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Inter-individual inequality in BMI: An analysis of Indonesian Family Life Surveys (1993–2007)

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A R T I C L E I N F O

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A B S T R A C T

Widening inequalities in mean Body Mass Index (BMI) between social and economic groups are well documented. However, whether changes in mean BMI are followed by changes in dispersion (or variance) and whether these inequalities are also occurring within social groups or across individuals remain understudied. In addition, a substantial body of literature exists on the global increase in mean BMI and prevalence of overweight and obesity. However, whether this weight gain is shared proportionately across the whole spectrum of BMI distribution, also remains understudied. We examined changes in the distribution of BMI at the population level over time to understand how changes in the dispersion reflect between-group compared to within-group inequalities in weight gain. Moreover, we investigated the entire distribution of BMI to determine in which percentiles the most weight gain is occurring over time. Utilizing four waves (from 1993 to 2007) of Indonesian Family Life Surveys (IFLS), we estimated changes in the mean and the variance of BMI over time and across various socioeconomic groups based on education and households' expenditure per capita in 53,648 men and women aged 20–50 years. An increase in mean and standard deviation was observed among men (by 4.3% and 25%, respectively) and women (by 7.3% and 20%, respectively) over time. Quantile-Quantile plots showed that higher percentiles had greater increases in BMI compared to the segment of the population at lower percentiles. While between socioeconomic group differences decreased over time, within-group differences increased and were more prominent among individuals with poor education and lower per capita expenditures. Population changes in BMI cannot be fully described by average trends or single parameters such as the mean BMI. Moreover, greater increases in within-group dispersion compared with between-group differences imply that growing inequalities are not merely driven by these socioeconomic factors at the population level.

1. Introduction

Rapid increases in the mean Body Mass Index (BMI) and the prevalence of overweight and obesity are widely documented in high-income countries, as well as low- to middle-income countries (LMICs) (Finucane et al., 2011; Jones-Smith, Gordon-Larsen, Siddiqi, & Popkin, 2011) including Indonesia (Roemling & Qaim, 2012; Usfar, Lebenthal, Atmarita Achadi, Soekirman, & Hadi, 2010). However, previous studies have predominantly relied on the change in mean or point estimates such as the prevalence of underweight, overweight and obesity as a proxy for population level changes in BMI. A study using Demographic Health Survey (DHS) data from 37 LMICs (excluding Indonesia) examined patterns of change across the entire distribution of BMI among women and revealed an increase in weight gain among higher BMI percentile groups suggesting that a single parameter, such as mean BMI or percent overweight do not capture the divergence in the degree of weight gain occurring across the population (Razak, Corsi, & Subramanian, 2013). However the DHS study was limited to a small number of repeated cross-sectional data and only to women. Therefore, further studies on both women and men in LMICs using

Abbreviations: BMI, Body Mass Index; IFLS, Indonesian Family Life Survey; LMICs, Low- and Middle-Income Countries; DHS, Demographic Health Survey; SD, Standard Deviation; QQ, Quantile-Quantile

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longitudinal datasets or datasets with a greater number of study cycles was suggested to provide deeper insight into the varying patterns of weight gain over time (Razak et al., 2013).

Previous studies in Indonesia have shown increases in the prevalence of overweight and obesity as children grow to adolescents (Julia, van Weissenbruch, Prawirohartono, Surjono, & Delemarre-van de Waal, 2008) or significant increases in body weight and mean BMI among women of productive age (Winkvist, Nurdiati, Stenlund, & Hakimi, 2000). A recent study on obesity trend and its determinants has likewise shown a pronounced rise in overweight among women, in rural areas, and among low income individuals of the population compared to men, urban areas and high income individuals, while underweight still persists in Indonesia (Roemling & Qaim, 2012). In addition, households' inequalities in dual burden of malnutrition – coexistence of both under- and overweight in the same household – were also examined between socioeconomic groups and residential environments reporting rising intra-household inequalities and between socioeconomic group differences (Roemling & Qaim, 2013; Vaezghasemi et al., 2014; Hanandita & Tampubolon, 2015). These prior papers that have focused on social group differences in health are necessary for targeting investments to the worst off groups and a group-level approach can support the creation of laws and programs that seek to eliminate social group differences. For example, we might ask how mean BMI of the poor compares to that of the rich. Moreover, the WHO recommends that health indicators should be reported by groups, or "equity stratifiers" for the purposes of monitoring health inequities (Zheng et al., 2011).

