Household Wealth and Neurocognitive Development Disparities among School-aged Children in Nepal

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Abstract

Background: Wealth disparities in child developmental outcomes are well documented in developed countries. We sought to (1) describe the extent of wealth-based neurocognitive development disparities and (2) examine potential mediating factors of disparities among a population-based cohort of children in rural Nepal.

Methods: We investigated household wealth-based differences in intellectual, executive and motor function of $n = 1692$ children aged between 7 and 9 years in Nepal. Using linear mixed models, wealth-based differences were estimated before and after controlling for child and household demographic characteristics. We further examined wealth-based differences adjusted for three sets of mediators: child nutritional status, home environment, and schooling pattern.

Results: We observed a positive gradient in child neurocognitive performance by household wealth. After adjusting for child and household control factors, disparities between children in the highest and lowest wealth quintiles persisted in intellectual and motor function, but not executive function. No statistically significant wealth-based differentials in outcomes remained after accounting for nutritional status, home environment, and schooling patterns. The largest differences in neurocognitive development were associated with schooling pattern.

Conclusions: Household wealth patterns child neurocognitive development in rural Nepal, likely through its influence on nutritional status, the home environment, and schooling. In the current context, improving early and regular schooling in this setting is critical to addressing wealth-based disparities in outcomes.

Keywords: *child development, cognitive function, motor function, household wealth, health disparities, Nepal.*

Introduction

Neurocognitive development in childhood influences future school achievement[1] and lifetime earnings,[2] which are critical contributors to health over the life course. Poverty in early childhood stands out as a consistent predictor of worse developmental outcomes later in life.[2–4] Both biological and social risk factors have been hypothesised to mediate the relation between household poverty and child neurocognitive function.[1,5,6] In resource-constrained settings, nutritional deficiencies resulting in intrauterine growth restriction, stunting, iodine deficiency, and iron-deficiency anemia, and deficits in the psychosocial environment due to inadequate cognitive

stimulation, lack of preschool education, and maternal depression, have been identified as poverty-related risk factors for child development.[1,7,8] The importance of these and other risk factors for child outcomes may depend on their relative distribution in a specific population.[9] Moreover, the role of household poverty in shaping outcomes may vary based on prevailing social conditions such as the overall levels of material deprivation, parental education, ethnic discrimination, government support for child health programmes and the like.[10,11] As a case in point, modern education was made available to the general public in Nepal only after 1951, and universal elementary education is far from implemented in rural areas.[12] The relevance of household poverty in determining access to education may be substantially different in Nepal compared to high-income countries where much of the research on poverty and development has been conducted. For this reason, effects of household poverty

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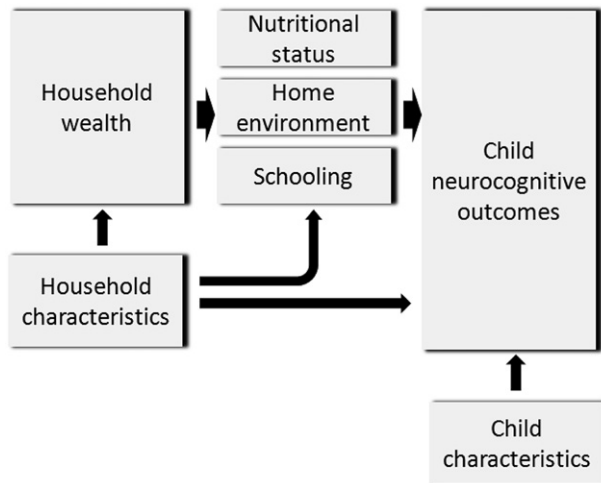E-mail: pchristi@jhsph.edu

Figure 1. Conceptual framework.

may be usefully studied in new settings to guide local interventions.

This paper examines the social determinants of child development in a population-based cohort between the ages of 7 and 9 years in rural Nepal, a country that is estimated to have among the highest proportion of children who are at risk for failing to meet their developmental potential.[8] We hypothesise that there is a wealth-based gradient in child neurocognitive performance, and that this gradient is independent of ethnicity, caste, parental education, and other potential demographic confounders of household wealth, as shown in Figure 1. We test this hypothesis, and additionally investigate the extent to which child nutritional status, home environment, and schooling mediate observed associations between household wealth and child neurocognitive development. We add to the literature on child development by focusing on middle childhood, a period when the role of socialisation and schooling may begin to manifest,[1] and when higher cognitive skills such as executive function continue to develop.[13] We further provide estimates for the prevalence of established risk and protective factors of neurocognitive development in this setting.

