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Original Article

The Epidemiological Transition and the Global Childhood Obesity Epidemic

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Running Head: Epidemiological Transition and Childhood Obesity

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37 **Abstract**

38 **Background/Objectives:** Childhood obesity is now recognized as a global public health issue.

39 Social patterning of obesity, consistent with the theory of epidemiologic transition, has not been
40 well described in children, and the limited research has focused on developed settings. The aim
41 of this study was to describe the relationship between childhood obesity and household income
42 using objective measures of adiposity and to explore how this relationship differs across levels
43 of country human development.

44 **Subjects/Methods:** The International Study of Childhood Obesity, Lifestyle and the
45 Environment (ISCOLE) was a multi-national cross-sectional study conducted in 12
46 urban/suburban study sites that represented all inhabited continents and wide ranges of
47 development. ISCOLE collected objectively-measured height, body mass, and percentage body
48 fat in 7 341 10-year-old children. Multi-level random-effects models were used to examine
49 income gradients in several obesity measures.

50 **Results:** The mean age of the children was 10.4 years, and 12.6% were obese, ranging from
51 5.4% (Finland) to 23.8% (China). For both boys and girls, obesity prevalence, body fat
52 percentage, and BMI z-score increased linearly with higher income at lower levels of
53 development (all p for trend ≤ 0.0012), but decreased linearly with higher income at higher levels
54 of development (all p for trend ≤ 0.0003). Country human development explained 75% of the
55 variation in the country-specific income-obesity relationships ($r = -0.87$, $p = 0.0003$).

56 **Conclusions:** Results are consistent with the theory of epidemiologic transition. Global efforts
57 to control obesity must account for socioeconomic factors within a country's context. Future
58 research should seek to understand global socioeconomic patterns in obesity-related lifestyle
59 behaviors.

60 **Keywords:** socioeconomic status, obesity, epidemiologic transition, nutrition transition, human
61 development

62 **Trial Registration:** ClinicalTrials.gov: Identifier NCT01722500

63 Introduction

64 Childhood obesity is now recognized as a global public health concern.¹ Because of the
65 recent rise in obesity rates in both developed and developing countries,² the obesity epidemic is
66 thought to be driven largely by environmental and social factors.¹ Social patterning of obesity,
67 consistent with the theory of epidemiologic transition,³ has been described in adults,⁴⁻⁷ though
68 research in children is more limited.^{4,8}

69 For children, the limited research on socioeconomic gradients in obesity has been
70 conducted predominantly in developed (high or very high human development) countries, with a
71 preponderance of single-country studies, and studies have used inconsistent measures of
72 individual socioeconomic status (SES) and adiposity.^{4,6,8} These prior studies have highlighted
73 inconsistent results across levels of development. To our knowledge, only one other published
74 study⁹ has investigated the relationship between a country's economic level and socioeconomic
75 differences in overweight based on a large, multi-national sample of children. That study,
76 however, failed to find a relationship. In contrast to the current (ISCOLE) study, the prior study
77 used self-reported measures of body mass and height and did not include countries with low or
78 middle levels of human development.

79 Both low childhood socioeconomic status¹⁰⁻¹³ and childhood obesity^{14,15} impart significant
80 future health consequences. To address this current global epidemic and to plan for future
81 health needs, it is essential to understand how childhood obesity relates to socioeconomic
82 status across countries of varying levels of economic and social development. Thus, the aim of
83 this study was to describe the relationship between childhood obesity and household income
84 using several objective measures of adiposity and to explore how this relationship might differ
85 across a wide range of country human development.

