BMJ Global Health

Economic inequality in malnutrition: a global systematic review and meta-analysis

Rotimi Alao,[1] Hayaan Nur,[1] Emily Fivian,[1] Bhavani Shankar,[2] Suneetha Kadiyala,[1] Helen Harris-Fry [1]

To cite: Alao R, Nur H, Fivian E, *et al*. Economic inequality in malnutrition: a global systematic review and meta-analysis. *BMJ Global Health* 2021;**6**:e006906. doi:10.1136/bmjgh-2021-006906

Handling editor Seye Abimbola

► Additional supplemental material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/bmjgh-2021-006906).

RA and HN are joint first authors.

Received 14 July 2021
Accepted 17 November 2021

[1]Department of Population Health, London School of Hygiene & Tropical Medicine, London, UK
[2]Department of Geography, The University of Sheffield, Sheffield, UK

Correspondence to
Dr Helen Harris-Fry;
helen.harris-fry@lshtm.ac.uk

ABSTRACT

Objective To describe the evidence on global and regional economic inequality in malnutrition, and the associations between economic inequality and malnutrition.

Methods We conducted a systematic review and meta-analysis. Between 1 November 2020 and 22 January 2021, we searched Medline, Embase, Global Health, Eldis, Web of Science and EBSCO Discovery Service. We contacted 39 experts and tracked citations. We included any study reporting a concentration index (CIX) relating economic status and nutritional status and any multilevel study reporting an association between economic inequality and nutritional status. Nutritional status was measured as stunting, wasting, anaemia, or overweight in children (<5 years), or underweight, overweight or obesity, or anaemia in adults (15–49 years). We had no study date or language restriction. Quality was assessed using the Appraisal Tool for Cross-Sectional Studies (AXIS tool). We mapped estimates and pooled them using multilevel random-effects meta-analyses.

Results From 6185 results, 91 studies provided 426 CIX (>2.9 million people) and 47 associations (~3.9 million people). Stunting (CIX −0.15 (95% CI −0.19 to −0.11)) and wasting (−0.03 (95% CI −0.05 to −0.02)) are concentrated among poor households. Adult overweight and obesity is concentrated in wealthier households (0.08 (95% CI −0.00 to 0.17)), particularly in South Asia (0.26 (95% CI 0.19 to 0.34)), but not in Europe and Central Asia (−0.02 (95% CI −0.08 to 0.05)) or North America (−0.04 (95% CI −0.10 to 0.03)). We found no association between 0.1 increase in Gini coefficient and adult underweight (OR 1.03 (95% CI 0.94 to 1.12)) or overweight and obesity (0.92 (95% CI 0.80 to 1.05)).

Conclusions There is good evidence that the prevalence of malnutrition varies by levels of absolute economic status. Undernutrition is concentrated in poor households, whereas concentration of overweight and obesity by economic status depends on region, and we lack information on economic inequalities in anaemia and child overweight. In contrast, links between malnutrition and relative economic status are less clear and should not be assumed; robust evidence on causal pathways is needed.

PROSPERO registration number CRD42020201572.

Key questions

What is already known?

- Progress in improving nutrition is being hampered by economic inequalities.
- Several individual studies have characterised economic inequalities in nutrition, but we lack understanding of where inequalities are largest and where evidence gaps are.
- Reviews show positive associations between measures of economic inequality and health outcomes, but none have reviewed associations with nutritional status.

What are the new findings?

- Child undernutrition is concentrated among poor households, and this is not explained by country-level measures of income, food security or healthcare coverage.
- Adult overweight and obesity is concentrated in better-off households globally, but this is explained by evidence from lower-income countries and not higher-income countries.
- Associations between economic inequality and nutrition outcomes show no clear overall trend.
- There are large gaps in evidence on anaemia and child overweight, which is concerning given the lack of progress on these global targets.

What do the new findings imply?

- Our findings highlight the need for pro-poor targeting in undernutrition interventions, whereas the level and direction of targeting for interventions on overweight and obesity will need to be determined by context.
- Although countries' economies, food systems and healthcare systems protect against undernutrition, work is needed to ensure they benefit those who need it most.

INTRODUCTION

No country is on track to meet all World Health Assembly global nutrition targets by 2025.[1] One in nine people is hungry or undernourished, while one in three is overweight or obese,[1] and there are wide cross-country disparities. Undernutrition rates are up to 10 times higher in lower-income countries, while overweight and obesity are up to five times higher in higher-income countries.[1]

Furthermore, national-level statistics mask wide socioeconomic disparities within countries. There is now consensus that further progress in reducing the burden of malnutrition worldwide will require targeted action to address these within-country inequalities.[1 2]

A growing but disparate literature has sought to characterise economic inequalities in malnutrition in different countries, using metrics from economics: concentration curves (CCs) and concentration indices (CIXs).[3–5] CCs plot the cumulative proportion of a health outcome in a population against the cumulative proportion of the population ranked in ascending order of economic status, and CIX are twice the area between the CC and line of equality (the 45° line from the origin). Rather than simply compare the richest against the poorest, CC and CIX capture the inequality across the full study population, and CC also visualise where the biggest health burdens lie.[4 6] However, this effort has not been systematically mapped and individual estimates are difficult to interpret in isolation. We lack an understanding of where and why economic inequalities in nutritional status are largest.

Furthermore, these economic inequalities in nutrition outcomes often lead to the assumption that relative economic inequality—rather than absolute economic status—causes malnutrition. Economic inequality in society could plausibly harm nutritional status through different pathways.[7–10] These include direct and indirect pathophysiological effects of social comparisons[11–13] and effects on appetite, diets, breastfeeding behaviour and physical activity; social exclusion[14–17] and effects on access to health services and other entitlements; and disinvestment in human development, for example, in public education, food systems and sanitation infrastructure.[18–20] Reviews on the effects of income inequality on population health more generally (using aggregate outcomes such as mortality and life expectancy) show that the effect of inequality is heterogeneous and often harmful to health,[21–23] but the effects on malnutrition are less understood.

The latest Global Nutrition Report[1] highlighted a need to better understand inequalities in nutrition, to inform priority setting, redress inequalities and aid countries to meet global targets of eliminating world hunger and reversing the rise in overweight and obesity. Our study responds to this call with two study aims, to systematically review evidence that: (1) characterises economic inequality in malnutrition of adults and children worldwide, and (2) estimates the association between economic inequality and malnutrition.

METHODS

Search strategy and selection criteria

Our systematic review and meta-analyses followed a registered protocol[24] and Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.[25] The study population was children aged <5 years or adults aged 15–49 years. Outcomes were chosen because they align with World Health Assembly Global Nutrition Targets.[1 26] For children, outcomes were stunting (height-for-age z-score SD <-2 of WHO child growth standards median), wasting (weight-for-height z-score SD <-2), anaemia (haemoglobin <110 g/L) and overweight (weight-for-height SD >2). For adults, outcomes were underweight (low body mass index (BMI) <18.5 kg/m^2), overweight or obesity (BMI >25 kg/m^2) and anaemia (pregnant women <110 g/L; non-pregnant women <120 g/L; men <130 g/L).

Our exposures were inequalities in economic status, where economic status was measured as household-level wealth, total expenditure or income. We excluded studies that used an incomplete measure of economic status, such as land size or food expenditures, or measured economic status at the individual level. We considered the household as an economic unit, because individual-level income data are not routinely collected or meaningful for young children. For adults, household wealth enables us to rank subjects without misclassifying household members who benefit from household economic status but lack personal income or wealth, although there is some risk of misclassification due to intrahousehold inequalities in income or wealth allocation.[27]

First, to characterise economic inequality in nutrition outcomes, we included evidence using any study design that reported a CC or CIX.[3] CC and CIX were chosen based on an initial scoping search and dissertation by author (RA)[5] that determined these to be the most common metric to capture inequality across the full wealth distribution. As mentioned, CCs plot the cumulative proportion of a health outcome in a population against the cumulative proportion of the population ranked in ascending order of economic status. The CC lies above or below the line of equality (the 45° line from the origin) if the outcome is more prevalent among the poorer or richer households respectively.[4 6 28 29] The CC may also intersect the line of equality, which would mean that households at that point in the wealth distribution have exactly their proportionate level or prevalence of the health outcome, and those to the left and right of the intersection have proportionately more and less of the outcome respectively (or vice versa). The CIX is twice the area between the CC and the line of equality. Negative (positive) CIX values indicate the health outcome is more concentrated among poor (rich) households.[4 6 18 28 29] We converted CIX to the Erreygers version,[30] which corrects for dependence on the mean of the outcome but retains the same qualitative interpretation.

Second, to review the association between economic inequality and nutrition outcomes, we included multilevel studies where households were nested within larger geographical areas, and the exposure was the Gini coefficient. Gini coefficients were also chosen because our scoping research found this to be the most common measure of income inequality. Gini coefficients are based on Lorenz curves, which are similar to CC except they depict economic inequality rather than health inequality.[31] This means that they plot the cumulative proportion of economic status (rather than a health outcome) against the cumulative

proportion of the population ranked by economic status. Analogous to CC and CIX, the Gini coefficient is twice the area between Lorenz curve and the 45° line of equality. Values closer to 0 or 1 indicate lower or higher inequality, respectively. A key difference between Lorenz curves and CC is that the former must always be below line of equality whereas the CC can be above or below it, and this means that Gini coeffficients are bounded by 0 and 1, whereas CIX are bounded by −1 and +1. This is because health outcomes can be concentrated among the poor, while wealth, by definition, cannot.

We only included multilevel studies because they permit the inclusion of household-level economic status, so can disentangle effects of economic inequality from absolute economic status,[32] and are at lower risk of bias from ecological fallacy.[32 33]

We searched Medline, Embase, Global Health, Eldis, Web of Science and EBSCO Discovery Service between 1 November 2020 and 3 November 2020. EBSCO Discovery Service includes the National Bureau of Economic Research, EconLit, Jstor and Scopus. We used keywords for 'wealth or income,' 'inequality,' 'concentration index' or 'multilevel models,' and, 'nutritional status' (sample search string in online supplemental table S1). There were no date or language restrictions. We contacted 39 experts and tracked citations of relevant reviews and articles included for full-text screening.

Two reviewers (HN and RA) doubly screened the articles, first by title and abstract, and then by full text. Disagreements were resolved by a third reviewer (EF).

Data extraction

Data were doubly extracted by HN, RA, EF and HH-F. We extracted data on sample characteristics; sample size; response rate; outcome indicator and prevalence; measure of economic status; data source and year; geographical unit; measure of inequality; effect sizes that could be converted into CIX or logit estimates; measures of variance that could be converted into 95% CIs; covariates; author names; survey date and publication year. When estimates were disaggregated by obesity and overweight, or by gender, we extracted the aggregated results if presented, and otherwise used the disaggregated estimates. We contacted authors to retrieve missing data on outcome prevalence and SEs or where interpretations needed clarification. CCs were extracted with the web plot digitiser online tool.[34] We handled duplicates (estimates on the same outcome from the same survey data) by selecting estimates with the highest quality rating and averaging the remaining duplicates. For maps, we handled duplicates in the same way but only included latest and nationally representative estimates.

Quality assessment

The quality of evidence was assessed using the Appraisal Tool for Cross-Sectional Studies (AXIS tool) at the study level.[35] Two reviewers independently graded each included study as 'low', 'moderate', 'high' or 'critical' risk of bias. Grades are given in online supplemental table S2,S4A. Discrepancies in overall ratings were discussed and resolved. We excluded no studies based on quality but conducted subgroup analyses to assess if study quality unduly affected our conclusions.

Data analysis

We conducted meta-analyses and mapped CIX for child stunting, wasting and adult overweight or obesity; other outcomes produced ≤2 studies so were not included in a meta-analysis or mapped but are narratively described. For associations between Gini coefficient and nutritional outcomes, results were standardised to logit estimates and meta-analyses were possible for adult underweight, and overweight and obesity. To account for the hierarchical structure of the data (several estimates per country and region), all meta-analyses were performed as multilevel random effects meta-analyses.[36]

We cleaned and plotted CCs with Stata (V.16.1), ran multilevel models with R (V.4.0.3) and created maps using ArcMap (V.10.8.1).

We report Q statistic to describe heterogeneity in study estimates. Funnel plots and Egger tests assessed publication bias.

Prespecified subgroup analyses were: study quality rating, tertiles of country-level estimates of food security (dietary energy supply, measured as kcal/capita/d),[37] country income level (low, lower-middle, upper-middle and high gross national income, as per World Bank classification),[38] tertiles of WHO universal health coverage score (scale of 0–100, measured as the mean of 14 indicators),[39] seven World Bank geographical regions, and tertiles of study date. Additionally, for associations between Gini coefficient and nutrition outcomes, we disaggregated by the geographical unit the Gini coefficient was measured (first, second and third and lower subnational levels) as this was suggested as an important mitigating factor.[40 41]

RESULTS

Figure 1 shows the study selection process. We included 79 articles reporting economic inequalities in malnutrition outcomes using CIX.[29 42–119] Of these, 46 studies (426 estimates) were included in meta-analyses, giving 277 estimates (90 countries) for stunting, 60 (33 countries) for wasting and 89 (21 countries) for adult overweight or obesity.

A summary of study characteristics for CIX included in meta-analysis is given in online supplemental table S2. Most estimates were from sub-Saharan Africa for stunting (47%) and wasting (50%). For overweight and obesity, most estimates were from Europe and Central Asia (49%).

