 ref.	8·76	0·30***
Socially maladjusted	9·59	0·35	9·57	0·09 ref.	9·36	0·23

HAZ, height for age *z*-score.
†Mean values of SAED *z*-scores among HAZ groups were significantly different from those of the normal height group (–2 < HAZ < 2, reference group): **P* < 0·05; ***P* < 0·01; ****P* < 0·001.

apparent in grades 5–6 (Fig. 2). Perhaps the height–OSC association is malleable. Since the present study found household (parental and socio-economic) and schooling determinants of the height–OSC association, they are likely to be more relevant for girls than for boys.

Elementary schoolchildren in Taiwan are automatically promoted each year regardless of school performance but often with in and out of school catch up programmes. At least every student is progressively exposed with advancing grade to a more mature educational environment, and with it, the association between shortness and school performance disappears. It remains uncertain how much getting older in its own right or schooling accounts for the changing association.

In the present study, the gender difference in susceptibility where no significant relationship is seen in boys by comparison with girls is striking. It is possible that this represents sociocultural differences in upbringing and schooling, in timing of menarche or puberty, or in some other biological difference. However, most children were

Table 3 Multiple linear regressions for overall school competence (OSC) and HAZ by gender

	Regression coefficients (β) for HAZ						
OSC	≤−2	95 % CI	−2 < HAZ < 2	≥ 2	95 % CI	Model *P* value	$P_{for\ trend}$
Boys (*n* 1219)	2·18 %*		96·0 %*	1·81 %*			
Crude model	−0·71	−2·36, 0·94	0·00 (Ref.)	−0·85	−2·19, 0·49	0·363	0·967
Model 1†	−0·68	−2·36, 1·01	0·00	−1·07	−2·38, 0·24	0·239	0·867
Model 2‡	−1·16	−2·83, 0·51	0·00	−0·64	−1·94, 0·67	0·233	0·671
Model 3§	−1·54	−3·30, 0·22	0·00	−0·93	−2·22, 0·37	0·095	0·727
Model 4‖	−1·50	−3·30, 0·30	0·00	−0·89	−2·17, 0·40	0·110	0·726
Model 5¶	−1·64	−3·36, 0·08	0·00	−0·61	−1·95, 0·74	0·120	0·490
Girls (*n* 1055)	1·76 %*		95·7 %*	2·55 %*			
Crude model	−1·64	−2·89, −0·38	0·00	1·82	1·00, 2·64	<0·001	<0·001
Model 1	−1·69	−2·92, −0·46	0·00	1·73	0·81, 2·66	<0·001	<0·001
Model 2	−0·60	−1·98, 0·78	0·00	1·72	1·06, 2·38	<0·001	<0·001
Model 3	−0·62	−2·04, 0·80	0·00	1·60	0·78, 2·43	<0·001	<0·001
Model 4	−0·64	−1·90, 0·61	0·00	1·75	0·98, 2·53	<0·001	<0·001
Model 5	−0·72	−1·94, 0·50	0·00	1·80	1·03, 2·58	<0·001	<0·001

HAZ, height for age *z*-score; YHEI-TW, The Youth Healthy Eating Index-Taiwan.
*Percentages are weighted by SUDAAN to reflect their representativeness in the population.
†Model 1: adjusted for grade and region.
‡Model 2: Model 1 + mother's education.
§Model 3: Model 2 + household income.
‖Model 4: Model 3 + YHEI-TW, and physical activity.
¶Model 5: Model 4 + low birth weight (yes or no), and BMI (underweight, normal, and overweight or obese).

pre-pubertal and there were no differences in mean age by height status. Puberty was not ascertained in our study and is a limitation.

Intra-uterine development

In the present population, the shorter children were more likely to have had lower birth weights (by threefold) and to be currently underweight (by 2·5-fold); their taller counterparts had neither problem. We have previously found that Taiwanese elementary school girls who had lower birth weights are predisposed to poorer OSC and emotional problems, but that if they have a nutritious varied diet, this risk is diminished[12]. In this study, we were unable to detect a contribution by current dietary quality to OSC or emotional disturbance by height after consideration of lower birth weight. These findings imply that intra-uterine development is a more important factor, amenable to diet, than is the current height insofar as OSC and emotional disturbance are concerned.