Methods

Study design and participants

This study took place in Sarlahi District, Nepal, a resource-constrained setting in the Terai (plains) region of the India-Nepal border. Subsistence agriculture is the backbone of the local economy. The study population included children between ages of 7 and 9 years who were previously enrolled in cluster-randomised, placebo-controlled trials testing the effects of prenatal and preschool micronutrient supplementation.[14–16] The prenatal supplementation trial was conducted from 1999–2001 and involved pregnant women who were supplemented with different combinations of micronutrients from early gestation until 3 months post partum to assess birth outcomes and infant mortality.[14] The second preschool supplementation trial was conducted from 2001–2005 among 1- to 35-month-old children to test the effects of iron-folic acid and zinc supplementation on child survival.[15,16] A subset of treatment groups in the prenatal and preschool micronutrient supplementation trials was selected for a follow-up neurocognitive assessment study. The groups who were randomised to receive iron-folic acid with and without zinc in both the prenatal and preschool periods, multiple micronutrients in the prenatal period, zinc alone in the preschool period, and placebo in both the prenatal and preschool periods were followed-up. Excluded from follow-up were 1748 children in the parent trials not enrolled in supplementation groups of interest. In all, 1927 children were eligible for the neurocognitive follow-up study, and 1822 (95%) children were assessed during home- and clinic-based visits (see Figure 2). Loss to follow-up was low, and was accounted by refusal ($n = 14$), death, migration, or inability to locate ($n = 78$), or lack of a clinic-based assessment ($n = 13$). Of these, the present study was an observational analysis of $n = 1692$ children (93% of those eligible) who had complete data for all risk factors of interest and had at least one developmental outcome assessed. Parents provided oral consent for their children, and children provided assent for being tested.

Neurocognitive outcomes

Intellectual, executive, and motor domains of neurocognitive development were assessed at a central clinic by trained psychological evaluators. Intellectual function describes general intelligence, and was measured using the Universal Non-verbal Intelligence Test (UNIT).[17] The UNIT is designed to nonverbally measure general intelligence in cross-cultural settings so that test results are unbiased on
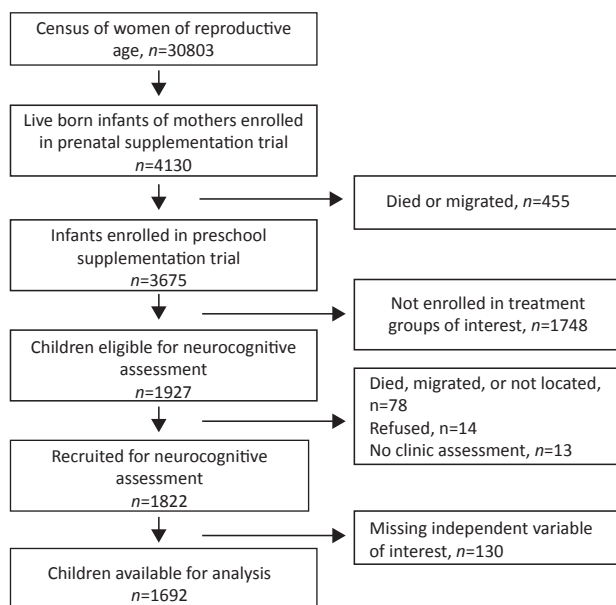
Figure 2. Diagram of study participation and determination of analytic sample.

race, sex, ethnicity, nationality or language.[17] Children were assessed on the symbolic memory, cube design, object memory, and mazes components of the UNIT; the raw score was transformed into a *t*-score based on age.[18] Executive function refers to inhibitory control and the ability to initiate action and sustain attention.[19] A go/no-go task[20] was chosen for this analysis as a test of executive function because this task did not rely on numeracy or literacy skills. We used the proportion of correct responses to 'no-go' stimuli, reported as per cents, as the outcome. Motor function refers to gross motor skills that allow for child mobility and fine motor skills that require hand–eye coordination and muscle control, such as writing or drawing. To measure motor function, we used the Movement Assessment Battery for Children (MABC).[21] The MABC measures motor impairment so that higher scores indicate worse motor function. Although at the child-level the MABC assessment does not identify the source of the impairment and may be sensitive to chance positive performance,[22] we deemed it appropriate to describe average relative performance of children by risk factors. The total raw MABC score was standardised against a reference sample per its manual. Details regarding outcome assessment procedures have been published previously.[18]

Household wealth

A household wealth index was constructed from multiple indicators of household asset ownership collected by parent interview during the follow-up study. Principal components analysis was used to create a weighted combination of the indicators in a way that maximised the amount of information in the first principal component. Quintiles of the first principal component (standardised to have mean = 0, SD = 1) were used as the household wealth index.[23] This method is widely used in developing country settings,[23] and previous work has shown that household asset ownership is a valid measure of household wealth comparable to household expenditure in Nepal.[24] Asset indicators included house wall and roof materials (cement vs. other); the ratio of number of rooms in the household to household size; household servant; household latrine; >1 hectare of farmland owned; possession of a mobile phone, landline phone, bullock cart, bicycle, radio, television, watch, motorcycle and/or any cattle. The first principal component explained 22% of the variation contained in the asset indicators, and the correlation between indicators and the first principal component ranged from $r = 0.17$ to $r = 0.68$.