Figure 2A–C maps nationally representative CIX for stunting (88 countries), wasting (30 countries) and adult overweight and obesity (19 countries). They show a lack of evidence on the concentration of stunting or wasting by

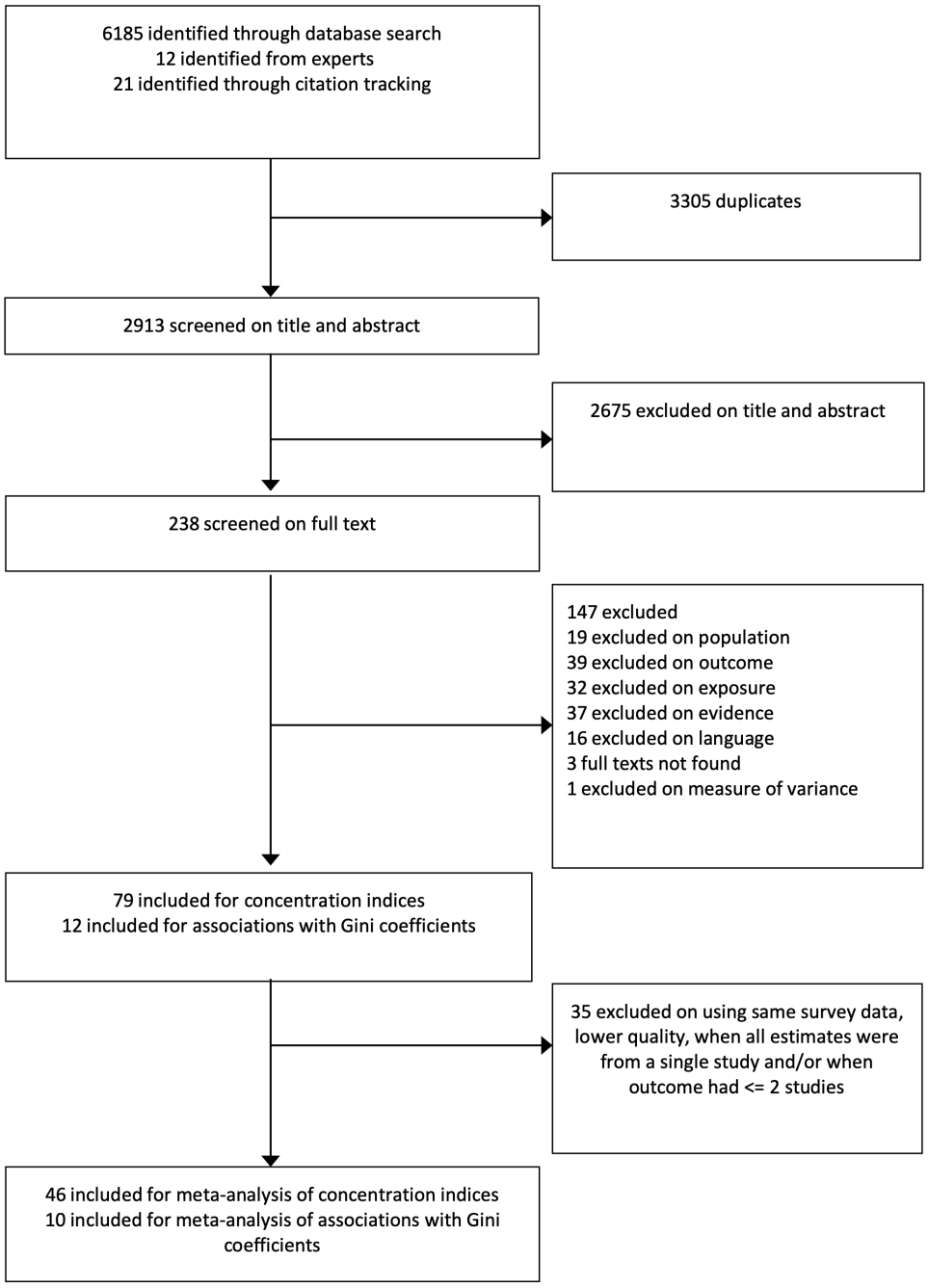

Figure 1 Study selection.

economic status in some African and Southern Asian countries, where stunting and wasting remains prevalent but CIX have not been published, and very few CIX for overweight and obesity published across Africa, Asia and Latin America.

Figure 3A shows the pooled CIX estimate for stunting of −0.15 (95% CI −0.19 to −0.11), and a global average CC which bulges towards the upper left of the plot and is strictly above the equality line, indicating concentration of stunting among poor households within studies. Stunting is more concentrated within than between studies, except for the richest 20% of the population and the richest 20% of study contexts. There is high overall heterogeneity (Q=9299, p<0.01) (online supplemental figure S1). Individual CCs (online supplemental figure S2) confirm virtually all estimates find stunting concentrated in poorer households.

Figure 3B shows the inequality in stunting is most pronounced in Latin America and the Caribbean (CIX −0.22 (95% CI −0.29 to −0.15)) and South Asia (−0.21 (95% CI −0.29 to −0.13)). The map of most recent stunting estimates in figure 2A supports this and illustrates that, despite the relatively narrow CI, the Latin America and Caribbean region still contains large levels of heterogeneity, with some of the most and least extreme concentrations (eg, Guatemala (2008) with CIX −0.42 vs Brazil (2006) with CIX −0.03). The map also indicates consistently low CIX in the most recent estimates for

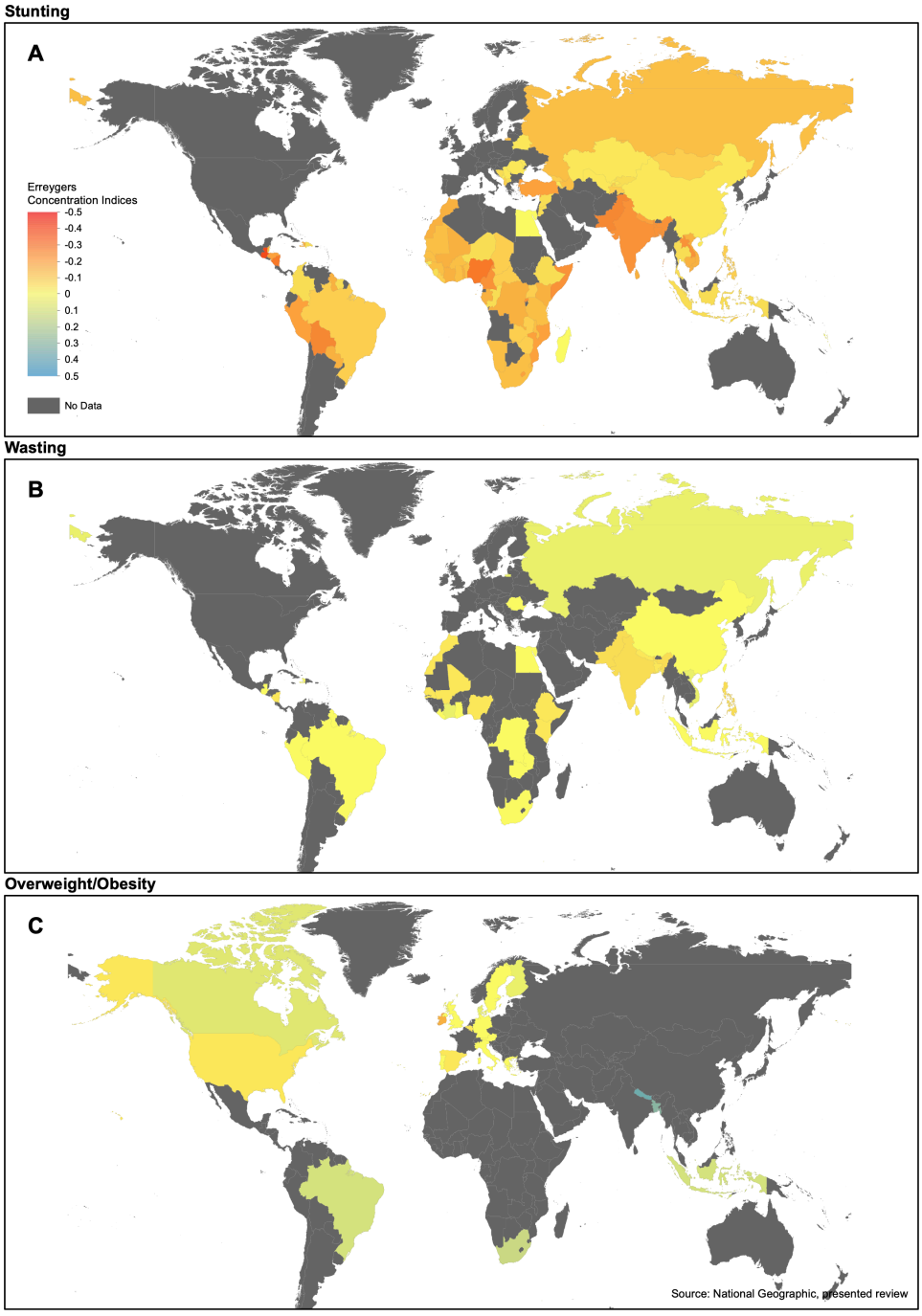

Figure 2 Map of most recent concentration indices for prevalence of stunting, wasting and overweight and obesity.

South Asia, and higher CIX in some Eastern European countries, Brazil, China, Egypt and Madagascar.

Figure 3C shows wasting is also concentrated among poor households (pooled CIX −0.03 (95% CI −0.05 to −0.02), and it is also more concentrated within than between studies. Estimates are also heterogeneous (Q=446; p<0.01) (online supplemental figure S3). The regionally disaggregated curves (figure 3D) show wasting is concentrated among the poor in all regions, with smaller differences between regions than stunting. There are slightly higher CIX in South Asia, and lower CIX in Europe and Central Asia (the latter due to estimates from Armenia and Thailand, as shown in online supplemental figure S4).

Figure 4A shows overweight and obesity is slightly more concentrated among better-off households (CIX 0.08 (95% CI −0.00, 0.17)) and there is also more inequality within than between studies. Results are heterogeneous (Q=34 324; p<0.01) (online supplemental figure S5).

Regional subgroups (figure 4B) show more concentration of overweight and obesity among better-off households in studies from South Asia (0.26 (95% CI 0.19 to 0.34)), sub-Saharan Africa (0.13 (95% CI 0.05 to 0.20)) and East Asia and Pacific (0.11 (95% CI 0.03 to 0.18)), and comparatively more concentration among poorer households in North America (−0.04 (95% CI −0.10 to 0.03)) and Europe and Central Asia (−0.02 (95% CI −0.08 to 0.05)). Figure 2C and online

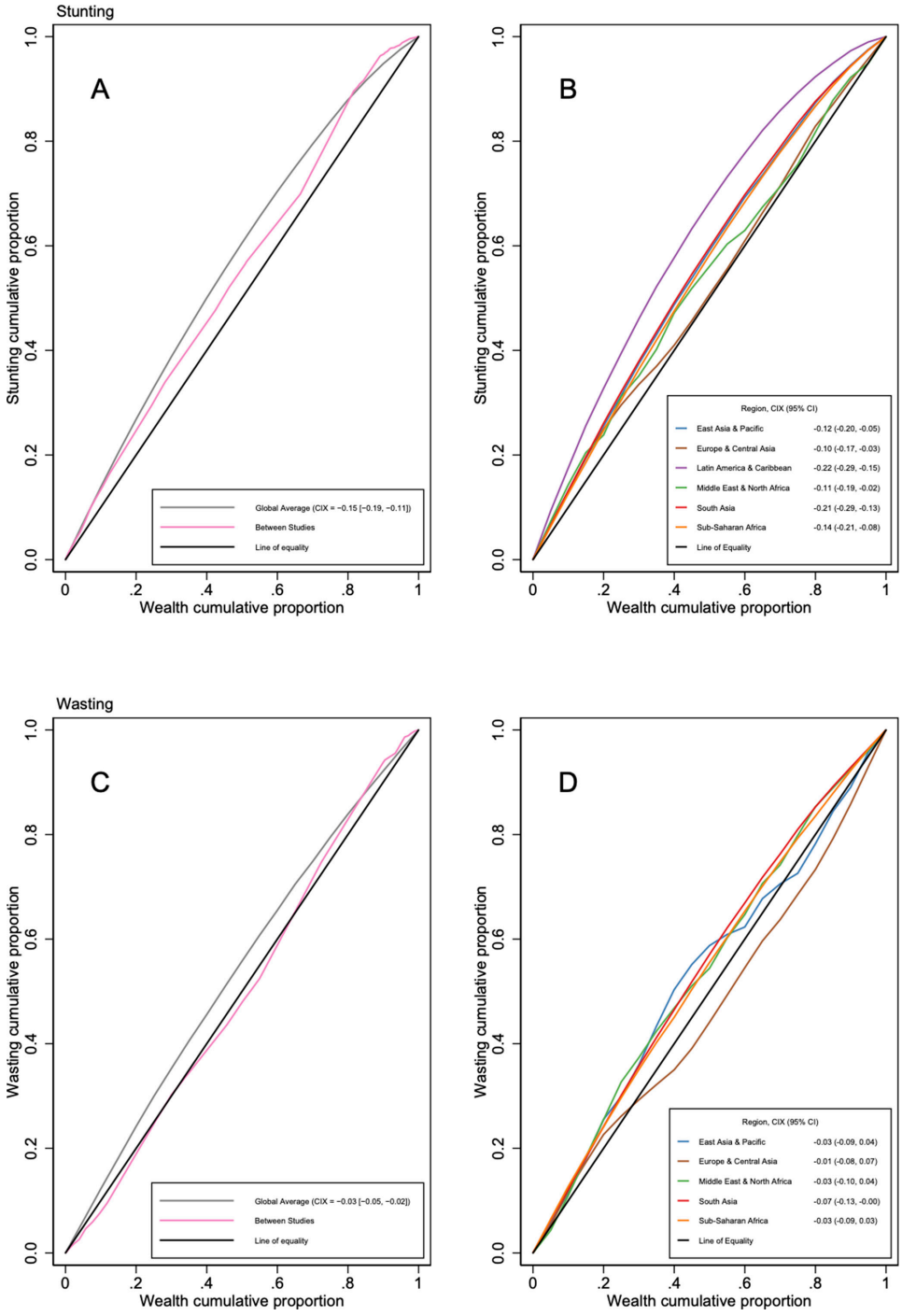

Figure 3 Concentration of stunting and wasting by economic status. Average concentration curves plot population-weighted average cumulative proportion of malnourished subjects over the population-weighted average cumulative proportion of economic status. Between studies concentration curve plot cumulative product of population and prevalence over the cumulative Gross Domestic Product of countries. CIX, concentration index.

supplemental figure S6 show these pooled CIX estimates are driven by higher CIX in studies from Nepal, Bangladesh, Indonesia and a multicountry study from Africa, and lower CIX in Canada, USA and western Europe. Consistent with this, subgroup analyses show that overweight and obesity is concentrated among better-off households in studies from low-income and lower-middle-income countries (0.18 (95% CI 0.09 to 0.28) for both) (online supplemental figure S5).

Aside from the subgroups mentioned, other subgroups for stunting, wasting, or overweight and obesity do not show consistent trends (online supplemental figures S1, S3 and S5, respectively).