86

87

88 **Methods**

89 The International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE)
90 ISCOLE was a multi-national cross-sectional study that collected objectively-measured height,
91 body mass, and percentage body fat in 7 341 children across 12 urban/suburban study sites.
92 The rationale, design and methods have been published in detail.¹⁶ Each ISCOLE study site was
93 responsible for recruiting and enrolling at least 500 children; a target sample size of 500 children
94 per site was chosen based on a power calculation that suggested this size would provide 90%
95 power to detect as significant predictors explaining 3% of the variability in BMI.¹⁶ The primary
96 sampling frame was schools, which was typically stratified by an indicator of socio-economic
97 status in order to maximize variability within sites.¹⁶ The Institutional Review Board at the
98 Pennington Biomedical Research Center (coordinating center) approved the overarching
99 ISCOLE protocol, and the Institutional/Ethical Review Boards at each participating institution
100 also approved the local protocol. Written informed consent was obtained from parents or legal
101 guardians, and child assent was obtained as required by local Institutional/Ethical Review
102 Boards.

103 **Setting**

104 The 12 urban/suburban sites included in ISCOLE represented countries ranging from low
105 (0.509, Kenya) to very high (0.929, Australia) country human development (2011 Human
106 Development Index, HDI¹⁷). Data were collected from September 2011 through December
107 2013. Data collection occurred during the school year, and each site completed their data
108 collection over a single 12-month period. Across the study, data collection proceeded in a
109 staggered fashion, with 2-5 sites engaged in data collection at any particular time.

110 **Participants**

111 ISCOLE targeted 10-year-old children, and each study site determined the grade level to
112 target that would ensure a sample with minimal variability around a mean age of 10 years. All

113 children within the targeted grade level in a sampled school were eligible to participate; thus, the
114 sample necessarily included children aged 9-11 years. A total of 7 372 boys and girls
115 participated in the ISCOLE study, of which 7 341 remained in the analytic dataset after
116 excluding participants who did not have valid BMI (n=31).

117 **Measurement**

118 *Anthropometry*

119 All ISCOLE sites collected objectively-measured height, body mass, and percentage body
120 fat according to a common protocol, and all study personnel were required to complete a
121 rigorous system of training and certification that included web-based training modules and
122 regional in-person training meetings.¹⁶ Standing height, body mass and body fat percentage
123 were measured using standard procedures and instrumentation across all study sites. Height
124 was measured without shoes, using a Seca 213 portable stadiometer (Hamburg, Germany),
125 with the head in the Frankfort Plane. Body mass and body fat percentage were determined with
126 a portable Tanita SC-240 bioelectrical impedance scale (Arlington Heights, IL), after all outer
127 clothing, heavy pocket items and shoes were removed. Each measurement was repeated, and
128 the average was used for analysis (a third measurement was obtained if the first two
129 measurements were greater than 0.5 cm, 0.5 kg, or 2.0% apart for height, body mass and body
130 fat percentage, respectively, and the average of the two closest measurements was used in
131 analyses). The body mass index (BMI; kg/m²) was calculated, and BMI z-scores were computed
132 using age- and sex-specific reference data from the World Health Organization.¹⁸ Participants
133 were classified as obese (BMI z-score >+2 SD) or non-obese (BMI z-score ≤2 +SD).

134 *Household Income*

135 Parents self-reported household income levels across eight to ten country-specific
136 categories determined by the study site. Within each country, income was collapsed into four

137 levels to facilitate multi-country analysis. While not corresponding exactly to quartiles, the four
138 levels were created to ensure the most balanced distribution possible within each country.

139 *Country Human Development Index*

140 The relationship between household income and adiposity was investigated across levels of
141 human development, measured by the 2011 Human Development Index (HDI).¹⁷ Values for the
142 2011 HDI corresponding to the 10th, 50th, and 90th percentiles within the ISCOLE country sample
143 were chosen to represent lower, middle, and higher levels of human development. Percentiles
144 were calculated based on weighted averages. The use of sample-based percentiles ensures
145 that the results are not extrapolated beyond the sample HDI range, and also reduces the
146 likelihood of results being interpreted to correspond to specific countries in the sample.

147 **Treatment of Missing Data**

148 A total of 7 372 children participated in ISCOLE. BMI was missing for 31 (<1%) participants;
149 these participants were excluded from all analyses. Body fat percentage was missing for an
150 additional 76 (1%) participants; analysis of this outcome was conducted among participants with
151 non-missing data.