Personal behaviour, diet, infection, height and overall school competence

Recurrent infection is one of the most accepted contributors to the perceived height–cognitive performance linkage, but even deworming in children highly affected by helminthiasis has not supported convincingly this association[35]. In this study, we do not have information about exposure to recurrent infection. In Taiwan, schoolchildren are routinely provided with vaccination and deworming programmes, and school hygiene is emphasised so that helminthiasis is unlikely to contribute to height and OSC. However, remoteness and being indigenous in mountainous areas with limited health care facilities may increase susceptibility to this problem; these children are shorter and could fall into this category.

Children who exercise ≥ 60 min/d are less likely to be shorter. However, both might be socio-economically dependent and coincidentally related. Although no food or food pattern differences were evident in relation to height, greater carbohydrate consumption was associated with less shortness. It is noteworthy that the index of dietary quality used, namely YHEI-TW, is not different among girls or boys according to stature, but the taller children consume more energy, as might be expected. The prevailing conversation about shortness and tallness has to do with food intake. We wanted to thoroughly test the proposition that any association of stature with school performance might actually have been attributable to a dietary characteristic such as pattern, particular food or foods, nutrient or nutrient density. As it transpired, only macronutrient densities (carbohydrate and fat) were associated as shown in Table 1.

Parental and household factors as modulators in height and overall school competence

We have found that socio-economic factors, reflected in household income, together with schooling itself, offset the effects of height on school performance and emotional disturbance. This may not be surprising given that household functionality will ordinarily be a composite of the activities, educational achievements and economics of its several members. It is for this reason that we have described the present study as one of both household and schooling in their potential consequences for how height might be achieved and relevant.

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Table 4 Multiple linear regressions for SAED and HAZ in girls