For outcomes not meta-analysed, we found two studies each on child anaemia, adult anaemia, and adult underweight, and one for child overweight. For child anaemia, one study showed moderate concentration of anaemia

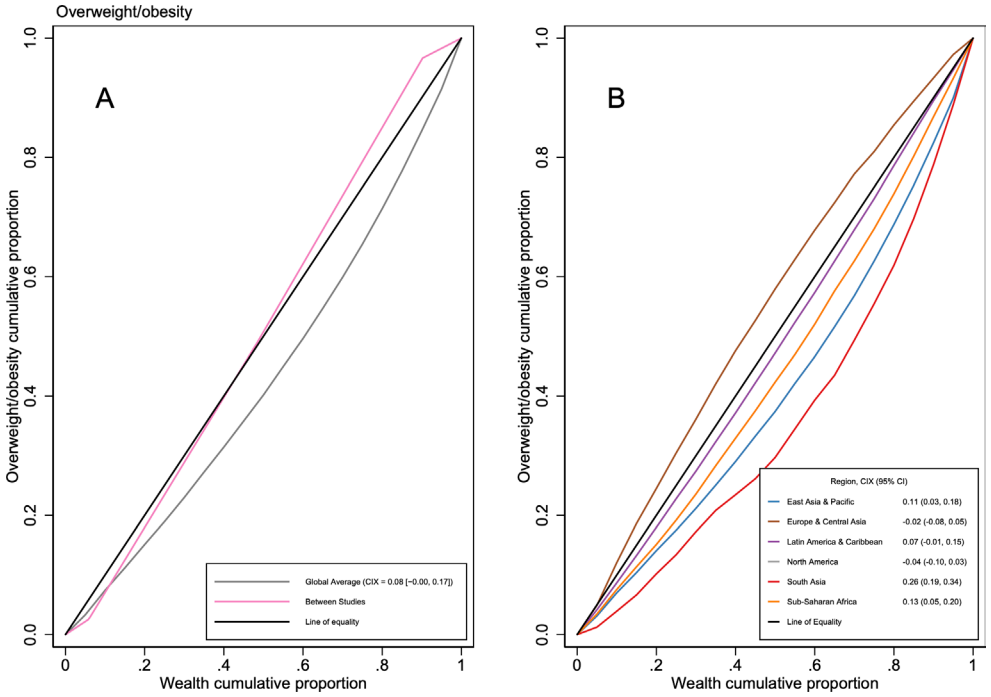

Figure 4 Concentration of overweight and obesity by economic status. Average concentration curves plot population-weighted average cumulative proportion of malnourished subjects over the population-weighted average cumulative proportion of economic status. Between studies concentration curve plot cumulative product of population and prevalence over the cumulative Gross Domestic Product of countries. No concentration curves available for North America. CIX, concentration index.

among poor households across 35 countries in sub-Saharan Africa −0.10 (95% CI −0.11 to −0.10),[83] and the other showed the same in Cambodia, reported as CC.[105] For anaemia in adults, one study showed small CIXs in Nepal (range: −0.05 to 0.02)[93] and another showed larger CIX in Bangladesh (−0.14 (95% CI −0.17 to −0.11)).[79] For adult underweight, studies also showed a smaller CIX from Nepal (−0.04 (95% CI −0.07 to −0.00))[94] and a larger CIX from Bangladesh (−0.23 (95% CI −0.24 to −0.21).(75) For child overweight we found a small CIX from households in 35 sub-Saharan African countries (CIX 0.01 (95% CI 0.01 to 0.02)).[83]

Assessing within-study bias, we classified most CIX studies as moderate risk (44/79; 56%), but this proportion was lower in estimates included in meta-analysis due to removal of duplicates with higher risk of bias (online supplemental table 2). The most common limitation was risk of misclassifying economic status. Subgroups analyses found no clear differences by risk of bias. Egger tests and funnel plots (online supplemental table S3 and figure S7) indicate effect sizes and heterogeneity may be exaggerated by small-study effects for stunting and overweight and obesity, but not wasting.

To review the association between Gini coefficient and nutrition outcomes, we identified 12 studies (47 estimates)[40 41 120–129] (online supplemental table S4A). Of these, 10 were included in meta-analyses. We identified 6 estimates for stunting, 6 for adult underweight (4 independent), 33 for adult overweight and obesity (16 independent), 1 each on adult and child anaemia, and none on wasting. Authors' covariate adjustments are given in online supplemental table S4B.

Child stunting estimates emanate from the same study on two countries: Bangladesh and Kenya.[41] Effect sizes range from highly negative (logit: −2.53 (95% CI −4.40 to −0.65)) to highly positive (logit: 3.84 (95% CI 0.28 to 7.41)).

For adult underweight, estimates come from three studies in USA, India and Indonesia. Figure 5A shows no consistent association with the Gini coefficient (logit: 0.25 (95% CI −0.62 to 1.11); four estimates). In terms of ORs, this is 1.03 (95% CI 0.94 to 1.12). Subgroup analyses show no clear differences (online supplemental figure S8).

For adult overweight and obesity (figure 5B), we find no consistent association with Gini coefficient (logit: −0.88 (95% CI −2.24 to 0.48); 16 estimates). OR is 0.92 (95% CI 0.80 to 1.05). Effects are heterogeneous (Q=175, p<0.01), and most of the precise estimates are close to zero, whereas estimates showing positive or negative associations are less precise. Subgroup analyses show no consistent differences (online supplemental figure S9).

For anaemia, we found one study, which showed higher odds of children having anaemia if they lived in a country with higher inequality (logit coefficient 0.61 (95% CI 0.34 to 0.88); 30 countries) but no difference for anaemia in women (0.16 (95% CI −0.06 to 0.38); 33 countries).[122]

We classified most (9/12, 75%) associational studies as moderate risk of bias. Common limitations were unclear measurement of outcome or exposure, and not justifying the sample size. Risk of bias did not explain the heterogeneity of associations in the subgroup analyses. There

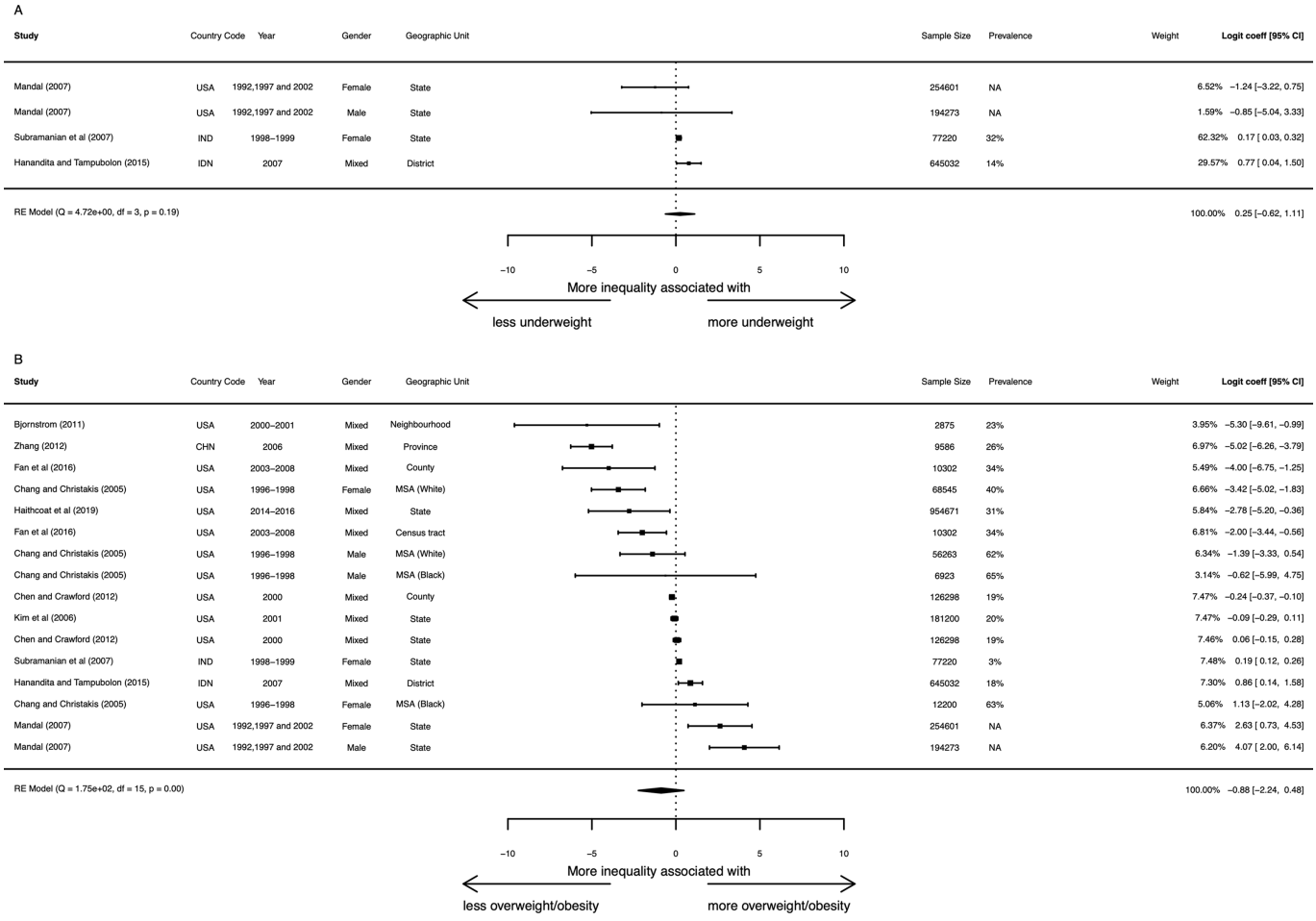

Figure 5 Meta-analysis of association between economic inequality and malnutrition. Random effects meta-analysis adjusting for clustering within countries and regions, where exposure (Gini coefficient) is on a 0–1 scale, and effect size is logged odds of malnutrition. MSA (black)—individuals of black ethnicity in Metropolitan Statistical Areas, MSA (white)—individuals of white ethnicity in MSA. MSA, metropolitan statistical areas.

is some indication of small-study effects for adult overweight and obesity but not adult underweight (online supplemental table S5 and figure S10).

DISCUSSION

Our review found that almost all CIX for child undernutrition were negative, indicating that child undernutrition is disproportionately concentrated in the poorest households worldwide. In contrast, the direction of CIX in overweight and obesity varies regionally. In some places, like South and East Asia and sub-Saharan Africa, overweight and obesity are concentrated among better off households, while in North America and Europe and Central Asia, if anything, poorer households are more affected. We also find important evidence gaps, with a lack of studies reporting CIX for child overweight, and adult and child anaemia. Although these CIX show wide inequalities in the distribution of malnutrition, we find overall null associations between our measure of income inequality (Gini coefficients) and nutritional status. Evidence on the links between economic inequality and undernutrition is too thin to draw robust conclusions, and heavily biased towards the USA for adult overweight and obesity. We need globally representative research to unpack causal pathways between economic inequality and the different forms of malnutrition.

Our study has some limitations. First, reviews of observational studies carry a risk of bias. We find some evidence of bias within and between studies, as shown by some potential small-study effects, perhaps due to the lack of methodological standardisation. Second, to minimise risk of bias, we restricted our review of associations with Gini coefficients to multilevel studies. This may produce conservative estimates and have narrower geographical coverage. However, ecological studies we discuss below find a similarly heterogeneous picture. Third, all studies were published before the COVID-19 pandemic; country-specific estimates may need to be updated after such a large shock to both health and economies.

Our review shows that, while still a global problem,[130] undernutrition is most common in poor households in low-income countries. These results are consistent with other studies that only look at the extremes of the distribution or compare wealth groups across countries.[1] The

concentration of stunting is also regionally clustered, perhaps because neighbouring countries share common factors that affect nutrition and economic status, such as agroecological conditions, structural barriers, food environments, dietary behaviours, sanitation, education and employment levels.[131–133]

Given that almost every undernutrition CIX in our review was negative, isolated studies producing another negative CIX provide limited additional value. Our global and regional CIX give context for future inequality studies, so magnitudes can be compared against our estimates. These results also highlight the need for undernutrition interventions to be 'pro-poor', for example, by providing targeted interventions (such as social safety nets) and ensuring universal interventions have equitable reach and quality (such as universal healthcare).[1 134] However, none of the country-level factors that we thought might modify the relationship between economic status and nutrition—income level, food security and healthcare coverage—explain economic inequalities in undernutrition. Therefore, although they protect against undernutrition,[135 136] work is needed to ensure countries' economies, food systems, and health systems benefit those who need it most.

In contrast, we find more concentration of overweight and obesity in better-off households from lower-income countries compared with high-income countries. These findings are consistent with a systematic review,[137] which showed that the association between economic status and obesity varies by country income level; our review adds to this by describing and mapping the extent of the concentration within and between study populations. Our findings also align with the broader evidence base on the global nutrition transition, whereby overweight and obesity (historically more common in richer households from higher-income countries) is now more common in poorer households in higher-income countries and in better-off households in lower-income countries.[138 139] However, our subgroup analyses (online supplemental figures S1, S3, S5) do not reveal clear time trends, and small cell sizes do not permit exploration of heterogeneity in time trends between higher-income and lower-income countries.

Nevertheless, our results indicate that the level and direction of targeting of overweight and obesity interventions will need to be contextually specific. Depending on the intervention and country, it may be useful to target better-off households from lower-income countries (eg, social and behaviour change interventions to discourage unhealthy food selection in supermarkets and retail outlets frequented by the well-off)[140] or poorer households in higher-income countries (eg, providing healthy free school meals).[141] However, to comprehensively address the multilevel drivers of all forms of malnutrition, it is increasingly recognised that macrolevel interventions across sectors and countries are needed to increase individual's agency, and create healthy food environments and equitable food systems.[1 142]

Despite large economic inequalities in the burden of malnutrition, and previous studies showing that economic inequality is associated with poor health,[21–23] we found little overall support that economic inequality is associated with malnutrition. We lack evidence on the associations between Gini coefficients and undernutrition, limiting our ability to draw robust conclusions. As noted, evidence on overweight and obesity is disproportionately from the USA. Although significant trends may be observed in other countries, an ecological study of 31 OECD countries found that the positive correlation between economic inequality and obesity disappeared after excluding the USA and Mexico, suggesting this may not be the case.[143] Ecological studies also show wide heterogeneity, finding that economic inequality is associated with higher,[144 145] lower[146] or no difference[147] in overweight or obesity. It is difficult to discern whether these inconsistent trends are due to the difficulties in identifying unbiased estimates or variation in true effects. A further complication is that associations between Gini coefficients and nutritional outcomes may be non-linear, and could interact with absolute levels of economic status. Although all studies included in our review adjusted for household-level income or wealth status, they predominantly focused on linear associations between economic inequality and nutrition, and were not designed to compare the effects of absolute vs relative income or wealth on malnutrition. Future research could include wider geographical contexts, include different forms of malnutrition, and characterise the nature of the relationship between absolute and relative income or wealth.

Acknowledgements We thank Megan Deeney for her input in conceptualising this review and Prof Elizabeth Allen for guidance with the meta-analyses. We thank Prof William Masters and Keith Lividini for their advice regarding the presentation of data. We are grateful to the authors who responded with clarifications, and subject matter experts who responded with study suggestions.