152 Overall, 810 participants (11.0%) were missing data on household income. Four sites had
153 missing income data in excess of 10%: UK (15.3%), Brazil (22.0%), Portugal (23.3%), and
154 South Africa (32.6%). Participants missing income data were similar to those with complete data
155 with respect to sex, age, obesity, BMI z-score, and body fat percentage.

156 Missing values for income were multiply-imputed to reduce the chance of bias due to
157 exclusion of the cases with missing income data. Missing values were multiply-imputed (5
158 imputations) using fully conditional specification (FCS) methods, under missing at random
159 (MAR) assumptions¹⁹ and using SAS version 9.3 (PROC MI). Country-specific models were
160 used to impute income categories, which were subsequently collapsed into the four income
161 levels, as described above.

162 **Statistical Analysis**

163 Multi-level random effects models (PROC MIXED and PROC GLIMMIX) that accounted for
164 clustering at both the school and country levels were used to examine income gradients in the
165 various obesity measures. Denominator degrees of freedom for statistical tests pertaining to
166 fixed effects were calculated using the Kenward and Roger approximation.²⁰ Interactions were
167 used to test for differences in the income-obesity relationship across HDI levels (income-by-HDI
168 interaction) and for differences between boys and girls (income-by-HDI-by-sex interaction). For
169 presentation, least-square means for the obesity measures were estimated separately for boys
170 and girls at values corresponding to the 10th, 50th, and 90th percentiles for the 2011 HDI within
171 the ISCOLE sample. Linear regression “slopes-as-outcome” models overall and by sex, with
172 the country-specific SES-obesity slope (SES level as ordinal, analyses stratified by study site)
173 as the outcome and HDI as the predictor, were used to investigate the association of HDI with
174 the between-country differences in the SES-obesity relationships.

175 To properly account for the multiply-imputed income data, results from all statistical analyses
176 were averaged across the five imputed datasets, and the standard errors were adjusted using
177 the MIANALYZE procedure in SAS. Sensitivity analyses were used to compare results from
178 imputed datasets to those from analyses of participants with complete data, and results were
179 similar.

180 **Results**

181 Descriptive characteristics of the study sample, stratified by sex and study site, are provided
182 in Table 1. The mean age of the children was 10.4 years, and 12.6% of children were obese,
183 which ranged from 5.4% (Finland) to 23.8% (China). ISCOLE study sites represented all
184 inhabited continents and levels of human development (human development index, HDI)
185 ranging from low (0.509, Kenya) to very high (0.929, Australia) (Table 2).

186 For both boys and girls, obesity was positively associated with income at lower levels of HDI
187 and negatively associated with income at higher levels of HDI (Table 3 and Figure 1). There
188 was a significant interaction between obesity prevalence and HDI in both boys ($p=0.0351$) and
189 girls ($p=0.0041$), but no indication of different relationships between the two groups.
190 Furthermore, this pattern – that the income gradient in obesity reverses itself as one moves
191 from low to high levels of development – was consistent across all measures of adiposity
192 (Figure 1 and Figure 2). For all adiposity measures, there was a significant interaction with HDI
193 (Boys: BMI z-score ($p=0.0002$), body fat ($p=0.0009$); Girls: BMI z-score ($p=0.0013$), body fat
194 ($p=0.0071$)); however, there was no indication of different income gradients for boys and girls.
195 Finally, across successively higher levels of country human development, obesity levels decline
196 in the highest income group, while they increase in the lowest income group.

197 Our analysis reveals a very strong negative relationship between HDI and the country-
198 specific income-obesity gradients (Figure 3). Across countries, HDI explained 75% of the
199 variation in the country-specific income-obesity relationships ($r = -0.87$, $p=0.0003$). The
200 relationships were similar in boys and girls (p for interaction= 0.56). The income-obesity
201 gradient is estimated to be zero for countries near a 2011 HDI of 0.76, with positive income
202 gradients in obesity at lower levels of development and negative income gradients at higher
203 levels. In stratified analysis, BMI z-score was significantly associated with income in six of the
204 twelve ISCOLE countries.