SAED components	Regression coefficients (β) for HAZ					Model P value	$P_{for\ trend}$
	≤−2	95 % CI	−2 < HAZ < 2	≥ 2	95 % CI		
Inability to learn							
Crude model	0·36	−0·96, 1·68	0·00 (Ref.)	−1·24	−1·92, −0·56	<0·001	0·006
Model 1*	0·31	−1·09, 1·72	0·00	−1·16	−1·83, −0·49	0·002	0·015
Model 2	−0·43	−2·34, 1·47	0·00	−1·11	−1·81, −0·41	0·009	0·104
Model 3	−0·24	−2·07, 1·59	0·00	−0·89	−1·63, −0·15	0·062	0·176
Model 4	−0·30	−2·01, 1·40	0·00	−0·98	−1·73, −0·23	0·037	0·128
Model 5	−0·17	−1·84, 1·51	0·00	−1·03	−1·77, −0·29	0·025	0·077
Relationship problems							
Crude model	−0·36	−1·34, 0·62	0·00	−1·20	−1·59, −0·81	<0·001	0·031
Model 1	−0·45	−1·68, 0·78	0·00	−1·11	−1·58, −0·63	<0·001	0·151
Model 2†	−0·90	−2·61, 0·81	0·00	−1·07	−1·50, −0·65	<0·001	0·247
Model 3	−0·82	−2·45, 0·80	0·00	−0·93	−1·41, −0·46	<0·001	0·391
Model 4	−0·90	−2·50, 0·70	0·00	-0·90	−1·42, −0·38	0·002	0·479
Model 5	−0·72	−2·36, 0·93	0·00	−0·96	−1·47, −0·44	0·001	0·322
Inappropriate behavior							
Crude model	−0·42	−1·10, 0·26	0·00	−0·75	−1·08, −0·42	<0·001	0·138
Model 1	−0·42	−1·22, 0·38	0·00	−0·76	−1·18, −0·34	0·002	0·225
Model 2	−0·67	−1·83, 0·48	0·00	−0·74	−1·16, −0·33	0·002	0·297
Model 3‡	−0·57	−1·62, 0·48	0·00	−0·68	−1·14, −0·23	0·012	0·327
Model 4	−0·56	−1·55, 0·43	0·00	−0·76	−1·25, −0·27	0·008	0·241
Model 5	−0·47	−1·46, 0·52	0·00	−0·80	−1·31, −0·29	0·008	0·174
Unhappiness or depression							
Crude model	−0·17	−1·51, 1·18	0·00	−1·04	−1·68, −0·41	0·007	0·128
Model 1	−0·23	−1·71, 1·25	0·00	−0·90	−1·64, −0·15	0·054	0·293
Model 2	−0·65	−2·82, 1·51	0·00	−0·75	−1·46, −0·04	0·088	0·545
Model 3	−0·59	−2·67, 1·50	0·00	−0·64	−1·43, 0·14	0·222	0·657
Model 4§	−0·64	−2·55, 1·26	0·00	−0·79	−1·45, −0·13	0·048	0·507
Model 5	−0·55	−2·45, 1·36	0·00	−0·83	−1·47, −0·19	0·032	0·391
Physical symptoms or fears							
Crude model	−0·30	−1·71, 1·11	0·00	−1·17	−1·82, −0·53	0·002	0·118
Model 1	−0·48	−1·98, 1·01	0·00	−1·05	−1·71, −0·39	0·009	0·281
Model 2	−0·89	−2·56, 0·78	0·00	−0·79	−1·44, −0·14	0·044	0·549
Model 3	−0·82	−2·40, 0·76	0·00	−0·61	−1·36, 0·14	0·197	0·788
Model 4	−0·80	−2·29, 0·70	0·00	−0·76	−1·51, −0·01	0·084	0·595
Model 5‖	−0·86	−2·40, 0·69	0·00	−0·74	−1·48, 0·00	0·085	0·649
Socially maladjusted							
Crude model	0·02	−0·71, 0·75	0·00	−0·21	−0·72, 0·30	0·697	0·493
Model 1	−0·03	−0·86, 0·80	0·00	−0·21	−0·82, 0·39	0·786	0·626
Model 2	0·13	−1·09, 1·35	0·00	−0·14	−0·81, 0·53	0·880	0·623
Model 3	0·26	−0·81, 1·34	0·00	−0·07	−0·90, 0·77	0·855	0·644
Model 4	0·30	−0·76, 1·36	0·00	−0·12	−0·96, 0·73	0·795	0·553
Model 5	0·37	−0·63, 1·37	0·00	−0·15	−1·00, 0·69	0·668	0·444
SAED total							
Crude model	−0·12	−1·32, 1·09	0·00	−1·29	−1·85, −0·73	<0·001	0·021
Model 1	−0·19	−1·58, 1·20	0·00	−1·20	−1·81, −0·60	<0·001	0·077
Model 2	−0·76	−2·73, 1·20	0·00	−1·10	−1·67, −0·53	<0·001	0·223
Model 3	−0·62	−2·46, 1·23	0·00	−0·92	−1·57, −0·28	0·019	0·335
Model 4	−0·66	−2·37, 1·06	0·00	−1·02	−1·66, −0·39	0·007	0·257
Model 5	−0·53	−2·25, 1·19	0·00	−1·07	−1·71, −0·44	0·005	0·178

HAZ, height for age z-score; SAED, Scale for Assessing Emotional Disturbance; YHEI-TW, The Youth Healthy Eating Index-Taiwan.
*Model 1: adjusted for grade and region.
†Model 2: Model 1 + mother's education.
‡Model 3: Model 2 + household income.
§Model 4: Model 3 + YHEI-TW, and physical activity.
‖Model 5: Model 4 + low birth weight (yes or no), and BMI (underweight, normal, and overweight or obese).