Contributors HH-F, RA and SK conceptualised the systematic review with inputs from BS, EF and HN. RA and HN conceived and ran the search strategy with inputs from HH-F. HN, RA and EF screened references retrieved, selected eligible studies based on the eligibility criteria and critically appraised studies. HN conducted the statistical analyses, with support from HH-F. RA, HN and HH-F wrote the manuscript with inputs from SK, EF and BS. Guarantors HH-F, RA, and HN accept full responsibility for the work and the conduct of the study, had access to the data, and controlled the decision to publish.

Funding Funding of RA and HN was provided by Innovative Methods and Metrics for Agriculture and Nutrition Actions (IMMANA). IMMANA is cofunded with FCDO from the UK government (Project 300654) and the Bill & Melinda Gates Foundation (Investment ID INV-002962). Funding of author HH-F was provided by a Sir Henry Wellcome grant (210894/Z/18/Z). All authors had full access to all of the data (including statistical reports and tables) in the study and can take responsibility for the integrity of the data and the accuracy of the data analysis.

Disclaimer The study funders had no role in the study design; in the collection, analysis, and interpretation of data; in the writing of the report; or in the decision to submit the article for publication. We confirm the independence of researchers from funders.

Competing interests All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: HN, RA and EF had financial support from IMMANA (co-funded by FCDO and Bill & Melinda Gates Foundation) and HH-F had financial support from Wellcome Trust for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Patient consent for publication Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement No data are available.

ORCID iD

Helen Harris-Fry http://orcid.org/0000-0003-2367-908X

REFERENCES

1 Development Initiatives. *2020 global nutrition report: action on equity to end malnutrition*. Bristol, UK, 2020.
2 Victora CG, Christian P, Vidaletti LP, *et al*. Revisiting maternal and child undernutrition in low-income and middle-income countries: variable progress towards an unfinished agenda. *Lancet* 2021;397:1388–99.
3 Hosseinpoor A, Bergen N. *Health inequality monitoring*. Luxembourg: WHO Press, 2013.
4 Kakwani N, Wagstaff A, Van Doorslaer E. Socioeconomic inequalities in health: measurement, computation, and statistical inference. *J Econom* 1997;77:87–103.
5 Alao R. Measures of socioeconomic inequality and their associations with maternal and child health outcomes in sub-Saharan Africa: a systematic review, 2020. Available: https://drive.google.com/file/d/1q_tdOfbFX0aVzvzGuklKcepBfBkqyaw5/view?usp=sharing [Accessed 9 Nov 2021].
6 Wagstaff A, Paci P, van Doorslaer E. On the measurement of inequalities in health. *Soc Sci Med* 1991;33:545–57.
7 Pickett K, Wilkinson R. Income inequality and psychosocial pathways to obesity. *Proceedings-British Academy* 2013:179–98.
8 Kaplan GA. People and places: contrasting perspectives on the association between social class and health. *Int J Health Serv* 1996;26:507–19.
9 Adler NE, Boyce T, Chesney MA, *et al*. Socioeconomic status and health. The challenge of the gradient. *Am Psychol* 1994;49:15–24.
10 Kahn RS, Wise PH, Kennedy BP, *et al*. State income inequality, household income, and maternal mental and physical health: cross sectional national survey. *BMJ* 2000;321:1311–5.
11 Kondo N, Kawachi I, Subramanian SV, *et al*. Do social comparisons explain the association between income inequality and health? Relative deprivation and perceived health among male and female Japanese individuals. *Soc Sci Med* 2008;67:982–7.
12 Kondo N, Kawachi I, Hirai H, *et al*. Relative deprivation and incident functional disability among older Japanese women and men: prospective cohort study. *J Epidemiol Community Health* 2009;63:461–7.
13 Wilkinson RG. Health inequalities: relative or absolute material standards? *Br Med J* 1997;314:591–5.
14 Subramanian SV, Kawachi I. Income inequality and health: what have we learned so far? *Epidemiol Rev* 2004;26:78–91.
15 Wilkinson RG, Pickett KE. Income inequality and population health: a review and explanation of the evidence. *Soc Sci Med* 2006;62:1768–84.
16 House JS, Landis KR, Umberson D. Social relationships and health. *Science* 1988;241:540–5.
17 Diez-Roux AV, Link BG, Northridge ME. A multilevel analysis of income inequality and cardiovascular disease risk factors. *Soc Sci Med* 2000;50:673–87.
18 Kondo N, Sembajwe G, Kawachi I, *et al*. Income inequality, mortality, and self rated health: meta-analysis of multilevel studies. *BMJ* 2009;339:b4471.
19 Smith GD. Income inequality and mortality: why are they related? *BMJ* 1996;312:987–8.
20 Lynch JW, Kaplan GA. Understanding how inequality in the distribution of income affects health. *J Health Psychol* 1997;2:297–314.
21 Wagstaff A, van Doorslaer E. Income inequality and health: what does the literature tell us? *Annu Rev Public Health* 2000;21:543–67.
22 Lynch JW, Smith GD, Kaplan GA. Income inequality and mortality: importance to health of individual income, psychosocial environment, or material conditions. *Br Med J* 2000;320:1200–4.
23 Mellor JM, Milyo J. Reexamining the evidence of an ecological association between income inequality and health. *J Health Polit Policy Law* 2001;26:487–522.
24 et alAlao R, Nur H, Fivian E. Association between relative economic inequality and nutrition: review protocol. PROSPERO, 2020. Available: https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=201572 [Accessed 2 Feb 2021].
25 Page MJ, McKenzie JE, Bossuyt PM, *et al*. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021;372:n71.
26 World Health Organization. *Global nutrition targets 2025: policy brief series (WHO/NMH/NHD/14.2)*. Geneva, 2014.
27 Canberra Group. *United Nations Economic Commission for Europe, Canberra group*. Geneva: Household Income Statistics, 2011.
28 Bryden M, Blair C. *Measuring income inequality–a holistic approach*, 2015.
29 Van de Poel E, Hosseinpoor AR, Speybroeck N, *et al*. Socioeconomic inequality in malnutrition in developing countries. *Bull World Health Organ* 2008;86:282–91.
30 Kjellsson G, Gerdtham U-G. On correcting the concentration index for binary variables. *J Health Econ* 2013;32:659–70.
31 De Maio FG. Income inequality measures. *J Epidemiol Community Health* 2007;61:849–52.
32 Subramanian SV, Jones K, Duncan C. Multilevel methods for public health research. Kawachi, Ichiro; Berkman L, editor. *Neighb Heal* 2003:65–111.
33 Detels R, Gulliford M, Karim QA. *Oxford textbook of global public health*. 6th edn. Oxford: Oxford University Press, 2015: 411–5.
34 Rohatgi A. Web plot digitizer, 2020. Available: https://apps.automeris.io/wpd/ [Accessed 20 Jan 2021].
35 Downes MJ, Brennan ML, Williams HC. Development of a critical appraisal tool to assess the quality of cross-sectional studies (axis). *BMJ Open* 2016;6:1–7.
36 Harrer M, Cuijpers P, Furukawa TA. *Doing meta-analysis in R: a hands-on guide*, 2019.
37 Food and Agriculture Organisation of the United Nations. Suite of food security indicators, 2020. Available: http://www.fao.org/faostat/en/#data/FS [Accessed 30 Dec 2020].
38 World Bank. World bank classification of countries, 2020. Available: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups [Accessed 30 Dec 2020].
39 WHO. *Global monitoring report on financial protection in health 2019*. Geneva: Switzerland, 2019.
40 Chen Z, Gotway Crawford CA, Crawford GC. The role of geographic scale in testing the income inequality hypothesis as an explanation of health disparities. *Soc Sci Med* 2012;75:1022–31.
41 Reinbold GW. Economic inequality and child stunting in Bangladesh and Kenya: an investigation of six hypotheses. *Popul Dev Rev* 2011;37:691–719.
42 Almasian Kia A, Rezapour A, Khosravi A, *et al*. Socioeconomic inequality in malnutrition in under-5 children in Iran: evidence from the multiple indicator demographic and health survey, 2010. *J Prev Med Public Health* 2017;50:201–9.
43 Angdembe MR, Dulal BP, Bhattarai K, *et al*. Trends and predictors of inequality in childhood stunting in Nepal from 1996 to 2016. *Int J Equity Health* 2019;18:42.
44 Arokiasamy P, Jain K, Goli S, *et al*. Health inequalities among urban children in India: a comparative assessment of Empowered Action Group (EAG) and South Indian states. *J Biosoc Sci* 2013;45:167–85.
45 Assaf S, Pullum T. Levels and trends in maternal and child health disparities by wealth and region in eleven countries with DHS surveys. *DHS Comp Reports* 2016;1:50–8.

46 Asuman D, Ackah CG, Fenny AP. Assessing socioeconomic inequalities in the reduction of child stunting in sub-Saharan Africa. *J Public Heal* 2019;28:563–73.
47 Axelson H, Gerdtham U-G, Ekman B, *et al*. Inequalities in reproductive, maternal, newborn and child health in Vietnam: a retrospective study of survey data for 1997-2006. *BMC Health Serv Res* 2012;12:456.
48 Sipahi BB. Effect of socioeconomic factors and income inequality to obesity in female in Turkey. *J Soc Sci* 2020;19:350–66.
49 Bilger M, Kruger EJ, Finkelstein EA. Measuring socioeconomic inequality in obesity: looking beyond the obesity threshold. *Health Econ* 2017;26:1052–66.
50 Bredenkamp C, Buisman LR, Van de Poel E. Persistent inequalities in child undernutrition: evidence from 80 countries, from 1990 to today. *Int J Epidemiol* 2014;43:1328–35.
51 Nwosu CO, Ataguba JE-O. Explaining changes in wealth inequalities in child health: the case of stunting and wasting in Nigeria. *PLoS One* 2020;15:1–16.
52 Jonah CMP, Sambu WC, May JD. A comparative analysis of socioeconomic inequities in stunting: a case of three middle-income African countries. *Arch Public Health* 2018;76:77.
53 Adali T, Tezcan S. A reflection of social inequality: childhood malnutrition in Turkey. *Turkish J Popul Stud* 2013;35:3–17.
54 Madden D. The socioeconomic gradient of obesity in Ireland. *Econ Soc Rev* 2010;44:181–96.
55 Davillas A, Benzeval M. Alternative measures to BMI: exploring income-related inequalities in adiposity in Great Britain. *Soc Sci Med* 2016;166:223–32.
56 Edeh HC, Ichoku HE, Iloka EC. Inequality in under-five child malnutrition: evidence from Nigeria multiple indicator cluster survey. *J Econ Sustain Dev* 2017;8:14–20.
57 Flores-Quispe MDP, Restrepo-Méndez MC, Maia MFS, *et al*. Trends in socioeconomic inequalities in stunting prevalence in Latin America and the Caribbean countries: differences between quintiles and deciles. *Int J Equity Health* 2019;18:156.
58 Fotso J-C, Kuate-Defo B. Household and community socioeconomic influences on early childhood malnutrition in Africa. *J Biosoc Sci* 2006;38:289–313.
59 Hajizadeh M, Campbell MK, Sarma S. Socioeconomic inequalities in adult obesity risk in Canada: trends and decomposition analyses. *Eur J Health Econ* 2014;15:203–21.
60 Hangoma P, Aakvik A, Robberstad B. Explaining changes in child health inequality in the run up to the 2015 millennium development goals (MDGs): the case of Zambia. *PLoS One* 2017;12:1–21.
61 Harutyunyan T. *Socio-economic determinants of child nutritional status in Armenia: the analysis of 2000 and 2005 Demographic and Health Surveys [dissertation]*. University of North Carolina, 2011.
62 Huda TM, Hayes A, El Arifeen S, *et al*. Social determinants of inequalities in child undernutrition in Bangladesh: a decomposition analysis. *Matern Child Nutr* 2018;14:1–12.
63 Amirian H, Poorolajal J, Roshanaei G. Analyzing socioeconomic related health inequality in mothers and children using the concentration index. *Epidemiol Biostat Public Heal* 2014;11:e9086-1–10.
64 Nikolaou A, Nikolaou D. Income-related inequality in the distribution of obesity among Europeans. *J Public Heal* 2008;16:403–11.
65 Islam MR, Rahman MS, Rahman MM, *et al*. Reducing childhood malnutrition in Bangladesh: the importance of addressing socio-economic inequalities. *Public Health Nutr* 2020;23:72–82.
66 Jayawardena P. Socio-economic determinants and inequalities in child socio-economic determinants and inequalities. *Well-being Soc Policy* 2017;8:1–22.
67 Mariapun J, Ng C-W, Hairi NN. The gradual shift of overweight, obesity, and abdominal obesity towards the poor in a multi-ethnic developing country: findings from the Malaysian national health and morbidity surveys. *J Epidemiol* 2018;28:279–86.
68 Keetile M, Navaneetham K, Letamo G. Socioeconomic inequalities in non-communicable disease risk factors in Botswana: a cross-sectional study. *BMC Public Health* 2019;19:1–9.
69 Wong KLM, Restrepo-Méndez MC, Barros AJD, *et al*. Socioeconomic inequalities in skilled birth attendance and child stunting in selected low and middle income countries: wealth quintiles or deciles? *PLoS One* 2017;12:1–17.
70 Khadse RP, Chaurasia H. Nutrition status and inequality among children in different geographical regions of Maharashtra, India. *Clin Epidemiol Glob Heal* 2020;8:128–37.
71 Eide KT, Fadnes LT, Engebretsen IMS, *et al*. Impact of a peer-counseling intervention on breastfeeding practices in different socioeconomic strata: results from the equity analysis of the PROMISE-EBF trial in Uganda. *Glob Health Action* 2016;9:30578.
72 Kumar A, Kumari D, Singh A. Increasing socioeconomic inequality in childhood undernutrition in urban India: trends between 1992-93, 1998-99 and 2005-06. *Health Policy Plan* 2015;30:1003–16.
73 Kumar A, Mohanty SK. State of child health among poor and non-poor in urban India. *Genus* 2011;1:1–19.
74 Laillou A, Gauthier L, Wieringa F, *et al*. Reducing malnutrition in Cambodia. A modeling exercise to prioritize multisectoral interventions. *Matern Child Nutr* 2020;16:e12770.
75 Ahmed S, Hasan M, Ahmed MW. Socioeconomic inequity of malnutrition among under-five children and women at reproductive age in Bangladesh. *J Nutr Heal* 2013;1:18–22.
76 Limwattananon S, Tangcharoensathien V, Prakongsai P. Equity in maternal and child health in Thailand. *Bull World Health Organ* 2010;88:420–7.
77 Ljungvall A, Gerdtham U-G. More equal but heavier: a longitudinal analysis of income-related obesity inequalities in an adult Swedish cohort. *Soc Sci Med* 2010;70:221–31.
78 Mahumud RA, Gow J, Sarker AR, *et al*. Distribution of wealth-stratified inequalities on maternal and child health parameters and influences of maternal-related factors on improvements in child health survival rate in Bangladesh. *J Child Health Care* 2021;25:1–17.
79 Restrepo-Mendez MC, Barros AJD, Requejo J. Progress in reducing inequalities in reproductive, maternal, newborn, and child health in Latin America and the Caribbean: an unfinished agenda. *Pan Am J Public* 2015;38:9–16.
80 Sumit M. Determinants of inequality in child malnutrition in India: the poverty-undernutrition linkage. *Asian Popul Stud* 2010;6:307–33.
81 Zere E, McIntyre D. Inequities in under-five child malnutrition in South Africa. *Int J Equity Health* 2003;2:1–10.
82 Meitei WB. Nutritional status of under-five children in northeast India: effect of household socioeconomic status. *Indian J Public Heal Res Dev* 2020;11:1003.
83 Ekholuenetale M, Tudeme G, Onikan A, *et al*. Socioeconomic inequalities in hidden hunger, undernutrition, and overweight among under-five children in 35 sub-Saharan Africa countries. *J Egypt Public Health Assoc* 2020;95:9.
84 Pulok MH, Sabah MN-U, Enemark U. Socioeconomic inequalities of child malnutrition in Bangladesh. *Int J Soc Econ* 2016;43:1439–59.
85 Monteiro CA, Benicio MHD, Conde WL, *et al*. Narrowing socioeconomic inequality in child stunting: the Brazilian experience, 1974-2007. *Bull World Health Organ* 2010;88:305–11.
86 Aizawa T, Helble M. Socioeconomic inequity in excessive weight in Indonesia. ADBI Working Papers 2016.
87 Negasi MY. *Essays on dynamics of inequality in undernutrition, and impact of social protection program on nutrition and educational attainment in Ethiopia [dissertation]*. University of Milano-Bicocca, 2019.
88 Alaba O, Chola L. Socioeconomic inequalities in adult obesity prevalence in South Africa: a decomposition analysis. *Int J Environ Res Public Health* 2014;11:3387–406.
89 Ovrum A, Rickertsen K. Inequality in health versus inequality in lifestyles. *Nord J Heal Econ* 2011;1:1–16.
90 Pei L, Wang D, Ren L, *et al*. Evaluation of the rural primary health care project on undernutrition equity among children in rural Western China. *Health Policy Plan* 2013;28:429–34.
91 Rabbani A, Khan A, Yusuf S, *et al*. Trends and determinants of inequities in childhood stunting in Bangladesh from 1996/7 to 2014. *Int J Equity Health* 2016;15:186.
92 Rahman MS, Rahman MM, Gilmour S, *et al*. Trends in, and projections of, indicators of universal health coverage in Bangladesh, 1995–2030: a bayesian analysis of population-based household data. *Lancet Glob Heal* 2018;6:e84–94.
93 Rai A, Khan MN, Thapa S. Trends and determinants of anaemia in women of Nepal: a multilevel analysis. *Matern Child Nutr* 2020;16:e13044.
94 Rai A, Gurung S, Thapa S, *et al*. Correlates and inequality of underweight and overweight among women of reproductive age: evidence from the 2016 Nepal demographic health survey. *PLoS One* 2019;14:e0216644.
95 Ravaghi V, Quiñonez C, Allison PJ. Comparing inequalities in oral and general health: findings of the Canadian health measures survey. *Can J Public Health* 2013;104:e466.
96 Rizal MF, van Doorslaer E. Explaining the fall of socioeconomic inequality in childhood stunting in Indonesia. *SSM Popul Health* 2019;9:100469.
97 Akombi BJ, Agho KE, Renzaho AM, *et al*. Trends in socioeconomic inequalities in child undernutrition: Evidence from Nigeria Demographic and Health Survey (2003 - 2013). *PLoS One* 2019;14:e0211883.