205 **Discussion**

206 This is the first study of childhood obesity that included children from countries of low to very
207 high levels of human development, that collected objective anthropometric measures, and that
208 collected these measures according to a common protocol. Results demonstrated a strong
209 relationship between childhood obesity and income, which is modified by the level of a country's
210 development. For both boys and girls, obesity prevalence, body fat percentage, and BMI z-

211 score were positively associated with income at lower levels of human development and
212 negatively associated with income at higher levels of development.

213 For children, the limited research on socioeconomic gradients in obesity has been
214 conducted predominantly in developed (high or very high HDI) countries, with a preponderance
215 of single-country studies, and studies have used inconsistent measures of individual
216 socioeconomic status and adiposity, precluding meta-analyses.^{4,6,8} These prior studies have
217 highlighted inconsistent results across levels of development. Results from the current study
218 show that for countries with moderate levels of human development in which the income
219 gradient would be plateauing before reversing, income gradients are generally non-significant.
220 This observation could help to explain the inconsistent results from prior studies while also
221 placing them within a clear pattern of income-obesity gradients across levels of country
222 development.

223 To our knowledge, only one other published study⁹ has investigated the relationship
224 between a country's economic level and levels of socioeconomic differences in overweight
225 based on a large, multi-national sample of children. That study, however, failed to find a
226 relationship. In contrast to the current (ISCOLE) study, the prior study used self-reported
227 measures of body mass and height and represented countries with more limited variability in
228 human development (2011 HDI from 0.729 to 0.943). If the current (ISCOLE) analysis had been
229 restricted to sites with comparable levels of human development, we would also have failed to
230 identify the strong relationship between human development and income gradients in obesity,
231 reinforcing the importance of including less-developed countries this research.

232 Our results are consistent with the theory of epidemiologic transition, which characterizes
233 changes across levels of a country's development in patterns of morbidity and mortality from
234 infectious causes to chronic and "man-made" diseases.³ With respect to obesity, the
235 epidemiologic transition encompasses both dietary changes (shifts from undernutrition and

236 malnutrition to overnutrition, and from traditional diets to more energy-dense “western” diets)
237 and changes in physical activity (shifts away from high levels of occupational and transportation-
238 based physical activity to more sedentary lifestyles) often referred to as the “nutrition
239 transition”²¹ and the “physical activity” transition.²²

240 The epidemiologic transition predicts a social patterning of obesity in countries in transition,
241 such that groups with higher income, standards of living, and levels of nutrition shift first,
242 resulting in higher levels of obesity compared to lower-income groups.³ Furthermore, in these
243 settings, obesity may be valued as an indicator of relative affluence, reinforcing the prevalence
244 of obesity in higher-income groups. As a country’s development increases, food scarcity,
245 famine, and malnutrition become less common, such that lower income groups experience less
246 malnutrition, increasing their relative adiposity. The lack of a consistent relationship between
247 income and obesity in mid-HDI countries may be related to increased access to low-cost,
248 energy-dense foods coupled with the necessity of physically-intense labor among low income
249 groups resulting in an increased obesity prevalence approaching that of high income
250 populations in these countries. Then, as countries complete the transition to a more western
251 “modern” lifestyle and standards of living increase, overfeeding and being less active become
252 economically possible. At high HDI, the income-obesity gradient shifts with lower income groups
253 experiencing higher levels of obesity, potentially related to lower costs of energy-dense foods²³
254 and decreased access to safe places to be physically active.^{24,25}

255 The incidence of major cardiovascular events is currently highest in low-income countries,
256 despite lower levels of obesity.²⁶ At present, policies in most low- and mid-HDI countries favor
257 prevention of undernutrition, and only some countries have implemented policies to prevent
258 obesity.²⁷ Consequently, as childhood obesity levels increase globally, lower income countries
259 will be more impacted by cardiovascular disease and associated medical and social costs. Also,

260 as global development increases, poorer segments of the population are projected to see the
261 highest increases in obesity, further compounding the global burden of cardiovascular disease.