Mediating factors

Three sets of factors were hypothesised to partially mediate the relation between household wealth and outcomes: child nutritional status, home environment, and child schooling history. These factors were selected to represent parental investments in their children that are facilitated by wealth and that have been found to positively relate to child development in other settings.[25] Moreover, these were each time-varying, modifiable factors that were more likely to be affected by household wealth than to be an underlying cause of household wealth. Taken together, we felt there was sufficient justification to consider these factors as components of the causal pathway linking household wealth to child development.

Nutritional status was measured by height-for-age and body mass index Z-scores (HAZ and BMIZ, respectively) based on the international reference standard,[26] and anemia status (blood hemoglobin level <11.5 g/dL measured by fingerstick with B-Hemoglobin Analyzer, HemoCue, Lake Forest, CA, USA). HAZ reflects long-term dietary intake, while

BMIZ is an indicator of recent dietary intake. Anemia was also considered a mediator because it is largely due to iron deficiency in this area and may reflect quality of diet. Height, weight, and anemia data were collected by trained field staff at the time of child neurocognitive assessment.

The home environment was assessed using an adapted version of the Middle Childhood Home Observation for the Measurement of the Environment (HOME) Inventory.[27] Though not developed or validated in this setting, we selected this tool because it possessed content validity to serve our purpose of assessing the quality of the proximal family and household environment as it related to the index child. It is used to measure parenting behaviors, family interactions, and the physical environment relevant to child development in a variety of cultural settings throughout the world.[28] In the analysis, we used the sum of eight Middle Childhood HOME component scales: parental responsivity, encouragement of maturity, emotional climate, learning materials and opportunities, enrichment, family companionship, family integration, and physical environment.[27] References to parent-supervised outings were adapted to be culturally appropriate.

Parents provided school enrolment status of children for each grade. We classified schooling history as five mutually exclusive categories: (1) no school attendance; (2) nursery, lower kindergarten or upper kindergarten attendance only ('early schooling only'); (3) first grade only; (4) school attendance post-first grade with no prior schooling ('late schooling only'); and (5) school attendance initiated before and continuing after first grade ('regular schooling').

Control variables

Potential control variables were determined through the literature. In contrast to mediators of interest, these factors were largely fixed, exogenous, demographic characteristics of children or households expected to influence outcomes or household wealth, and not to be affected by household wealth at the time of follow-up. Child characteristics included age at assessment, gender, and birth order. Prenatal iron + folic acid supplementation in the parent trials was associated with survival at age 7[29] and neurocognitive outcomes.[18] An indicator for enrolment in this treatment group was created. Household characteristics included social background and paren-

tal factors. Household ethnicity was classified as either Pahadi (originating from the hills) or Madheshi (originating from the plains). Three categories of caste in order of least to most privileged were grouped as (1) non-Hindu (not within official caste system; Muslim, Christian or Buddhist) or Shudra (worker or servant caste); (2) Vaishya (merchant caste); and (3) Brahmin or Chhetri (priestly and warrior caste, respectively). We considered parental educational background a potential confounder because it is more plausible that parental education causally precedes household wealth acquisition rather than wealth acquired in adulthood determines parental educational background. We used paternal and maternal literacy (literate vs. not) to describe the educational background of each parent because of the high correlation between years of education and literacy ($r = 0.89$ and $r = 0.91$ for fathers and mothers, respectively). Maternal age (years) and her reasoning capacity measured by the Raven's Coloured Progressive Matrices[30] were used in the analysis as measures of care giving capacity and inherited intellectual ability.