98 Yaya S, Uthman OA, Ekholuenetale M, *et al*. Socioeconomic inequalities in the risk factors of noncommunicable diseases among women of reproductive age in sub-saharan Africa: a multi-country analysis of survey data. *Front Public Health* 2018;6:1–11.
99 Siegel M, Luengen M, Stock S. On age-specific variations in income-related inequalities in diabetes, hypertension and obesity. *Int J Public Health* 2013;58:33–41.
100 da Silva ICM, França GV, Barros AJD, *et al*. Socioeconomic inequalities persist despite declining stunting prevalence in low- and middle-income countries. *J Nutr* 2018;148:254–8.
101 Triaca LM, Dos Santos AMA, Tejada CAO. Socioeconomic inequalities in obesity in Brazil. *Econ Hum Biol* 2020;39:100906.
102 Vallejo-Torres L, Hale D, Morris S, *et al*. Income-related inequality in health and health-related behaviour: exploring the equalisation hypothesis. *J Epidemiol Community Heal* 2014;68:615–21.
103 Merino Ventosa M, Urbanos-Garrido RMMMVGC. Disentangling effects of socioeconomic status on obesity: a cross-sectional study of the Spanish adult population. *Econ Hum Biol* 2016;22:216–24.
104 Wagstaff A, Watanabe N. Socioeconomic inequalities in child malnutrition in the developing world. World Bank Policy Research Working Paper 2000.
105 Wang W. Assessing trends in inequalities in maternal and child health and health care in Cambodia. DHS Further Analysis Report No. 86. Maryland 2013.
106 Yang H. *Socioeconomic inequality of obesity in Canada [dissertation]*. University of Ottawa, 2014.
107 Zegeye B, Shibre G, Idriss-Wheeler D. Trends in inequalities in childhood stunting in Ethiopia from 2000 to 2016: a cross sectional study. *J Public Health* 2020:1–9.
108 Ambel AA, Andrews C, Bakilana AM, *et al*. Examining changes in maternal and child health inequalities in Ethiopia. *Int J Equity Health* 2017;16:152.
109 Zulu T. *Socioeconomic inequalities in non-communicable diseases in South Africa [dissertation*. University of Cape Town, 2019.
110 Amarante VerÃ³nica, Figueroa N, Ullman H. Inequalities in the reduction of child stunting over time in Latin America: evidence from the DHS 2000-2010. *Oxford Dev Stud* 2018;46:519–35.
111 Li Z, Li M, Subramanian SV, *et al*. Assessing levels and trends of child health inequality in 88 developing countries: from 2000 to 2014. *Glob Health Action* 2017;10:1408385.
112 May J, TimÃ¡us IM. Inequities in under-five child nutritional status in South Africa: what progress has been made? *Dev South Afr* 2014;31:761–74.
113 Restrepo-Méndez MC, Barros AJD, Black RE, *et al*. Time trends in socio-economic inequalities in stunting prevalence: analyses of repeated national surveys. *Public Health Nutr* 2015;18:2097–104.
114 Sarker AR, Sultana M, Sheikh N, *et al*. Inequality of childhood undernutrition in Bangladesh: a decomposition approach. *Int J Health Plann Manage* 2020;35:441–68.
115 Wagstaff A. *Inequalities in health in developing countries: swimming against the tide? Policy research working paper*. Washington, USA, 2002.
116 Zere E, Moeti M, Kirigia J, *et al*. Equity in health and healthcare in Malawi: analysis of trends. *BMC Public Health* 2007;7:78.
117 Zhang Q, Zheng B, Zhang N, *et al*. Decomposing the intergenerational disparity in income and obesity. *B E J Econom Anal Policy* 2011;11:1–19.
118 Almqvist AK. *Socioeconomic inequity in Zambian children's health status - differences between rural and urban areas [dissertation]*. Lund University, 2009.
119 De Silva AP, De Silva SHP, Haniffa R, *et al*. Inequalities in the prevalence of diabetes mellitus and its risk factors in Sri Lanka: a lower middle income country. *Int J Equity Health* 2018;17:45.
120 Hanandita W, Tampubolon G. The double burden of malnutrition in Indonesia: social determinants and geographical variations. *SSM Popul Health* 2015;1:16–25.
121 Subramanian SV, Kawachi I, Smith GD. Income inequality and the double burden of under- and overnutrition in India. *J Epidemiol Community Health* 2007;61:802–9.
122 van Deurzen I, van Oorschot W, van Ingen E. The link between inequality and population health in low and middle income countries: policy myth or social reality? *PLoS One* 2014;9:e115109.
123 Fan JX, Wen M, Kowaleski-Jones L. Tract- and county-level income inequality and individual risk of obesity in the United States. *Soc Sci Res* 2016;55:75–82.
124 Haithcoat TL, Avery EE, Bowers KA. Income inequality and health: expanding our understanding of state-level effects by using a geospatial big data approach. *Soc Sci Comput Rev* 2019;1:1–19.
125 Zhang L. *A mutlilevel study of effects of socioeconomic status, income inequality, and the built environment on adult obesity in China [dissertation]*. University of Illinois at Urbana-Champaign, 2012.
126 Bjornstrom EES. An examination of the relationship between neighborhood income inequality, social resources, and obesity in Los Angeles County. *Am J Health Promot* 2011;26:109–15.
127 Mandal B. *Three essays on health econometrics [dissertation]*. The Ohio State University, 2007.
128 Chang VW, Christakis NA. Income inequality and weight status in US metropolitan areas. *Soc Sci Med* 2005;61:83–96.
129 Kim D, Subramanian SV, Gortmaker SL, *et al*. US state- and county-level social capital in relation to obesity and physical inactivity: a multilevel, multivariable analysis. *Soc Sci Med* 2006;63:1045–59.
130 Parliament UK. Hunger food insecurity and malnutrition in the UK, 2021. Available: https://publications.parliament.uk/pa/cm201719/cmselect/cmenvaud/1491/149105.htm
131 Kawachi I, Subramanian SV. Neighbourhood influences on health. *J Epidemiol Community Health* 2007;61:3–4.
132 Institute of Medicine,, National Research Council. U. S. health in international perspecitive shorter lives, poorer health. Panel on understanding cross-national health differences among high-income countries. Govt Reports Announcements & Index 2013:1–374.
133 van Lenthe FJ, Borrell LN, Costa G, *et al*. Neighbourhood unemployment and all cause mortality: a comparison of six countries. *J Epidemiol Community Health* 2005;59:231–7.
134 Heidkamp RA, Piwoz E, Gillespie S, *et al*. Mobilising evidence, data, and resources to achieve global maternal and child undernutrition targets and the sustainable development goals: an agenda for action. *Lancet* 2021;397:1400–18.
135 Headey DD. Developmental drivers of nutritional change: a cross-country analysis. *World Dev* 2013;42:76–88.
136 Smith LC, Haddad L. How potent is economic growth in reducing undernutrition? What are the pathways of impact? New cross-country. *Econ Dev Cult Change* 2002;51:55–76.
137 Dinsa GD, Goryakin Y, Fumagalli E, *et al*. Obesity and socioeconomic status in developing countries: a systematic review. *Obes Rev* 2012;13:1067–79.
138 Popkin BM, Gordon-Larsen P. The nutrition transition: worldwide obesity dynamics and their determinants. *Int J Obes Relat Metab Disord* 2004;28:S2–9.
139 Jaacks LM, Vandevijvere S, Pan A, *et al*. The obesity transition: stages of the global epidemic. *Lancet Diabetes Endocrinol* 2019;7:231–40.
140 Cawley J. An economy of scales: a selective review of obesity's economic causes, consequences, and solutions. *J Health Econ* 2015;43:244–68.
141 Vik FN, Van Lippevelde W, Averby NC, *et al*. Free school meals as an approach to reduce health inequalities among 10-12- year-old Norwegian children. *BMC Public Health* 2019;19:1–8.
142 Wells JCK, Marphatia AA, Amable G. The future of human malnutrition: rebalancing agency for better nutritional health. *Global Health* 2021;17:1–25.
143 Su D, Esqueda OA, Li L, *et al*. Income inequality and obesity prevalence among OECD countries. *J Biosoc Sci* 2012;44:417–32.
144 Offer A, Pechey R, Ulijaszek S. Obesity under affluence varies by welfare regimes: the effect of fast food, insecurity, and inequality. *Econ Hum Biol* 2010;8:297–308.
145 Kahn HS, Patel AV, Jacobs EJ, *et al*. Pathways between area-level income inequality and increased mortality in U.S. men. *Ann N Y Acad Sci* 1999;896:332–4.
146 Pickett KE, Kelly S, Brunner E, *et al*. Wider income gaps, wider waistbands? An ecological study of obesity and income inequality. *J Epidemiol Community Health* 2005;59:670–4.
147 Kahn HS, Tatham LM, Pamuk ER, *et al*. Are geographic regions with high income inequality associated with risk of abdominal weight gain? *Soc Sci Med* 1998;47:1–6.