262 A particular strength of the current research is the wide variability in levels of human
263 development present in the country sample and the analysis of objective obesity data collected
264 under a rigorous, common protocol; as such, the ISCOLE sample provides clearer insights into
265 how social determinants of health^{28,29} may be impacting childhood obesity globally. The ISCOLE
266 sample was limited to children in urban and suburban settings, so results may not generalize to
267 rural settings; however, this aspect of the study design also prevents confounding by the extent
268 of urbanization on the estimated relationships. Recent research in adults suggests that urban-
269 rural differences in obesity seen in less-developed countries may be mainly attributable to
270 socioeconomic status,³⁰ so our results may be relevant for rural settings as well.

271 In conclusion, childhood obesity prevalence is related to household income, though the
272 strength and direction of this relationship differs according a country's level of human
273 development. Consequently, as childhood obesity levels continue to rise, it will be important to
274 account for socioeconomic factors within a country's context in the global effort to control the
275 epidemic. This effort should include a better understanding of socioeconomic gradients in
276 specific behaviors that contribute to obesity, namely diet, physical activity, and sedentary
277 behavior. Finally, as global development increases, poorer segments of the population are
278 projected to see the highest increases in obesity.

279

280

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289

290 **Conflicts of Interest**

291 MF has received a research grant from Fazer Finland and has received an honorarium for
292 speaking for Merck. AK has been a member of the Advisory Boards of Dupont and McCain
293 Foods. RK has received a research grant from Abbott Nutrition Research and Development. VM
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295 speaking for The Coca-Cola Company. TO has received an honorarium for speaking for The
296 Coca-Cola Company. The authors reported no other potential conflicts of interest.

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370

371 **Figure Legends**

372 **Figure 1.** Income gradients in obesity prevalence across HDI levels in boys (**A**) and girls (**B**).

373 Data are shown as least-square means at HDI levels corresponding to the 10th, 50th, and 90th

374 percentiles of the ISCOLE sample (HDI=0.52, HDI=0.72, and HDI=0.91, respectively). Tests for
375 linear trend are indicated: * $p < 0.05$, ** $p < 0.001$; *** $p < 0.0001$.

376

377 **Figure 2.** Income gradients in adiposity measures across HDI levels in boys **(A)** and girls **(B)**.

378 Data are shown as least-square means at HDI levels corresponding to the 10th, 50th, and 90th

379 percentiles of the ISCOLE sample (HDI=0.52, HDI=0.72, and HDI=0.91, respectively). Tests for

380 linear trend are indicated: ** $p < 0.001$; *** $p < 0.0001$.

381

382 **Figure 3.** Relationship between country-specific income-obesity gradients and HDI.

Table 1. Descriptive characteristics of International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE) participants stratified by sex and study site (n=7 341).