Statistical analysis

The distribution of all child and household characteristics and potential mediating variables was described by quintiles of household wealth. Linear mixed models with random intercepts for the 30 Village Development Committees (sub-district administrative units akin to villages) of the catchment area were used to model each outcome to account for the residential clustering of children.[31] The analysis assessed whether associations in our sample were consistent with those shown in Figure 1. We estimated unadjusted differences in outcomes associated with household wealth and each mediating variable. We then proceeded to estimate five adjusted models for each outcome. In the first adjusted model, we regressed the outcome on household wealth and control variables. Each set of potential mediating variables (i.e. nutritional status, home environment, and schooling status) was next added separately to the control-adjusted model. The low correlation among the three measures of nutritional status (range: −0.10 to 0.16) allowed us to include all three together in models. We also report the per cent of the variance modeled through the fixed effects, approximated as 1 minus the unexplained variance for each model divided by the total variance

observed for the null outcome model, multiplied by 100. This has an interpretation similar to the 'R-squared'.[32] We did not find significant evidence for statistical interactions between gender and key variables of interest, and thus analyzed boys and girls together. Statistical analyses were performed in SAS, 9.3 (Cary, NC, USA).

Results

Distribution of study variables

Table 1 presents the prevalence and the means of child, household and maternal characteristics. Half the sample was male, and the mean (SD) age of children was 8.4 (0.7) years at the time of developmental assessment. Socially advantaged demographic and parental characteristics were more prevalent in higher wealth quintiles. Similarly, the mean HAZ was −2.2 (0.8) in the lowest wealth quintile and −1.5 (0.9) in the highest; anemia was more prevalent in the lowest vs. highest wealth quintile. The mean HOME inventory was 24.1 (6.1), with an 8.5 point HOME difference between the highest and the lowest wealth quintile. Nearly one-fifth of children had never attended school, and only 12.9% of children had regular schooling history. Children from the poorest households were more likely to have less schooling exposure than their peers in the wealthiest households.

In the overall sample, the mean UNIT was 50.0 (10.0), per cent correct no-go trials was 44.7 (20.7) and MABC was 8.5 (6.2).

Table 1. Child and household characteristics and developmental outcomes ($n = 1692$)

	Overall	Poorest quintile	2nd quintile	3rd quintile	4th quintile	Wealthiest quintile	P^{a}
Control variables							
Age, y, M (SD)	8.4 (0.7)	8.3 (0.7)	8.4 (0.7)	8.4 (0.7)	8.4 (0.6)	8.4 (0.6)	0.03
Male, n (%)	847 (50.1)	159 (47.9)	183 (54.1)	170 (50.1)	172 (50.4)	163 (47.7)	0.45
Child birth order							
First-born, n (%)	406 (24.0)	62 (18.7)	61 (18.0)	78 (23.0)	82 (24.0)	123 (36.0)	<0.01
2nd–4th child, n (%)	894 (52.8)	176 (53.0)	199 (58.9)	172 (50.7)	182 (53.4)	165 (48.2)	–
5th or higher, n (%)	392 (23.2)	94 (28.3)	78 (23.1)	89 (26.3)	77 (22.6)	54 (15.8)	–
Prenatal Iron + folic acid treatment group, n (%)	443 (26.2)	72 (21.7)	84 (24.9)	93 (27.4)	102 (29.9)	92 (26.9)	0.16
Pahadi ethnicity, n (%)	467 (27.6)	47 (14.2)	66 (19.5)	74 (21.8)	113 (33.1)	167 (48.8)	<0.01
Caste							
Shudra/Muslim/Other, n (%)	365 (21.6)	133 (40.1)	84 (24.9)	71 (20.9)	43 (12.6)	34 (9.9)	<0.01
Vishya, n (%)	1061 (62.7)	189 (56.9)	236 (69.8)	228 (67.3)	236 (69.2)	172 (50.3)	–
Brahmin or Chhetri, n (%)	266 (15.7)	10 (3.0)	18 (5.3)	40 (11.8)	62 (18.2)	136 (39.8)	–
Father literate, n (%)	869 (51.4)	76 (22.9)	134 (39.6)	151 (44.5)	221 (64.8)	287 (83.9)	<0.01
Mother literate, n (%)	359 (21.2)	15 (4.5)	26 (7.7)	40 (11.8)	95 (27.9)	183 (53.5)	<0.01
Maternal Raven's score, M (SD)	16.5 (5.2)	15.1 (4.1)	15.8 (4.6)	16.0 (4.6)	17.0 (5.5)	18.8 (5.9)	<0.01
Maternal age, y, M (SD)	31.3 (5.6)	32.2 (5.5)	31.7 (5.6)	31.3 (5.9)	31.2 (5.6)	30.4 (5.3)	<0.01
Child nutritional status							
Height-for-age z-score, M (SD)	−1.9 (0.9)	−2.2 (0.8)	−2.0 (0.8)	−1.9 (0.8)	−1.8 (0.8)	−1.5 (0.9)	<0.01
Body mass index z-score, M (SD)	−1.2 (0.8)	−1.3 (0.8)	−1.3 (0.8)	−1.2 (0.8)	−1.2 (0.7)	−1.0 (0.9)	<0.01
Anemia (Hb< 11.5 g/dL), n (%)	337 (19.9)	89 (26.8)	61 (18.0)	78 (23.0)	63 (18.5)	46 (13.5)	<0.01
HOME inventory score, M (SD)	24.1 (6.1)	20.2 (5.0)	22.2 (5.5)	23.3 (5.2)	25.8 (5.7)	28.7 (5.5)	<0.01
Schooling							
No schooling, n (%)	334 (19.7)	146 (44.0)	88 (26.0)	57 (16.8)	31 (9.1)	12 (3.5)	<0.01
Early schooling only, n (%)	362 (21.4)	23 (6.9)	46 (13.6)	76 (22.4)	79 (23.2)	138 (40.4)	–
1st grade only, n (%)	376 (22.2)	103 (31.0)	83 (24.6)	94 (27.7)	74 (21.7)	22 (6.4)	–
Late schooling only, n (%)	401 (23.7)	53 (16.0)	102 (30.2)	89 (26.3)	96 (28.2)	61 (17.8)	–
Regular schooling, n (%)	219 (12.9)	7 (2.1)	19 (5.6)	23 (6.8)	61 (17.9)	109 (31.9)	–