Supplementary material

Table S1: Medline search strategy

1	Wealth* or asset* or income* or earning* or poor* or povert* or depriv* or economic status or economic inequality or expenditure or equit* or equal* or inequal* or dispar*
2	Exp poverty/ or exp health equity/ or exp economic status/ or exp health status disparities/
3	Underweight or overweight or adipos* or BMI or body mass index or (body-mass adj2 ind*) or obes* or weight-for-height or weight-for-length or WHZ or WLZ or stunt* or HAZ or height-for-age or length-for-age or wasting or wasted or an?emi* or h?emoglob* or undernutri* or overnutri* or undernour* or overnour* or malnutri* or malnour* or thinness or overweight* or underweight* or nutritional status
4	Exp thinness/ or exp overweight/ or exp anemia/ or exp nutrition disorders/ or exp obesity/ or exp body mass index/
5	(Concentration* adj3 curve*) or (concentration adj3 ind*) or (Lorenz adj3 curve*)
6	(1 or 2) and (3 or 4) and 5
7	((Wealth* or income* or earning* or poor* or povert* or economic) adj3 (inequ* or equ* or distribut* or disparit*)) or gini or theil or pietra or schutz or Robin Hood-ind* or attkinson or (decile* adj3 ratio*) or inequality
8	Multilevel or multi-level or (two adj3 level*) or two-level or random effects or random effect or random-effect or random-effects or (control* adj5 individual*) or (mixed adj3 effect*) or mixed-effect or mixed-effects or nested data or random coefficient or random coefficients or (hierarchic* adj3 (model* or data*))
9	(3 or 4) and 7 and 8
10	6 or 9

Table S2: Characteristics of studies included in the meta-analysis of concentration indices

	Child stunting, number of estimates (N) =277		**Child wasting, N=60**		**Adult overweight /obesity, N=89**	
	Mean or %	**(Min, max)**	**Mean or %**	**(Min, max)**	**Mean or %**	**(Min, max)**
Survey date, mean year	2004	(1974, 2018)	2003	(1987, 2018)	2001	(1971, 2016)
% estimates measuring income	8.3%	..	33.3%	..	83.1%	..
% estimates measuring wealth	91.0%	..	63.3%	..	16.9%	..
% estimates measuring expenditure	0.7%	..	3.3%	..	..	..
Mean outcome prevalence	32.5%	(4.0%, 61.0%)	10.1%	(1.0%, 25.0%)	22.1%	(4.4%, 88.2%)
Mean concentration index	-0.164	(-0.441, 0.027)	-0.038	(-0.174, 0.018)	-0.012	(-0.280, 0.339)
WHO universal health coverage index	54.8	(22, 78)	51.6	(35, 78)	78.2	(46, 88)
FAO Food security index	108.1	(25, 155)	108.6	(82, 141)	133.9	(102, 149)
Low-income country, %	53.6%	..	56.7%		5.6%	
Region, %	..	..	..	..	..	..
East Asia & Pacific	6.1%	..	6.7%	..	5.6%	..
Europe & Central Asia	10.8%	..	3.3%	..	49.4%	..
Latin America & Caribbean	21.3%	..	11.7%	..	4.5%	..
Middle East & North Africa	5.4%	..	5%	..	0%	..
South Asia	8.7%	..	23.3%	..	5.6%	..
Sub-Saharan Africa	46.7%	..	50.0%	..	5.6%	..
North America	0%	..	0%	..	29.2%	..
Gender composition of sample	..	..	..	..	..	..
Mixed	100%	..	100%	..	30.3%	..
Male only	0%	..	0%	..	31.5%	..
Female only	0%	..	0%	..	38.2%	..
Risk of bias						
Low	0%		0%		7.9%	
Moderate	91.0%		91.7%		70.8%	
High	8.7%		6.7%		16.9%	
Critical	0.4%		1.7%		4.5%	

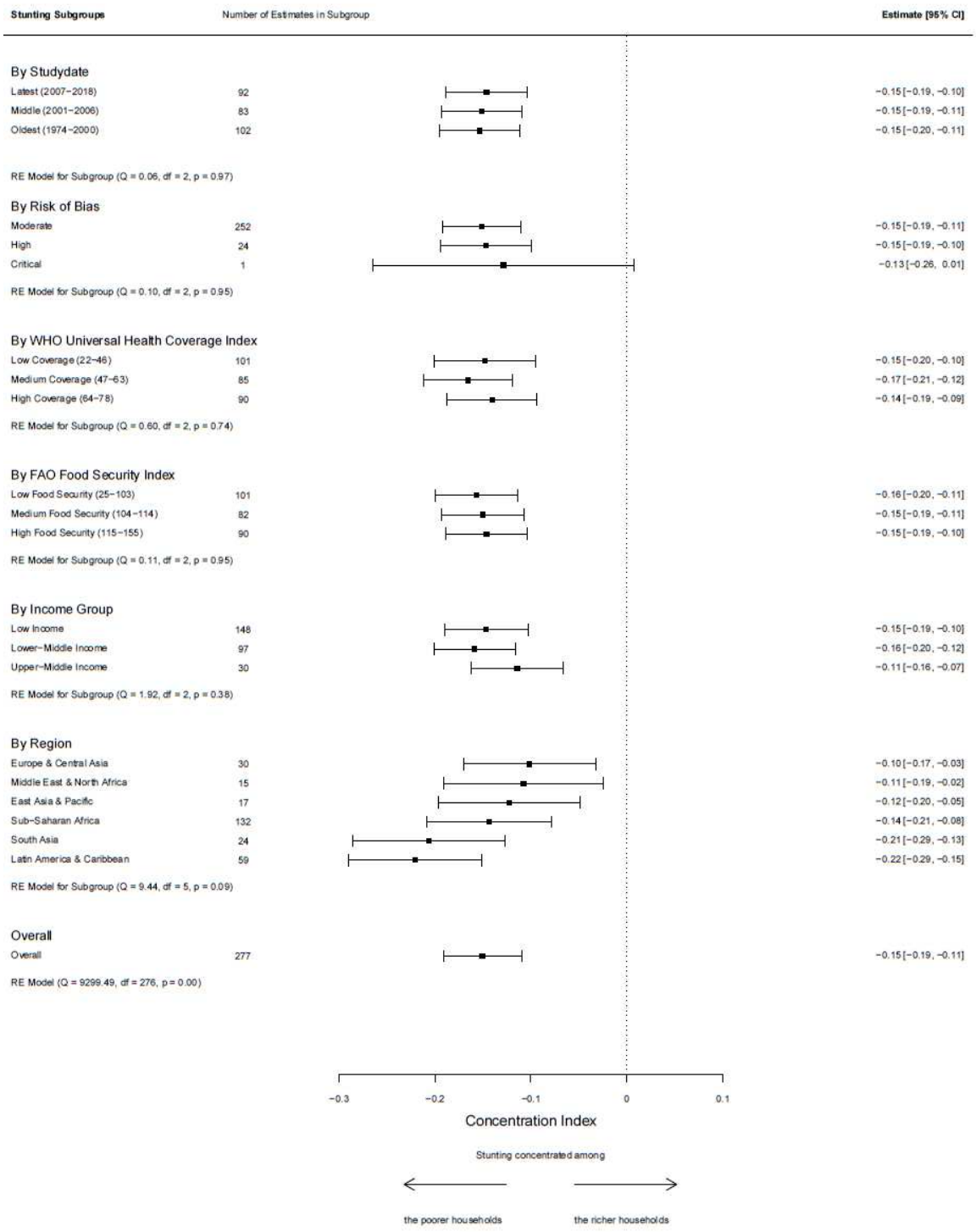

Figure S1: Subgroup analysis for concentration indices of stunting

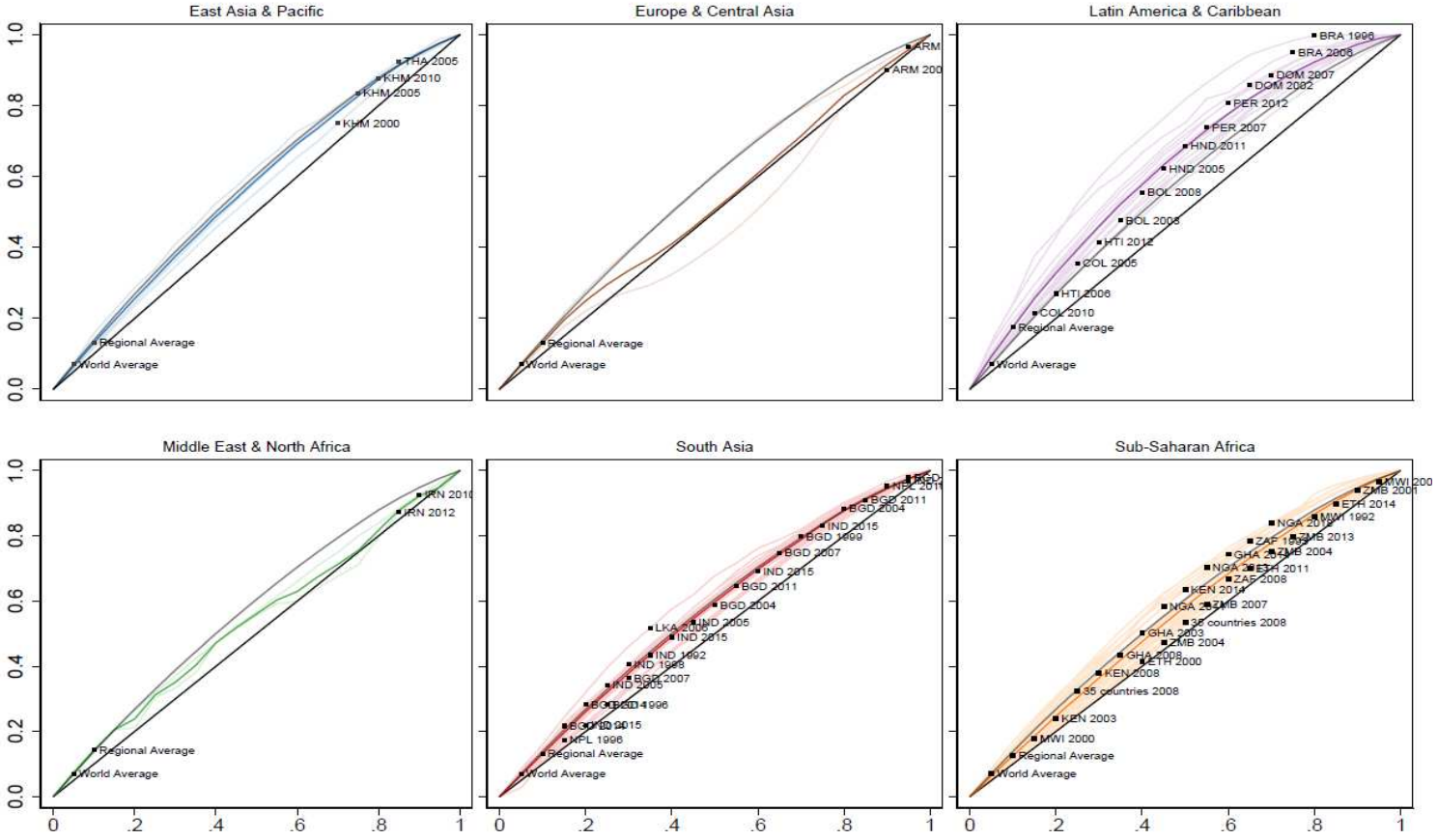

Figure S2: Regional stunting concentration curves with country names

Cumulative proportion of wealth on the X-axis. Cumulative proportion of stunting on the Y-axis. Earliest year of data collection and three-letter ISO country code call-outs.