However, few studies have examined whether inequalities in weight gain are occurring within social groups or specific segments of the population, which is a measure of *inter-individual inequalities* rather than *between-group inequalities* (Krishna, Razak, Lebel, Smith, & Subramanian, 2015). In this study, we utilized standard deviation (SD) and variance in BMI as measures of inequality to assess the population-level dispersion across individuals within groups. The theoretical framework of our study is based on what Murray and Gakidou defined as "*health inequality*", which is variation in health status across individuals in a population (Gakidou, Murray, & Frenk, 2000; Murray, Gakidou & Frenk, 1999). To study health inequalities, they proposed two complementary approaches: (i) measuring social group inequalities by differences in mean values or the prevalence of health outcomes between social groups and (ii) measuring individual inequalities by differences between individuals and within groups (Gakidou et al., 2000; Murray et al., 1999). Although less often considered in the epidemiologic literature, variations between individuals may provide critical information as the same average level of health could correspond to substantial variation across individuals in that population (Murray et al., 1999).

Indonesia is the fourth most populous country in the world and one of Southeast Asia's highly performing economies which has been experiencing striking social and economical changes during the last two decades. To the best of our knowledge, no study in Indonesia has previously addressed (i) changes in the distribution of BMI across various percentiles of the population and (ii) within-group or inter-individual inequalities in the distribution of BMI over time.

2. Subjects and methods

2.1. Data source

We utilized a nationally representative data from an on-going longitudinal socioeconomic and health survey, called the Indonesian Family Life Survey (IFLS) (http://www.rand.org/labor/FLS/IFLS.html). The IFLS employed a multi-stage stratified systematic sampling design based on the stratification of provinces and urban/rural locations. In the first wave (1993) thirteen of twenty-seven provinces, representing 83% of the population were selected. The IFLS consists of four waves of data collected in 1993, 1997–98, 2000, and 2007–08. Our analyses were mainly performed on the cross-sectional data from these waves. Relatively few large-scale longitudinal surveys are available for LMICs. IFLS is the only large-scale longitudinal survey available for Indonesia. Because data are available for the same individuals from multiple points in time, IFLS affords an opportunity to understand the dynamics of behavior at the individual, household and family, and community levels (Strauss, Witoelar, Sikoki, & Wattie, 2009).

2.2. Study subjects

We included only adult men and women aged 20–50 years. Consistent with prior work, individuals older than 50 years were not included due to changes in body composition inherent in aging (Razak et al., 2013). Moreover, BMI may not be appropriate among older individuals due to increasing body fat at similar levels of BMI compared with younger ones (Ogden, Yanovski, Carroll, & Flegal, 2007). Children and adolescents were also excluded from the analysis as BMI thresholds used for adults may not apply to them (de Onis & Lobstein, 2010) and nutritional determinants can be quite diverse for those age groups. We also excluded pregnant women, individuals with missing values in all the key independent covariates, and individuals with outlier values of weight (in kg; < 25 and > 200), height (in cm; < 100 and > 200) from the analysis (Razak et al., 2013). After exclusion of outliers and missing values in all variables, a total number of 8,119, 11,103, 15,514, and 18,912 individuals were included in the analysis from wave 1 (IFLS1), wave 2 (IFLS2), wave 3 (IFLS3), and wave 4 (IFLS4), respectively (Fig. 1). The number of excluded individuals was highest in IFLS3 and IFLS4 with about sixteen percent. The higher number of missing values found in the anthropometric measurements were mainly due to the fact that household members either moved or were not available for physical health measurements. We also created a panel dataset including all individuals (n=2,952) who participated in all four waves in order to compare their BMI distribution parameters as well as the prevalence of underweight, normal weight, overweight, and