Country (Site)	n		Age (y)		Obesity (%)		BMI z-score		Body Fat (%)	
	boys	girls	boys	girls	boys	girls	boys	girls	boys	girls
Australia (Adelaide)	243	285	10.4 (0.5)	10.3 (0.6)	11.5	9.5	0.6 (1.1)	0.6 (1.1)	18.9 (6.5)	23.9 (7.2)
Brazil (São Paulo)	277	287	10.0 (0.5)	10.0 (0.5)	28.9	14.6	1.0 (1.5)	0.7 (1.3)	21.3 (9.6)	24.7 (8.4)
Canada (Ottawa)	238	327	10.1 (0.4)	10.0 (0.4)	14.3	10.1	0.6 (1.2)	0.3 (1.2)	18.7 (7.2)	21.9 (7.3)
China (Tianjin)	293	258	9.4 (0.5)	9.4 (0.5)	33.4	12.8	1.1 (1.6)	0.3 (1.3)	20.2 (8.0)	20.7 (8.1)
Colombia (Bogotá)	454	462	10.0 (0.6)	10.0 (0.7)	7.9	3.7	0.3 (1.1)	0.1 (1.0)	18.4 (5.7)	21.6 (5.5)
Finland (Helsinki, Espoo & Vantaa)	253	282	10.0 (0.5)	10.0 (0.4)	7.5	3.6	0.3 (1.1)	0.2 (1.0)	16.9 (6.2)	20.9 (6.8)
India (Bangalore)	292	328	10.0 (0.6)	10.0 (0.6)	12.3	8.5	0.2 (1.5)	0.3 (1.3)	19.5 (7.5)	23.7 (7.0)
Kenya (Nairobi)	262	301	9.7 (0.7)	9.8 (0.7)	7.3	6.0	0.1 (1.3)	0.0 (1.2)	16.1 (7.0)	17.1 (8.5)
Portugal (Porto)	358	419	10.0 (0.2)	10.0 (0.3)	21.5	14.1	1.0 (1.2)	0.8 (1.1)	20.5 (7.2)	24.9 (7.1)
South Africa (Cape Town)	222	327	9.9 (0.7)	9.8 (0.7)	10.4	11.0	0.2 (1.3)	0.3 (1.3)	17.7 (7.2)	22.8 (7.8)
United Kingdom (Bath & NE Somerset)	237	287	10.4 (0.5)	10.4 (0.5)	10.1	9.4	0.5 (1.1)	0.4 (1.2)	18.2 (6.4)	23.3 (6.7)
United States (Baton Rouge)	281	368	9.6 (0.7)	9.5 (0.6)	19.6	18.2	0.9 (1.4)	0.8 (1.3)	20.9 (8.5)	24.9 (7.9)

BMI: Body Mass Index

Table 2. International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE)

country socioeconomic indicators and country-specific sample income levels.

Country (Site)	2011 Human Development Index	ISCOLE sample income levels: Within-country % ¹ Country currency range			
		L1 (ISO Code ²)	L2	L3	L4
Australia	0.929	23.9% ≤\$49 999 (AUD)	30.2% \$50 000–\$89 999	24.5% \$90 000–\$139 999	21.4% ≥\$140 000
Brazil	0.718	38.4% ≤R\$19 620 (BRL)	24.4% R\$19 621–\$32 700	21.5% R\$32 701–\$58 860	15.7% >R\$58 860
Canada	0.908	19.7% ≤\$59 999 (CAN)	28.1% \$60 000–\$109 999	14.3% \$110 000–\$139 999	37.9% >\$140 000
China	0.687	19.8% <¥20 000 (CNY)	19.5% ¥20 000–¥39 999	28.5% ¥40 000–¥79 999	32.2% >¥80 000
Colombia	0.710	35.0% ≤\$8 400 000 (COP)	24.8% \$8 400 001–\$12 000 000	17.7% \$12 000 001–\$18 000 000	22.6% >18 000 000
Finland	0.882	20.7% ≤39 999€ (EUR)	19.8% 40 000€–59 999€	19.5% 60 000€–79 999€	40.1% >80 000€
India	0.547	23.5% ≤Rs239 999 (INR)	19.9% Rs240 000–Rs479 999	18.7% Rs480 000–Rs719 999	38.0% >Rs720 000
Kenya	0.509	23.2% ≤Ksh121 991 (KES)	25.1% Ksh121 992–Ksh466 727	22.6% Ksh466 728–Ksh1 199 999	29.1% >Ksh1 200 000
Portugal	0.809	20.8% <€6 000 (EUR)	30.8% €6 000–€11 999	27.7% €12 000–€23 999	20.6% >€24 000
South Africa	0.619	50.4% <R11 500 (ZAR)	21.4% R11 500–R30 000	16.1% R30 001–R300 000	12.1% >R300 000
United Kingdom	0.863	27.0% ≤£19 999 (GBP)	28.7% £20 000–£39 999	23.3% £40 000–£59 999	21.0% >£60 000
United States	0.910	20.3% <\$10 000 (USD)	31.1% \$10 000–\$49 999	27.2% \$50 000–\$139 999	21.4% >\$140 000

¹ Across imputed datasets (m=5)

² International Organization for Standardization (ISO) 4217 standard currency codes

Table 3. Least-square mean estimates for measures of adiposity¹ across income levels, by sex and human development index: the International Study of Childhood Obesity, Lifestyle, and the Environment (ISCOLE).