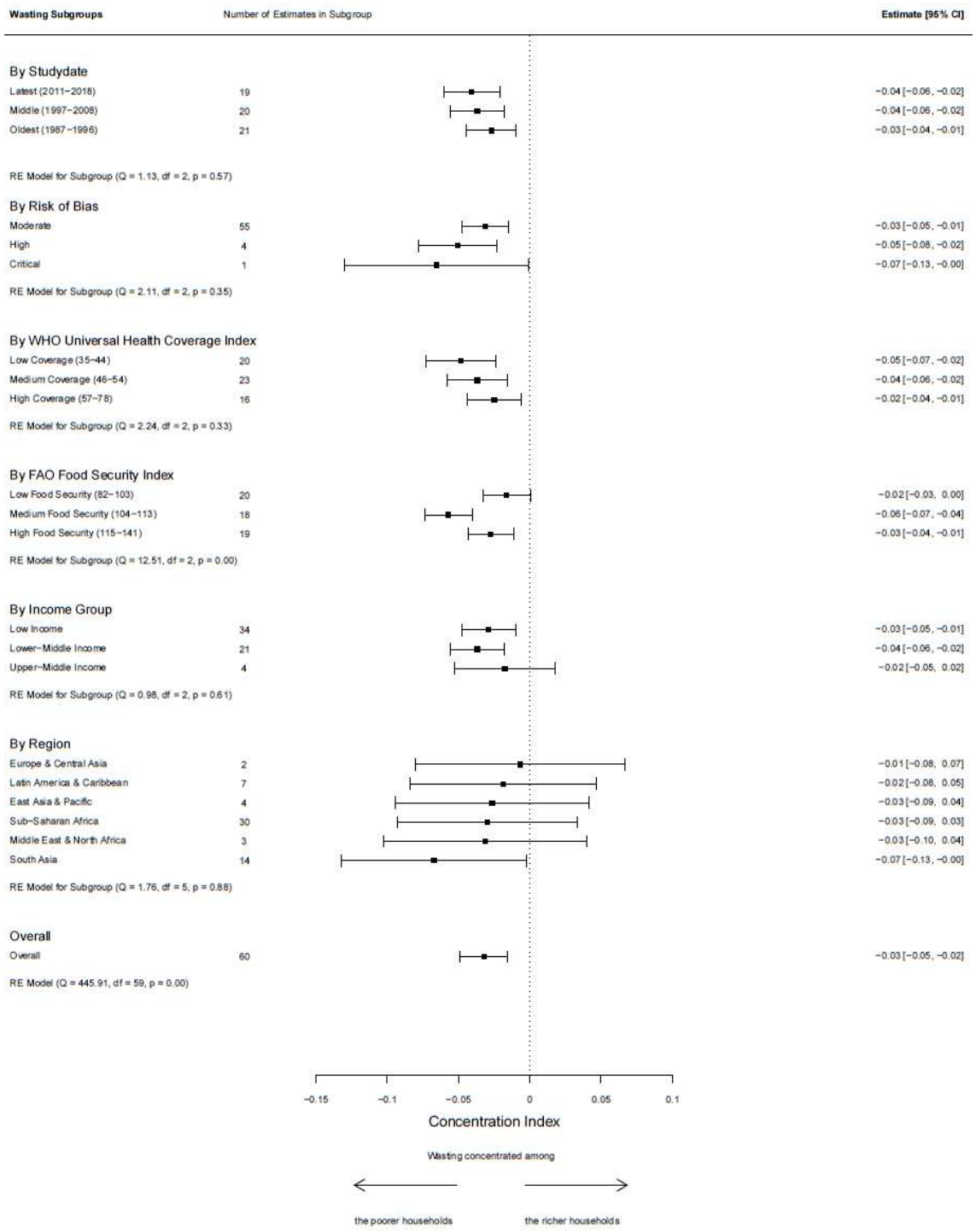

Figure S3: Subgroup analysis for concentration indices of wasting

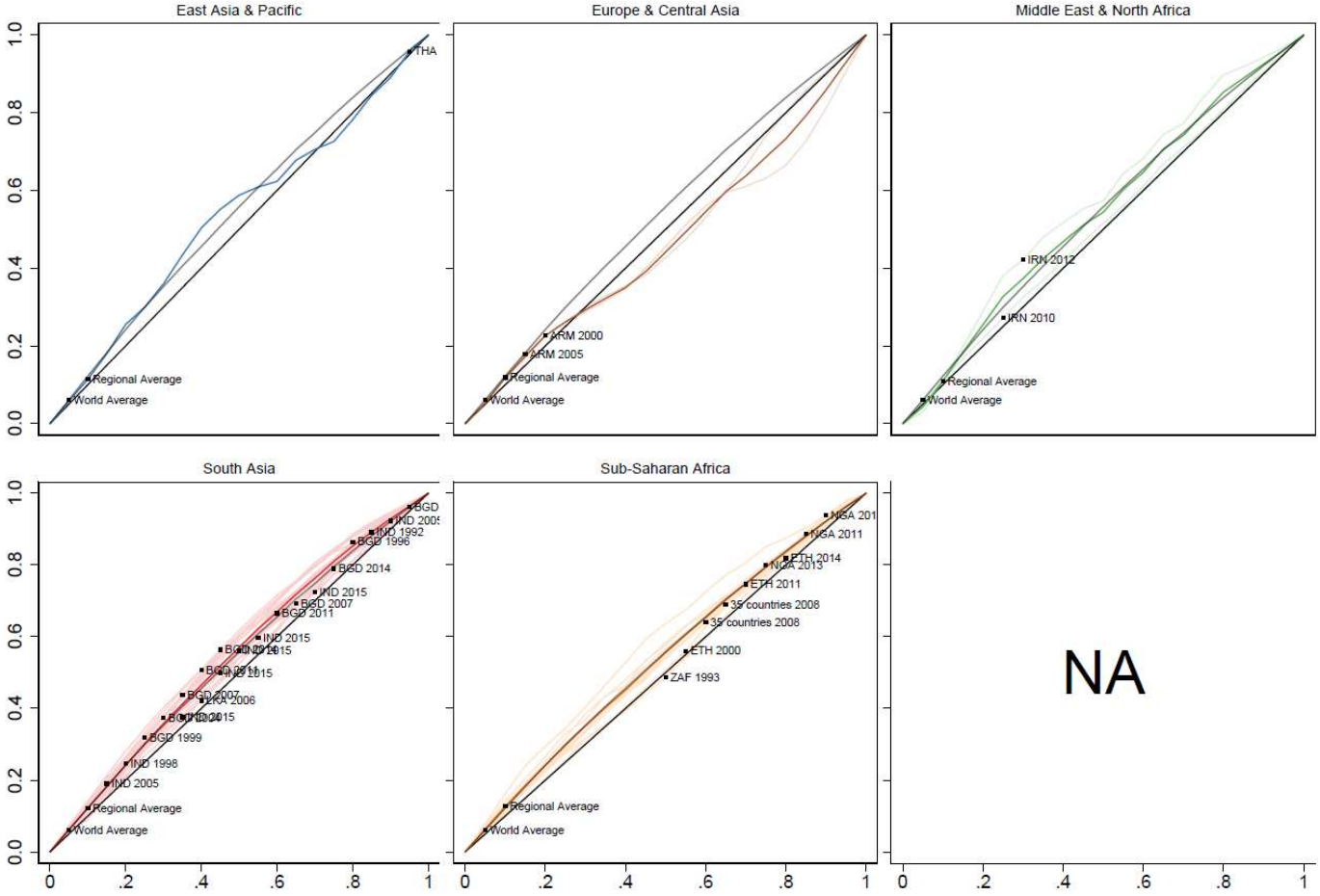

Figure S4: Regional wasting concentration curves with country names

Cumulative proportion of wealth on the X-axis. Cumulative proportion of stunting on the Y-axis. Earliest year of data collection and three-letter ISO country code call-outs.

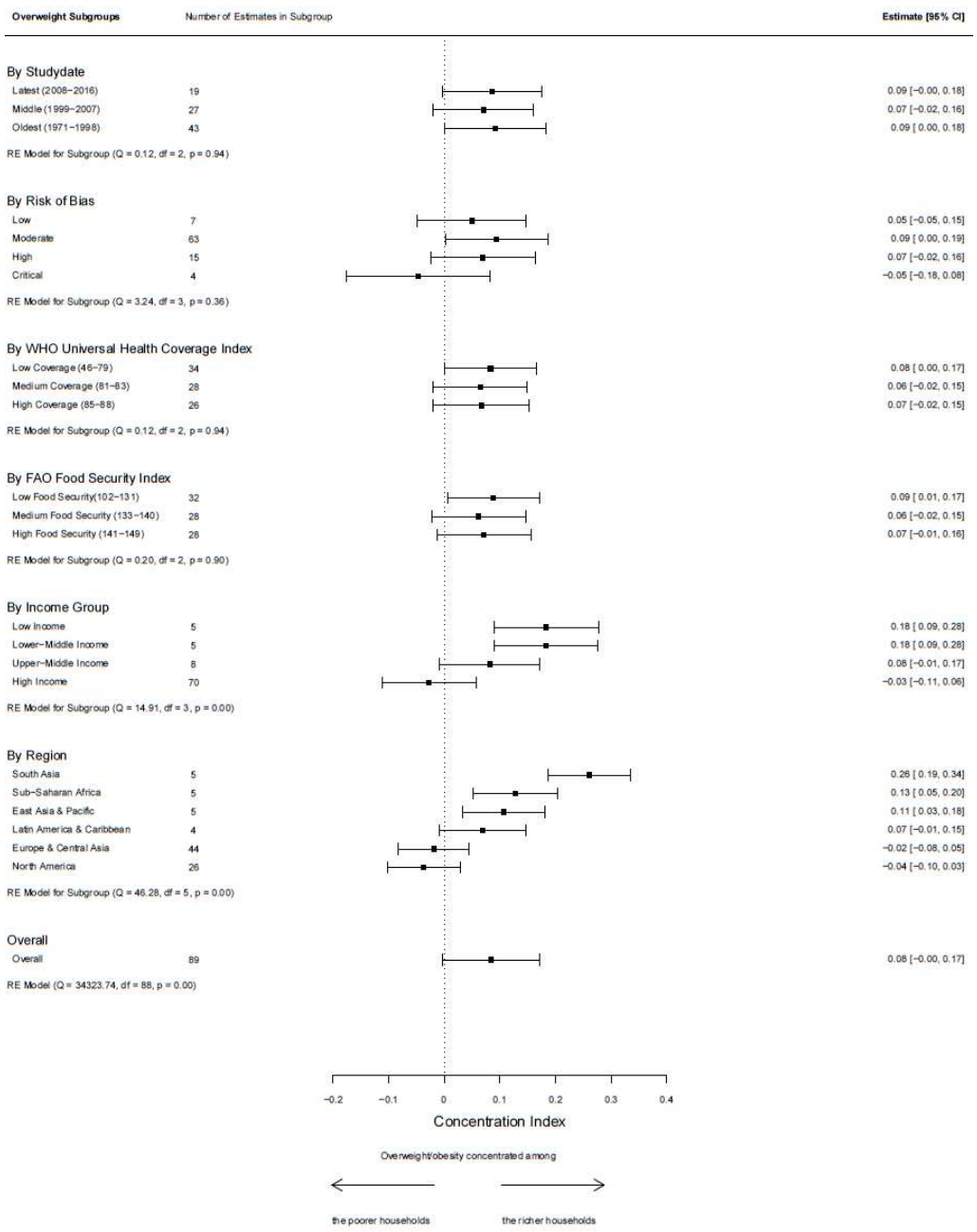

Figure S5: Subgroup analysis for concentration indices of adult overweight/obesity

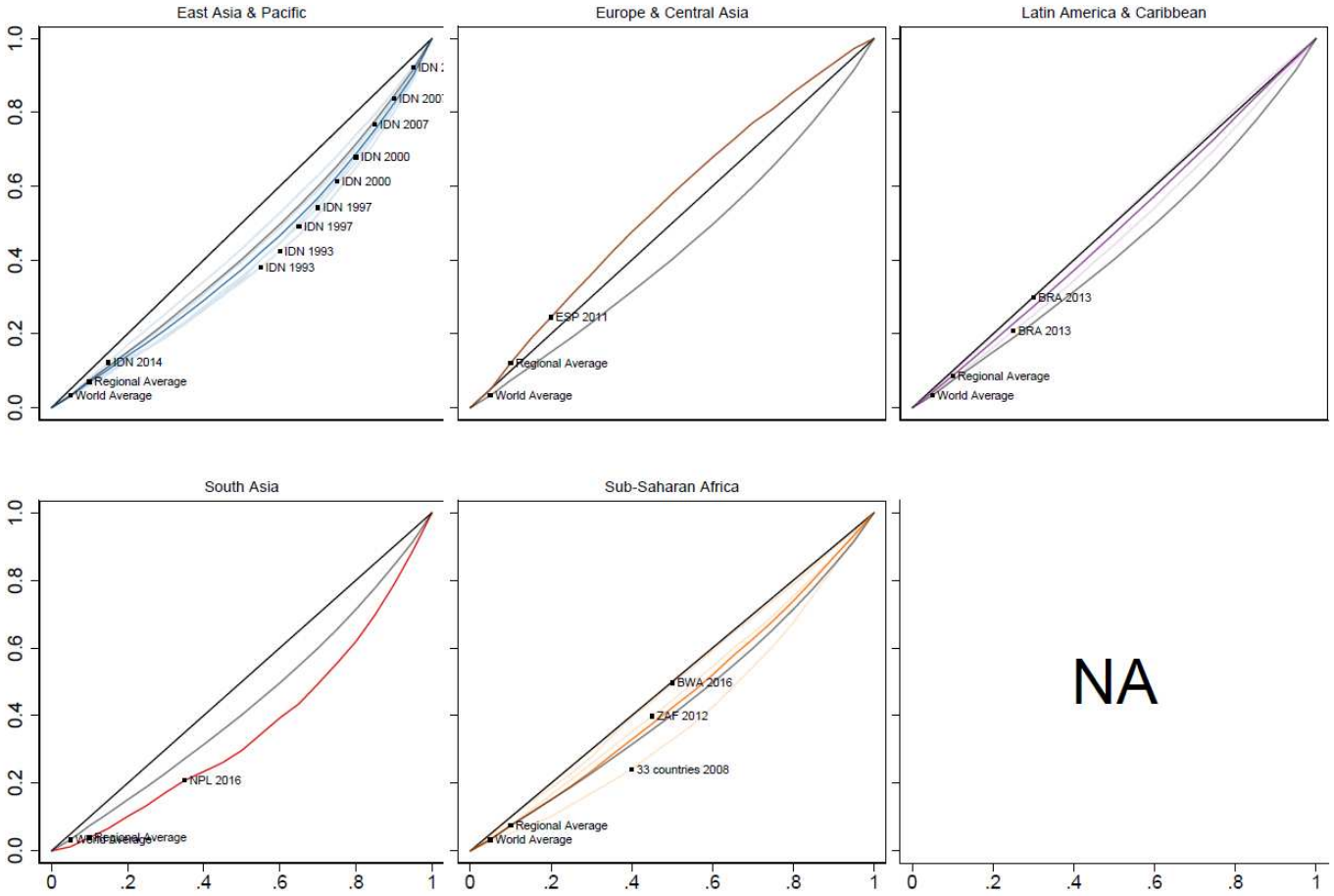

Figure S6: Regional overweight/obesity concentration curves with country names

Cumulative proportion of wealth on the X-axis. Cumulative proportion of adult overweight/obesity on the Y-axis. Earliest year of data collection and three-letter ISO country code call-outs.

Table S3: Eggers test on small-study effects for concentration indices

	Beta	SE of Beta	Z	P
Child Stunting	1.65	0.55	3.02	0.00
Child Wasting	-0.70	0.69	-1.02	0.31
Adult Overweight/Obesity	-1.50	0.61	-2.45	0.01

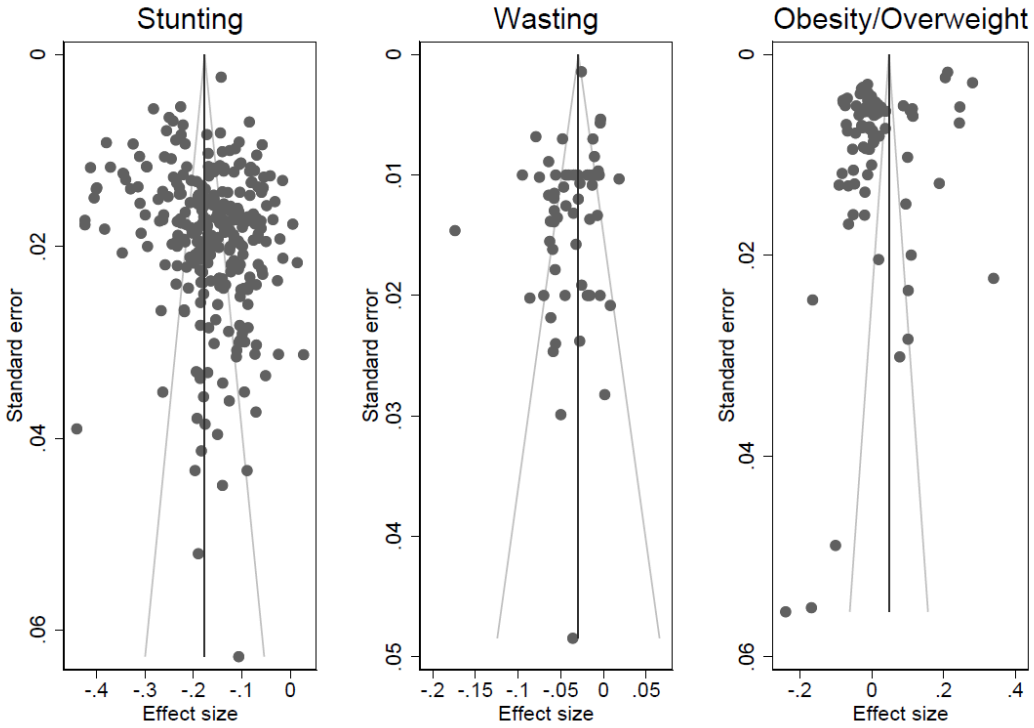

Figure S7: Funnel plots of concentration curves by outcome

Table S4A: Characteristics of multilevel studies measuring associations between economic inequality and nutrition prevalence

Author (publication year)	Survey years	Sample age (y)	Country	Sample size	Economic status measure	Outcome prevalence	Area level variable	Risk of Bias
Child stunting								
Reinbold (2011)*	2004	<5	Bangladesh	6908	DHS wealth Index	..	Region and district	Moderate
Reinbold (2011)*	2003	<5	Kenya	5767	DHS wealth Index	..	Region and district	Moderate
Child Anaemia								
van Deurzen et al (2014)*	2000-2011	<6	30 countries	152485	International Wealth Index Asset Score (DHS derived)	58.7%	Country	Moderate
Adult underweight								
Mandal (2007)	1992, 1997, 2002	<95	USA	448874	Not specified	..	State	Moderate
Subramanian et al (2007)	1998-1999, 1999-2000	15 - 49	India	77220	Expenditure	32.1%	State	Low
Hanandita and Tampubolon (2015)	2007	≥15	Indonesia	645032	Expenditure	14.4%	District	Moderate
Adult overweight/obesity								
Bjornstrom (2011)	2000-2001	..	USA	2875	Income	23%	Neighbourhood	Moderate
Zhang (2012)	2006	≥18	China	9586	Income	26%	Province	High