[a]ANOVA or chi-square tests were conducted for continuous and categorical variables, respectively.

Intellectual function

There was a graded association between household wealth and intellectual function in unadjusted models, with a mean UNIT difference of β = –8.96 [95% CI –10.41, –7.51] between children in poorest and wealthiest households (Table 2, Unadjusted). Each mediator was also associated with unadjusted differences in UNIT score (Table 2, Unadjusted). Household wealth alone accounted for 13% of the variance in UNIT scores. Though attenuated, wealth differences persisted after adjustment for demographic variables (Table 2, Model 1), child nutritional status (Table 2, Model 2), and home environment (Table 2, Model 3). The association between household wealth and UNIT was not statistically significant after adjusting for schooling history (Table 2, Model 4). In the fully adjusted model (Table 2, Model 5), the mediators HAZ, BMIZ, home environment, and schooling history were each statistically significantly associated with UNIT. Never attending school, compared to regular schooling, was associated with the largest adjusted difference in UNIT (β = –11.51 [95% CI –13.24, –9.77]) in the full model. Variables in the full Model 5 accounted for 43% of the variance in UNIT.

Executive function

Household wealth, HAZ, the HOME inventory, and schooling were associated with unadjusted differences in the per cent no-go correct. Wealth accounted for 2% of the variance in the executive function in the unadjusted model. Wealth-related differences in per cent correct no-go trials were not statistically significant after controlling for child and household demographic variables. In the fully adjusted model (Table 3, Model 5), never attending school compared to regular schooling was associated with the largest difference in no-go performance (β = –9.92, [95% CI –14.33, –5.50]). No other hypothesised mediating factors were associated with no-go in the full model, although HAZ and HOME inventory were positively associated with no-go prior to adjustment for schooling (Table 3, Models 2 and 3). In total, variables in the full model accounted for 13% of the no-go variance.

Motor function

Household wealth and all mediators were associated with unadjusted differences in the MABC (Table 4, Unadjusted). Children in the bottom two wealth quintiles displayed greater movement impairment than their wealthiest peers after adjustment for demographic variables (Table 4, Model 1). A statistically significant difference in MABC persisted between children of the poorest and wealthiest households after additional adjustment for nutritional status (β = 1.44, [95% CI 0.48, 2.39]) and for home environment (β = 1.40, [95% CI 0.40, 2.41]) (Table 4, Models 2 and 3). Never attending school, compared to regular schooling, was associated with the largest difference in movement impairment (β = 5.07, [95% CI 3.88, 6.26]) in the fully adjusted model. Variables in the full model accounted for 29% of the variance in MABC, whereas wealth alone accounted for 6%.

Comment

We observed a positive, graded association between household wealth and intellectual and motor, but not executive, domains of child neurocognitive function in a large population-based cohort in South Asia. The disparity in intellectual and motor outcomes between children from the poorest and wealthiest households was independent of demographic confounders, whereas wealth-based differences in executive performance appear to be confounded by demographic factors. Findings were consistent with the hypothesis that child nutritional status, home environment, and schooling patterns mediate the associations of household wealth with intellectual and motor outcomes.