Though father's education explains more variance (9·7 %) in OSC than does that of mother's (7·8 %), we chose to model maternal education in preference for two reasons. Firstly, there is a recognised relatively greater closeness of mothers to children's schooling and daily activities in Taiwanese society[36]. Secondly, paternal education is highly correlated with household income, another important covariate, which accounts for 5·4 % of the variance (additional file 1). Sensitivity analysis shows that the replacement of maternal with paternal education in the models for height and OSC or emotional disturbance makes little difference to the findings (data not shown).

We consider that maternal education is a construct which goes well beyond the simple stratification of years achieved and represents broad sociocultural relevance to child development. Likewise, other variables represent domains

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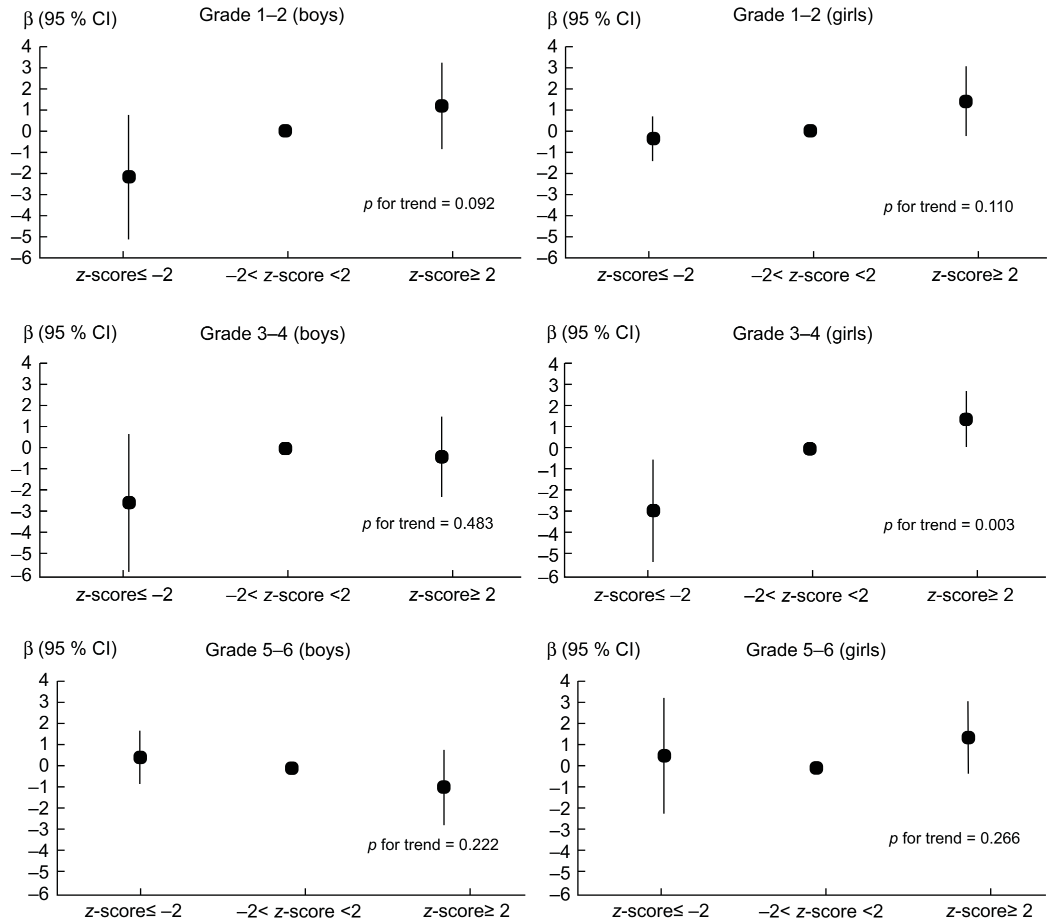

Fig. 2 Multiple linear regressions[1] for overall school competence and the height *z*-score by grade and gender. [1]Model adjusted for gender, region, mother's education, household income, YHEI-TW, physical activity, low birth weight and BMI. YHEI-TW, The Youth Healthy Eating Index-Taiwan

beyond the simple measures available by questionnaire and, therefore, residual confounding which is unavoidable.