	Level 1	Level 2	Level 3	Level 4	p for trend ²
<i>Boys</i>					
ISCOLE 10 th percentile of HDI					
Obesity prevalence	5.0 (2.3)	14.1 (5.4)	13.4 (5.3)	21.2 (6.8)	<0.001
BMI z-score	-0.19 (0.20)	0.27 (0.21)	0.36 (0.21)	0.77 (0.20)	<0.001
Body Fat (%)	15.8 (1.1)	18.1 (1.1)	18.6 (1.1)	20.6 (1.1)	<0.001
ISCOLE 50 th percentile of HDI					
Obesity prevalence	10.8 (2.2)	14.8 (2.8)	15.0 (2.9)	14.3 (2.7)	0.05
BMI z-score	0.40 (0.11)	0.54 (0.11)	0.55 (0.11)	0.62 (0.11)	0.003
Body Fat (%)	18.5 (0.6)	19.0 (0.6)	19.0 (0.6)	19.2 (0.6)	0.15
ISCOLE 90 th percentile of HDI					
Obesity prevalence	20.9 (5.3)	15.5 (4.1)	16.6 (4.4)	9.5 (2.9)	<0.001
BMI z-score	0.96 (0.16)	0.80 (0.15)	0.73 (0.15)	0.48 (0.15)	<0.001
Body Fat (%)	21.1 (0.8)	19.8 (0.8)	19.5 (0.8)	17.9 (0.8)	<0.001
<i>Girls</i>					
ISCOLE 10 th percentile of HDI					
Obesity prevalence	4.8 (2.0)	6.5 (2.6)	8.9 (3.4)	13.0 (4.3)	0.001
BMI z-score	-0.13 (0.16)	0.10 (0.16)	0.26 (0.16)	0.50 (0.15)	<0.001
Body Fat (%)	19.2 (1.3)	20.2 (1.2)	21.1 (1.3)	22.3 (1.2)	<0.001
ISCOLE 50 th percentile of HDI					
Obesity prevalence	8.8 (1.6)	9.2 (1.7)	8.6 (1.6)	8.9 (1.7)	0.95
BMI z-score	0.30 (0.08)	0.37 (0.08)	0.38 (0.08)	0.42 (0.08)	0.07
Body Fat (%)	22.0 (0.6)	22.2 (0.6)	22.2 (0.7)	22.4 (0.7)	0.29
ISCOLE 90 th percentile of HDI					
Obesity prevalence	15.2 (3.5)	12.7 (3.0)	8.3 (2.3)	6.1 (1.8)	<0.001
BMI z-score	0.71 (0.12)	0.63 (0.11)	0.50 (0.12)	0.34 (0.12)	<0.001
Body Fat (%)	24.6 (0.9)	24.1 (0.9)	23.3 (0.9)	22.6 (0.9)	<0.001

¹ Least-square mean estimates of adiposity measures at HDI levels corresponding to the 10th, 50th, and 90th percentiles of the ISCOLE country sample (HDI=0.52, HDI=0.72, and HDI=0.91, respectively).