Wealthier children were more likely to have a regular schooling pattern or be exposed to early schooling. A household's decision to send a child to school is affected by the local economy, household resources, and social values; the wealth-based differences we observed in school enrolment were consistent with previous findings at the national-level.[33] Schooling history was very irregular in this population-based cohort. Age at school entry, total years of schooling, and highest educational attainment may be inadequate to classify exposure to schooling in this context. Both duration and timing of schooling appear relevant, particularly for intellectual function. Children with regular schooling history performed the best in each domain, while children with no schooling or exposure to first grade only performed the worst. Interestingly, children exposed only in early years fared similarly to children who were enrolled

Table 2. Associations between household wealth index and the UNIT (n = 1668)

	Unadjusted[a] β [95% CL]	Model 1[b] β [95% CL]	Model 2[b] β [95% CL]	Model 3[b] β [95% CL]	Model 4[b] β [95% CL]	Model 5[b] β [95% CL]
Household wealth index						
Poorest quintile	−8.96 [−10.41, −7.51]	−4.45 [−5.90, −3.01]	−3.61 [−5.04, −2.17]	−3.35 [−4.85, −1.84]	−1.35 [−2.76, 0.06]	−0.51 [−1.95, 0.93]
2nd	−6.49 [−7.90, −5.08]	−3.26 [−4.63, −1.89]	−2.67 [−4.02, −1.32]	−2.47 [−3.87, −1.08]	−1.19 [−2.51, 0.13]	−0.58 [−1.91, 0.75]
3rd	−6.48 [−7.87, −5.08]	−3.20 [−4.54, −1.87]	−2.73 [−4.05, −1.41]	−2.56 [−3.92, −1.21]	−1.64 [−2.91, −0.38]	−1.14 [−2.41, 0.14]
4th	−2.87 [−4.25, −1.49]	−1.29 [−2.56, −0.03]	−0.92 [−2.17, 0.32]	−0.98 [−2.25, 0.28]	−0.31 [−1.50, 0.89]	0.01 [−1.17, 1.20]
Wealthiest quintile	1.00 [Reference]	1.00 [Reference]	1.00 [Reference]	1.00 [Reference]	1.00 [Reference]	1.00 [Reference]
Height-for-age z-score	3.02 [2.50, 3.53]		1.58 [1.11, 2.05]			1.12 [0.68, 1.57]
Body mass index z-score	2.06 [1.51, 2.62]		0.91 [0.42, 1.40]			0.73 [0.27, 1.19]
Anemia (Hb<11.5 g/dL)	−1.95 [−3.12, −0.78]		−0.55 [−1.54, 0.45]			−0.31 [−1.24, 0.62]
HOME inventory score	0.48 [0.41, 0.56]			0.19 [0.11, 0.26]		0.09 [0.02, 0.16]
Schooling						
No schooling	−17.36 [−18.86, −15.85]				−12.51 [−14.24, −10.79]	−11.51 [−13.24, −9.77]
Early schooling only	−4.41 [−5.81, −3.02]				−3.69 [−5.06, −2.32]	−3.56 [−4.91, −2.21]
1st grade only	−12.79 [−14.22, −11.35]				−9.28 [−10.86, −7.70]	−8.64 [−10.21, −7.07]
Late schooling only	−6.59 [−7.95, −5.24]				−4.25 [−5.67, −2.83]	−3.93 [−5.34, −2.53]
Regular schooling	1.00 [Reference]				1.00 [Reference]	1.00 [Reference]
Modeled variance	13%[c]	32%	35%	33%	41%	43%

[a]Separate models were estimated for each independent variable; β [95% CL] reflects bivariate association between variable and outcome.
[b]Adjusted for child age, sex, birth order, prenatal iron + folic acid supplementation, ethnicity, caste, paternal literacy, maternal literacy, maternal age, and maternal Raven's score.
[c]Per cent of total variance accounted for by household wealth variable alone.

Table 3. Associations between household wealth index and % No-Go Correct (n = 1687)