Exclusion criteria	IFLS1 (1993)	IFLS2 (1997)	IFLS3 (2000)	IFLS4 (2007)
Initial participants	24491	28958	42582	48002
Age < 20	10359	12654	17339	17933
Age > 50	4614	4596	6341	7528
Outliers and missing data*	1399	605	3388	3629
Total (Repeated cross-section)	**8119**	**11103**	**15514**	**18912**
Total (Panel data)	2952	2952	2952	2952

Fig. 1. Study population and exclusion criteria. *The outliers for the variables height (cm) and weight (kg) were (height < 100 & height > 200) and (weight < 25 & weight > 200), respectively. IFLS: Indonesian Family Life Survey.

obesity with those observed in the repeated cross-sectional data.

2.3. Outcome variable

The outcome of interest was BMI measured as a ratio of weight (kg) to the square of height (m). BMI is considered by the WHO to be a standard and useful population measure of weight status used in large-scale surveys of nutritional status in adults (WHO, 1995). It is an inexpensive and easy-to-perform method of screening for weight categories at the population level, for example underweight, normal or healthy weight, overweight, and obesity. The definition of normal weight is BMI 18.5–24.99, based on WHO (World Health Organization, 2000), whereas a BMI 18.5–23, may be more appropriate for Asians (Deurenberg, Deurenberg-Yap, & Guricci, 2002; WHO Expert Consultation, 2004). Two specially trained nurses recorded physical measurements, including height and weight on all household members (Strauss et al., 2009).

2.4. Covariates

The covariates were (i) gender (men and women), (ii) age (20–50 years), (iii) occupation (never worked and worked), (iv) education (no schooling, elementary, secondary, and university), (v) household's living standard presented as quartiles of per capita expenditure (with the first quartile being considered as “lowest per capita expenditure”), and (vi) place of residence (urban and rural). Household per capita expenditure (total household expenditure divided by number of household members) was used as a proxy for a household's living standard and contained information about households' food expenditures and non-food consumption during one month measured in Indonesian Rupiah (Strauss et al., 2009).

2.5. Analysis

2.5.1. Distributional parameters of BMI

BMI was age-adjusted prior to analysis. Age adjustment was achieved by regressing BMI on age and quadratic age, followed by the addition of the grand mean to the residuals from this model. We used age-adjusted BMI for both repeated cross-sectional and panel data to present and compare the distributional parameters over time: mean, SD, 5th, 50th, and 95th percentiles for all individuals (men and women separately) and for each study wave. We used both cross-sectional and panel data to compare the distributional parameter of BMI. For the rest of the analysis only repeated cross-sectional data were used. We calculated the percent change for all parameters in wave 1 (1993) to wave 4 (2007).

2.5.2. Graphical analysis of patterns of BMI distributional changes

Age-adjusted BMI was also used for the graphical analysis. There is no standard approach to graphically examining distributional changes in BMI (Flegal & Troiano, 2000). As demonstrated previously (Razak et al., 2013; Krishna et al., 2015) Quantile-Quantile (QQ) plots can provide useful information about changes in BMI distribution (Wilk & Gnanadesikan, 1968). Using this approach, we plotted percentiles of BMI at the recent study cycles (wave 2, wave 3, and wave 4) against percentiles of BMI from the baseline study cycle (wave 1). If the two distributions being compared were exactly the same, the points in the QQ plot would lie on the line y=x, and points above the equality line (y=x) represent a higher level of BMI in subsequent study waves. QQ plots are particularly suitable for detecting the increasing distance from the line of equality at the tails of the distribution (Wilk & Gnanadesikan, 1968).

2.5.3. Between-group and within-group differences of BMI mean and variance

We computed the mean and variance of BMI for each category of education, and for each quartile of per capita expenditure for men and women separately for each study wave. Absolute and relative differences in group mean BMI were calculated between the highest and lowest education level and the highest and lowest per capita expenditures. In addition, whithin-group differences (i.e. between individual differences) were calculated based on the percent change in SD and variance from IFLS1 to IFLS4. We applied mean comparison test (t-test) and variance comparison test (sdtest) and reported p-values for all the percentage changes in the analysis. P-values for percentage changes in absolute and relative differences was calculated by regressing BMI on the interaction between time (IFLS1 and IFLS4) and education or per capita expenditure.