Being indigenous

Those children who lived in mountainous Taiwan are principally indigenous. Relatively more of them are shorter than their non-indigenous counterparts. In addition, indigenous children have less good dietary quality and less favourable school performance. They will be represented among those shorter girls who exhibited less good OSC and this could be associated with their diet. However, after restricted analysis for indigenes children, diet did not account for the relationships between height and school performance any more than in Taiwanese children as a whole (additional file 2). The indigenous children can be expected to overcome any height-related disadvantage as they progress to higher school grades. Moreover, since indigenous adult Taiwanese whose diets are more diverse and nutritious overcome their survival disadvantage[37], nutritionally deprived indigenous children can expect longer-term benefit from attention to their less good dietary quality notwithstanding their shortness.

Schooling as a modulator of height-associated overall school competence

In early life, narrow time frames of a few months or of 1 or 2 years make a significant difference in biological, social and behavioural development. In our study, advancing from the lowest to the highest elementary school grades is associated with a disappearance of this linkage. This suggests that age or education/schooling may overcome the OSC disadvantage of relative shortness. It is likely that, as children grow older and are more educated, other factors to do with height and performance in general might become evident.

Strengths and weaknesses

Strengths of this study are that it is nationally representative and has linked child nutrition and health information to birth records.

It might be argued that it would be preferable to use the more internationally recognised WHO criteria for stunting in a study of shortness in Taiwan[38]. However, neither low birth weight (<2500 g) nor stunting (HAZ ≤ -2 by WHO reference) are common in Taiwan. Only 1·29 %, rather than

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the theoretical 2·3 % of children in this study, were stunted by WHO criteria. The question is whether, in a Taiwanese sociocultural setting, height is of consequence for school performance. For this reason, we have used local anthropometric reference criteria and a representative population. Moreover, an exploration of the relationship between child height and OSC using WHO reference standards revealed no detectable linkage, whereas it was evident using Taiwanese criteria (data not shown). Of particular relevance, the association in Taiwan was found to be dependent especially on maternal literacy, household income and schooling. These differences between the WHO and Taiwanese reference point analyses and the dependencies of the Taiwanese association have provided a measure of confidence that the potential adverse effects or benefits of achieved height are amenable to prevention or even optimisation.

Another limitation is that the study was cross-sectional. This means that the associations found with height may not have causal relevance. We have used grade to categorise children's progression with schooling and its relationship with height. The conclusion we reach about the loss of association of height and OSC by more senior grades may actually be a relationship with age, but this is methodologically not possible to separate in our study setting. An alternative interpretation of our findings might be that it is stage of maturity rather than school grade which overcomes any disadvantage of height for SAED. The data used in this study are not contemporary but address associations to do with biological principles about height. It must be acknowledged, however, that the socio-economic context of 2000–2001 may have evolved to alter the findings in this report.

We consider that maternal education is a construct which goes well beyond the simple stratification of years achieved and represents broad sociocultural relevance to child development. Likewise, other variables represent domains beyond the simple measures available by questionnaire and, therefore, residual confounding which is unavoidable.

Policy implications of childhood height

The present study has found that, where malnutrition is uncommon, the contribution of shortness to school performance has more to do with parental education and financial security than height itself. Moreover, schooling may enable the resolution of an adverse association. This understanding may be of greater importance to girls than boys. It follows that the simple provision of nutrient supplements is unlikely to be of benefit for children on account of a linkage between shortness and learning.

Conclusions

Shortness can compromise OSC among Taiwanese elementary schoolchildren, particularly girls, but this undergoes progressive remediation with advancing school grade. The major determinants of impaired OSC in short girls are household income and maternal education which, if avoided, offer preventive strategies for avoidance of short stature-related OSC impairment. In all cases, taller girls are OSC-advantaged over their shorter peers.

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Supplementary material

For supplementary material accompanying this paper, visit https://doi.org/10.1017/S136898002100121X

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