	Unadjusted[a] β [95% CL]	Model 1[b] β [95% CL]	Model 2[b] β [95% CL]	Model 3[b] β [95% CL]	Model 4[b] β [95% CL]	Model 5[b] β [95% CL]
Household wealth index						
Poorest quintile	−6.58 [−9.73, −3.43]	−2.01 [−5.44, 1.41]	−1.63 [−5.08, 1.83]	−0.44 [−4.02, 3.14]	1.18 [−2.36, 4.72]	2.06 [−1.60, 5.72]
2nd	−5.12 [−8.21, −2.03]	−1.29 [−4.56, 1.98]	−1.00 [−4.28, 2.28]	−0.16 [−3.51, 3.19]	0.62 [−2.71, 3.95]	1.29 [−2.09, 4.68]
3rd	−5.04 [−8.11, −1.97]	−1.59 [−4.78, 1.60]	−1.43 [−4.63, 1.77]	−0.68 [−3.92, 2.56]	−0.18 [−3.39, 3.03]	0.31 [−2.94, 3.57]
4th	−4.12 [−7.15, −1.08]	−2.41 [−5.44, 0.62]	−2.26 [−5.29, 0.77]	−1.96 [−5.00, 1.08]	−1.49 [−4.52, 1.53]	−1.24 [−4.28, 1.79]
Wealthiest quintile	1.00 [Reference]	1.00 [Reference]	1.00 [Reference]	1.00 [Reference]	1.00 [Reference]	1.00 [Reference]
Height-for-age z-score	2.25 [1.13, 3.37]		1.65 [0.51, 2.79]			1.11 [−0.02, 2.25]
Body mass index z-score	0.61 [−0.58, 1.80]		−0.51 [−1.70, 0.68]			−0.72 [−1.90, 0.46]
Anemia (Hb< 11.5 g/dl)	0.50 [−1.95, 2.95]		1.28 [−1.13, 3.68]			1.45 [−0.93, 3.82]
HOME inventory score	0.45 [0.30, 0.61]			0.27 [0.09, 0.45]		0.17 [−0.01, 0.35]
Schooling						
No schooling	−14.40 [−18.03, −10.78]				−10.88 [−15.22, −6.55]	−9.92 [−14.33, −5.50]
Early schooling only	−4.24 [−7.64, −0.84]				−1.68 [−5.15, 1.78]	−1.57 [−5.03, 1.89]
1st grade only	−12.00 [−15.48, −8.52]				−8.38 [−12.37, −4.39]	−7.90 [−11.92, −3.89]
Late schooling only	−3.73 [−7.02, −0.44]				−1.65 [−5.24, 1.95]	−1.30 [−4.90, 2.30]
Regular schooling	1.00 [Reference]				1.00 [Reference]	1.00 [Reference]
% Modeled variance	2%[c]	10%	11%	11%	13%	13%

[a]Separate models were estimated for each independent variable; β [95% CL] reflects bivariate association between variable and outcome.
[b]Adjusted for child age, sex, birth order, prenatal iron + folic acid supplementation, ethnicity, caste, paternal literacy, maternal literacy, maternal age, and maternal Raven's score.
[c]Per cent of total variance accounted for by household wealth variable alone.

Table 4. Associations between household wealth index and MABC score ($n = 1659$)

	Unadjusted[a] β [95% CL]	Model 1[b] β [95% CL]	Model 2[b] β [95% CL]	Model 3[b] β [95% CL]	Model 4[b] β [95% CL]	Model 5[b] β [95% CL]
Household wealth index						
Poorest quintile	3.46 [2.56, 4.36]	1.99 [1.03, 2.95]	1.44 [0.48, 2.39]	1.40 [0.40, 2.41]	0.59 [−0.38, 1.57]	0.05 [−0.95, 1.04]
2nd	2.08 [1.19, 2.96]	1.05 [0.13, 1.97]	0.68 [−0.22, 1.59]	0.63 [−0.30, 1.57]	0.20 [−0.72, 1.11]	−0.17 [−1.09, 0.75]
3rd	1.32 [0.44, 2.19]	0.28 [−0.61, 1.17]	−0.01 [−0.89, 0.87]	−0.06 [−0.97, 0.85]	−0.30 [−1.18, 0.58]	−0.62 [−1.50, 0.26]
4th	0.71 [−0.15, 1.58]	0.27 [−0.58, 1.12]	0.03 [−0.80, 0.87]	0.11 [−0.74, 0.96]	−0.06 [−0.89, 0.77]	−0.27 [−1.09, 0.55]
Wealthiest quintile	1.00 [Reference]	1.00 [Reference]	1.00 [Reference]	1.00 [Reference]	1.00 [Reference]	1.00 [Reference]
Height-for-age z-score	−1.69 [−2.01, −1.38]		−1.22 [−1.54, −0.91]			−1.01 [−1.32, −0.70]
Body mass index z-score	−0.70 [−1.05, −0.36]		−0.14 [−0.47, 0.19]			−0.07 [−0.39, 0.25]
Anemia (Hb< 11.5 g/dl)	1.14 [0.43, 1.85]		0.56 [−0.10, 1.23]			0.51 [−0.13, 1.16]
HOME inventory score	−0.20 [−0.25, −0.16]			−0.10 [−0.15, −0.05]		−0.05 [−0.10, −0.00]
Schooling						
No schooling	7.70 [6.69, 8.70]				5.76 [4.58, 6.95]	5.07 [3.88, 6.26]
Early schooling only	1.84 [0.91, 2.77]				1.40 [0.46, 2.35]	1.33 [0.40, 2.26]
1st grade only	4.68 [3.71, 5.64]				3.33 [2.23, 4.42]	2.89 [1.81, 3.97]
Late schooling only	2.18 [1.27, 3.08]				1.44 [0.46, 2.42]	1.20 [0.23, 2.17]
Regular schooling	1.00 [Reference]				1.00 [Reference]	1.00 [Reference]
% Modeled variance	6%[c]	22%	25%	23%	27%	29%