2.5.4. Variance differences in regression models

We ran several univariate regressions on BMI and each covariate (one at a time) for men and women separately for IFLS1 and IFLS4. We did this to observe how much of the variation is explained by each covariate separately compared with the null model (empty model reporting total variance around the global mean BMI), and how it was changing over time. In addition, for each study wave, we ran several different ordinary least squares regression models by regressing BMI on (i) age and gender (Model I); (ii) age, gender, and occupation (Model II); (iii) age, gender, occupation, education and per capita expenditure (Model III); and (iv) age, gender, occupation, education, per capita expenditure, and place of residence (Model IV). We only presented the variance to illustrate variability in the distribution of BMI over the study waves after accounting for the socioeconomic factors. We presented percent change in variance between Model I and Model IV to show the extent to which the variation in BMI is explained by these socioeconomic factors, and between wave 1 and wave 4 to show how population level variance was changing over time. For instance, we subtracted the variance in model I by the variance in model IV. We later divided this by the variance in model I and multiplied it by 100 (Merlo et al., 2006). This gives us the percentage of the variance attenuated or explained by inclusion of all the socioeconomic factors for each study wave. STATA software version 13.1 was used for analysis in this study (StataCorp. 2013. Stata: Release 13. Statistical Software. College Station, TX: StataCorp LP).

3. Results

3.1. General characteristics of the study population

Table A.1 presents descriptive statistics (numbers and percentages) about the IFLS from 1993–2007. In IFLS1 9.6% of men and 19% of women had no schooling. The percentage with no schooling decreased to 2% for men and 4.7% for women in IFLS4. In IFLS4 almost the same percentage of men (13.1%) and women (12.2%) had university education. Approximately 90% of men and 50% of women reported being employed across all the study waves. The proportion of men and women who lived in urban area increased from 47.9% in IFLS1 to 53.4% in IFLS4 and from 47.0% to 53.9%, respectively.

3.2. Distributional parameters of BMI

Among men, the mean BMI increased by 4.3% from IFLS1 (21.1) to IFLS4 (22.0). For women, the mean BMI increased by 7.3% from IFLS1 (21.9) to IFLS4 (23.5). The same trend was observed in the panel data with an increase in percent change for all individuals. As BMI mean increased, SD also increased over time. The change from IFLS1 to IFLS4 was higher among men (25%) than women (20%) (Table 1).

We also estimated the prevalence of underweight, normal weight, overweight, and obesity for both cross-sectional and panel data, based on both WHO and Asian cut-offs (Table A.7) demonstrating an increasing trend in overweight and obesity in the population. The

Table 1
Distributional parameters of BMI among 20–50 year olds across the four Indonesian Family Life Survey (IFLS) waves for repeated cross-sectional and panel data.