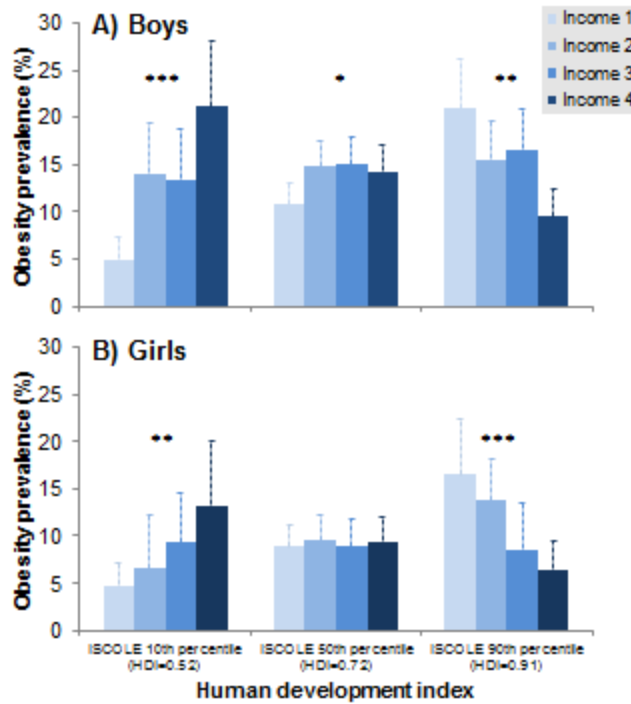
² Test for linear trend (linear contrast) across the four income levels

HDI: Human Development Index; BMI: Body Mass Index

Figure 1. Income gradients in obesity prevalence across HDI levels in boys (A) and girls (B). Data are shown as least-square means at HDI levels corresponding to the 10th, 50th, and 90th percentiles of the ISCOLE sample (HDI=0.52, HDI=0.72, and HDI=0.91, respectively). Tests for linear trend are indicated: *p<0.05, **p<0.001; ***p<0.0001.

Figure 2. Income gradients in adiposity measures across HDI levels in boys (A) and girls (B).

Data are shown as least-square means at HDI levels corresponding to the 10th, 50th, and 90th percentiles of the ISCOLE sample (HDI=0.52, HDI=0.72, and HDI=0.91, respectively).



as least-square levels the 10th, 50th, and the ISCOLE (HDI=0.52, HDI=0.91, Tests for linear

trend are indicated: ** $p < 0.001$; *** $p < 0.0001$.

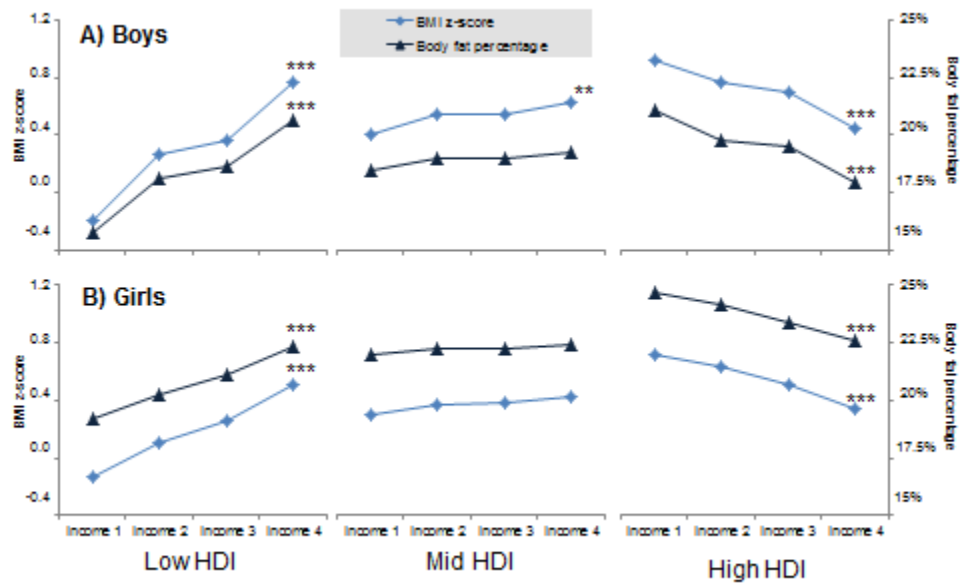


Figure 3. Relationship between country-specific income-obesity gradients and HDI.