[a]Separate models were estimated for each independent variable; β [95% CL] reflects bivariate association between variable and outcome.
[b]Adjusted for child age, sex, birth order, prenatal iron + folic acid supplementation, ethnicity, caste, paternal literacy, maternal literacy, maternal age, and maternal Raven's score.
[c]Per cent of total variance accounted for by household wealth variable alone.

only at higher grades in all domains, suggesting that early exposure to school may have an enduring impact on neurocognitive skills.

Consistent with prior studies,[7] we found that better child growth was independently associated with higher scores on developmental tasks. HAZ, an indicator of long-term nutritional inputs influenced by linear growth early in life, was associated with higher intellectual and motor, but not executive, function. BMIZ, an indicator of current nutritional input, was also positively associated with UNIT. Child anemia status at the time of assessment was not related to any outcome after accounting for other factors. The null association must be interpreted with caution. A review of randomised trials detected a modest but significant effect of iron supplementation on cognitive outcomes of children aged 7 and older,[34] and a previous observational found a positive association between hemoglobin and cognition.[35]

The HOME inventory provided information regarding aspects of the proximal family and household environment that is often unavailable in resource-constrained settings. Consistent with applications in other settings,[3,28] the HOME appeared to measure socioeconomically patterned dimensions of parenting in rural Nepal. This is reflected in the progressively higher HOME inventory for higher quintiles of household wealth in our sample. The home environment was associated with intellectual and motor function independent of other factors considered and was related to executive function before adjusting for schooling status. Differences in outcomes related to the home environment were small in magnitude, potentially due to the materially deprived home settings. Only 6% of children had access to age appropriate books, and less than 1% had a library card, indicators used in the HOME inventory. Similarly, the mean HOME inventory for even the wealthiest households was half of the maximum possible score. The low range of HOME scores in this sample restricted our ability to investigate the expected differences in child developmental outcomes across the full spectrum of home environments for children.

Household wealth was not associated with the per cent correct no-go trials, which we used to measure executive function. This task specifically measures inhibitory control and may not reflect the entire domain of executive function. Of all the domains assessed in this study, the per cent of modeled variance in the full model was lowest for the executive domain. The null association may be due to random error in this measure, the unfinished executive function development of children at this age, or a true null effect of wealth on inhibitory control. Future investigation of child development may benefit from exploring the determinants of executive skill formation in this setting.

Strengths of this study were the population-based design, large sample size, and measurement of a large number of covariates and confounders. This allowed us to look at the prevalence of developmental determinants and their associations with developmental outcomes. Because the study was conducted in a low-lying border district of Nepal, our findings may generalise to a wider rural population of South Asian children who share similar demographic features. Causality of associations must be interpreted with caution, however, because data regarding household wealth and mediating factors were collected contemporaneously to outcome assessment. Similarly, we were unable to conduct formal mediation analysis because household wealth, mediating factors, and outcomes were assessed at the same time point. Further studies with repeated exposure and outcome measurement are needed to distinguish the most relevant timing of household wealth or other exposures, or the influence of duration on time-varying exposures.

We found that wealth-based disparities in child neurocognitive abilities existed within a resource-constrained, agrarian region of Nepal. The wealth differentials in intellectual and motor function are independent of inequalities arising from the social factors of ethnicity, caste, and gender that structure many dimensions of local life. Nutritional status and the home environments of children, previously established poverty-induced risk factors for suboptimal development,[1,7] did not explain an appreciable portion of the variation in child intellectual function after accounting for social background confounders and wealth. Rather, wealth-based differences in exposure to schooling appear to be a principal determinant of disparities in middle childhood development in this setting. In addition to ongoing poverty alleviation efforts in the region, promoting universal schooling and maximising school enrolment in the early years (i.e. nursery, lower KG, and upper KG), is paramount to reducing observed neurocognitive disparities.

Acknowledgements

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