	Cross-sectional data					Panel data				
Waves	**Mean**	**SD**	**Percentile**			**Mean**	**SD**	**Percentile**		
All individuals			5th	50th	95th			5th	50th	95th
IFLS 1	21.5	3.2	17.2	21.1	27.6	22.2	3.0	18.2	21.8	27.9
IFLS 2	21.9	3.4	17.4	21.4	28.2	22.5	3.4	17.9	22.0	29.1
IFLS 3	22.1	3.5	17.4	21.6	28.6	22.6	3.7	17.7	22.2	29.5
IFLS 4	22.8	4.0	17.9	22.2	30.1	23.1	4.3	17.1	22.5	30.7
P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
% Change	**6.0%**	**25.0%**	**4.1%**	**5.2%**	**9.0%**	**4.0%**	**42.4%**	**−6.0%**	**3.2%**	**10.0%**
Men										
IFLS 1	21.1	2.8	17.3	20.6	26.3	21.6	2.4	18.2	21.3	26.1
IFLS 2	21.3	2.9	17.4	20.9	26.6	21.5	2.7	17.8	21.1	26.7
IFLS 3	21.5	3.1	17.4	21.0	27.2	21.5	2.9	17.6	21.0	27.3
IFLS 4	22.0	3.5	17.5	21.4	28.6	21.8	3.6	17.2	21.4	28.2
P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.102	< 0.001	< 0.001	< 0.001	< 0.001
% Change	**4.3%**	**25.0%**	**1.1%**	**3.9%**	**8.7%**	**0.9%**	**47.4%**	**−5.5%**	**0.5%**	**8.0%**
Women										
IFLS 1	21.9	3.5	17.1	21.5	28.5	22.5	3.2	18.1	22.0	28.7
IFLS 2	22.4	3.6	17.4	21.9	29.3	23.0	3.6	17.9	22.5	30.0
IFLS 3	22.6	3.7	17.5	22.1	29.6	23.2	3.9	17.7	22.9	30.1
IFLS 4	23.5	4.2	17.9	22.9	31.1	23.8	4.5	17.1	23.5	31.8
P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
% Change	**7.3%**	**20.0%**	**4.7%**	**6.5%**	**8.7%**	**5.8%**	**40.6%**	**−5.5%**	**6.8%**	**10.8%**

Percentage change was calculated based on the differences between IFLS1 and IFLS4. For BMI mean and percentiles, p-values were reported based on mean comparison test (t-test) and for SD, p-values were derived based on variance comparison test (sdtest). IFLS: Indonesian Family Life Survey.

results from the last cross-sectional data, based on the Asian cut-off illustrates that 41.1% of all individuals are overweight (28.5%) or obese (12.6%), while 10.7% are underweight.

3.3. Patterns of BMI distribution change over time

Fig. 2 illustrates the QQ plot of BMI. Overall, in men and women, the distribution of BMI is closer to the baseline survey at lower percentiles of BMI and there is increasing positive deviation of BMI values at higher percentiles.

3.4. Between-group and within-group differences in BMI

The results from Table 2 illustrate that the mean BMI increased within all subcategories of education and per capita expenditure, and it was higher among individuals with lower education compared to those with higher education, and among the lowest per capita expenditure group compared to the highest one. In order to capture the between group mean differences we presented both absolute and relative differences. The percent change in both absolute and relative difference in university vs. no schooling and highest per capita expenditure vs. lowest per capita expenditure decreased from IFLS1 to IFLS4. From this result we can say that weight gain of individuals with no schooling and lowest expenditure is occurring faster than among those with university and highest expenditure. Overall there was a decrease in between group differences, and the group means were very close. Higher disparity was observed among men compared to women. The decrease in group difference was not statistically significant between lowest and highest per capita expenditure. The full results for all IFLS waves can be seen in Table A.2.

Table 3 shows that variance also increased as the mean BMI increased, and it was higher among individuals with university education, those in the highest per capita expenditure group, and more prominent among women compared to men. Over time, variance increased more in the no schooling group (men, 49.0% and women, 58.7%) compared to the university category (men, 44.2% and women, 25.4%) (Table 3). The same pattern was observed for per capita expenditure. In summary, the results presented in Tables 2 and 3 demonstrate that although between group mean differences became relatively smaller, individuals became more variable within these groups over time (increasing variance). The full results for all IFLS waves can be seen in Table A.4. The same analysis was done for SD, which is shown in Table A.3.

3.5. Contribution of socioeconomic factors in inter-individual variation in BMI

We ran several simple regressions on BMI, and each covariate (one at a time) for men and women separately for IFLS1 and IFLS4 (Table A.6). In IFLS1, most of the variation in BMI was attributed to socioeconomic factors (e.g., per capita expenditure and place of residence), whereas in IFLS4, age was the greatest contributor in the variation of BMI (Table A.6). In Table 4, we reported the variances of two different multiple regression models (full results are available in Table A.5). Total variance increased over time. Comparing Model I and Model IV in Table 4 illustrates that the effect of socioeconomic factors on BMI became weaker over time among men (IFLS1, 8.9% and IFLS4, 5.9%) and among women (IFLS1, 6.2% and IFLS4, 1.8%).