Author (publication year)	Survey years	Sample age (y)	Country	Sample size	Economic status measure	Outcome prevalence	Area level variable	Risk of Bias
Fan et al (2016)	2000, 2003-2008,	20 - 64	USA	10302	Income	34.4%	County and census tract	Low
Chang and Christakis (2005)	1990, 1996-1998,	≥15	USA	143931	Income	38.7%	Metropolitan Statistical Area	Moderate
Haithcoat et al (2019)	2014-2016, 2016	..	USA	954671	Income	31%	State	Moderate
Chen and Crawford (2012)	2000	≥18	USA	126298	Income	18.5%	State and county	Moderate
Kim et al (2006)	1974-1994, 1975-1998, 1990-1994, 1990, 1996, 1997, 1998, 2000	≥18	USA	181200	Income	19.5%	State	Moderate
Subramanian et al (2007)	1998-1999, 1999-2000	15 - 49	India	77220	Expenditure	6.2%	State	Low
Hanandita and Tampubolon (2015)	2007	≥15	Indonesia	645032	Expenditure	17.9%	District	Moderate
Mandal (2007)	1992, 1997, 2002	<95	USA	448874	Not specified	..	State	Moderate
Adult (female) Anaemia								
van Deurzen et al (2014)*	2000-2011	15 - 49	33 countries	373735	Wealth	40.2%	Country	Moderate

* These studies were not included in the meta-analysis

Table S4B: Variable adjustment for studies on association between economic inequality and nutrition prevalence

Author	Adjusted variables in main model
Child stunting	
Reinbold (2011)	Child age, sex, religion, mother's education, mother's employment status, mother's partner's education, mother's partner lives at home, mother's partner's age, mother's partner's age squared, household size, household size squared
Child anaemia	
van Deurzen et al (2014)	Household wealth index quintiles, survey year
Adult underweight	
Mandal (2007)	Restaurants, food stamp rates, unemployment rate, metro residency, age, education, children, race, marital status, work status, income, smoking, and health insurance.
Subramanian et al (2007)	Age, religion, caste, marital status, education, wealth, occupation, urban/rural, parity, smoking, drinking, tobacco chewing, tuberculosis, malaria, and state economic development.
Hanandita and Tampubolon (2015)	Age, gender, marital status, education, employment status, physical activity, household size, per capita expenditure, median per capita expenditure, and deprivation.
Adult overweight/obesity	
Bjornstrom (2011)	Age, gender, marital status, race, education, log family income, insurance, chronic conditions, smoking, and median household income.
Zhang (2012)	Gender, age, marital status, education, work status, occupation, wealth, income, province mean income, province mean education, urban and, province urban
Fan et al (2016)	Age, gender, marital status, family size, education, race/ethnicity, birthplace, income, survey year, census tract median income, and county median income.
Chang and Christakis (2005)	Age, household income, education, median income, population, and region.
Haithcoat et al (2019)	Inequality uniformity, median state household income, % insured, % on food assistance, age, gender, ethnicity/race, education, income, marital status, health insurance status, smoking, exercising, and alcohol.
Chen and Crawford (2012)	Marital status, age, income, education, employment status, race, poverty rate county, median income county, interaction of county gini: low income, interaction of state gini: low income, and state gini.
Kim et al (2006)	Age, gender, race, marital status, educational attainment, household income, state social capital, mean household income, and % black.
Subramanian et al (2007)	Age, religion, caste, marital status, education, wealth, occupation, urban/rural, parity, smoking, drinking, tobacco chewing, tuberculosis, malaria, and state economic development.
Hanandita and Tampubolon (2015)	Age, gender, marital status, education, employment status, physical activity, household size, per capita expenditure, median per capita expenditure, and deprivation.
Mandal (2007)	Restaurants, food stamp rates, unemployment rate, metro residency, age, education, children, race, marital status, work status, income, smoking, and health insurance.
Adult (female) anaemia	
van Deurzen et al (2014)	Household wealth index quintiles, and survey year.

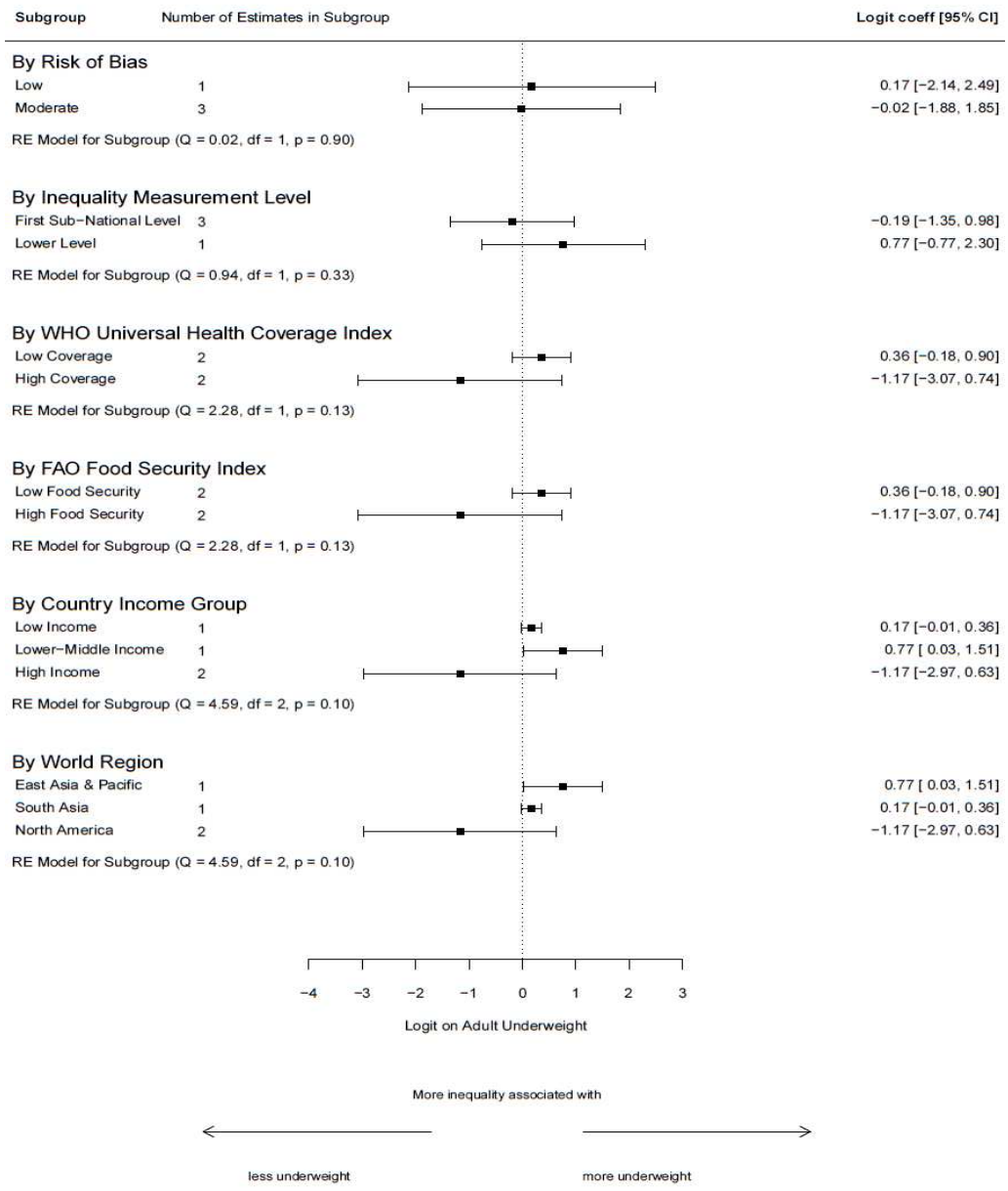

Figure S8: Subgroup analysis for associations between Gini coefficients and adult underweight

Logistic multilevel regression effects of Gini coefficient on a 0-1 scale on logged odds of malnutrition presented.

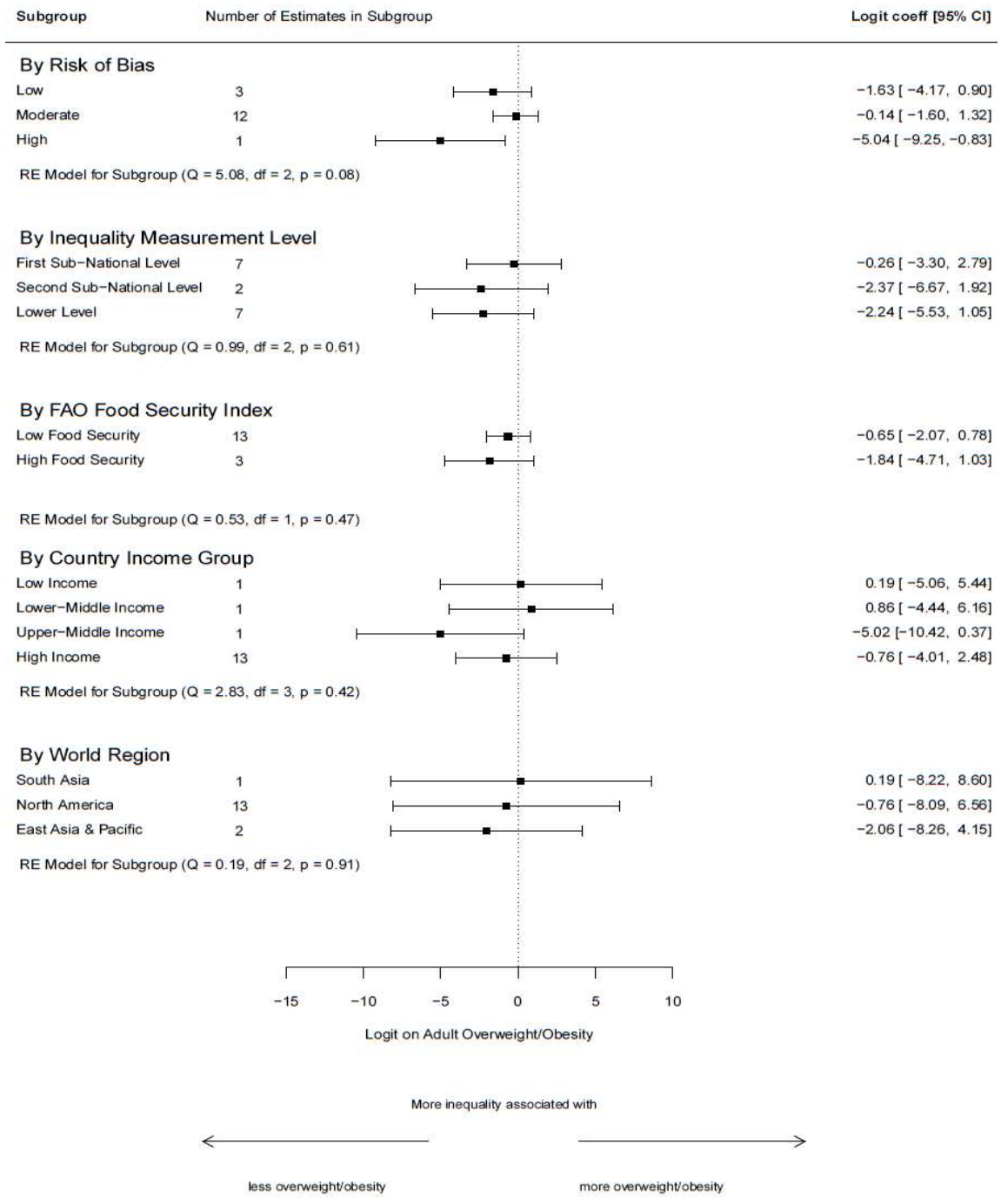

Figure S9: Subgroup analysis for associations between Gini coefficients and adult overweight/obesity

Logistic multilevel regression effects of Gini coefficient on a 0-1 scale on logged odds of malnutrition presented. Subgroup analysis by UHC Index omitted due to lack of variance.

Table S5: Eggers test on small-study effects for associations between Gini coefficients and nutrition outcomes

	Beta	SE of Beta	Z	P
Adult Underweight	-0.62	0.82	-0.75	0.45
Adult Overweight/Obesity	-1.23	0.55	-2.22	0.03

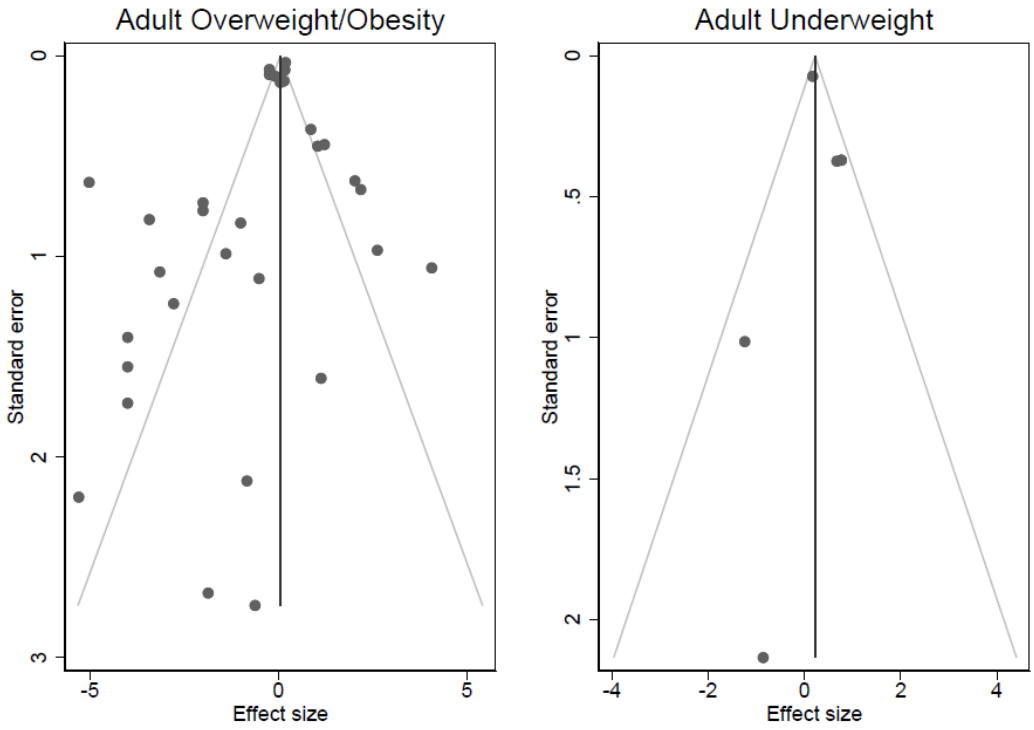

Figure S10: Funnel plots of studies on associations between Gini coefficients and nutrition outcomes