4. Discussion

The main findings in our study were: (i) changes in the BMI mean were not equally distributed across the entire BMI distribution over time, and higher baseline percentiles gained more weight relative to the segment of the population at lower baseline percentiles (Fig. 2); (ii) while between socioeconomic group differences decreased, within group inequalities increased over time, with greatest increase among individuals in low education and low per capita expenditure groups (Tables 2 and 3); (iii) the effect of socioeconomic factors, i.e. education, households per capita expenditure, occupation, and place of residency on the variation of BMI decreased in 2007 compared with 1993 (Table 4); (iv) a substantial gender gap was observed in the variation of BMI over time, as well as within and between groups throughout the analysis.

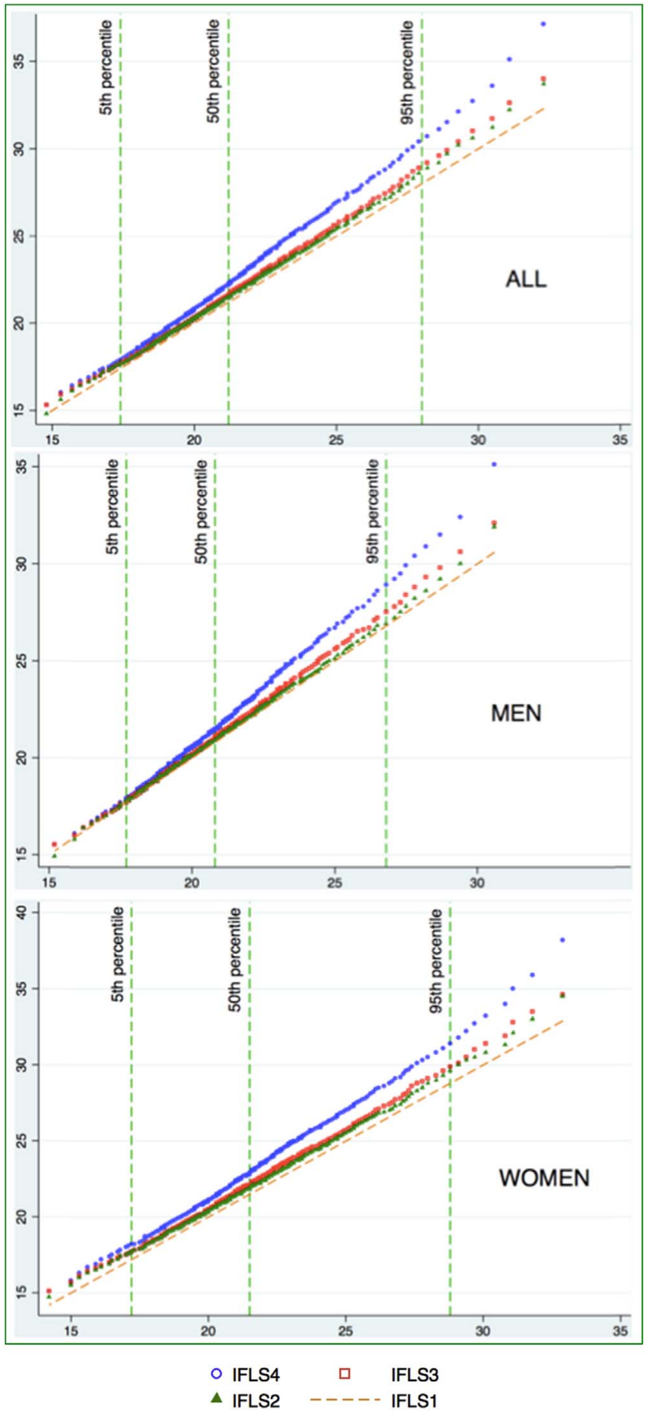

Fig. 2. Quantile-Quantile (QQ) plot of BMI by comparing the baseline with the subsequent study cycles. X-axis shows the BMI at the baseline survey. Y-axis shows the BMI at the following survey waves. The diagonal line y=x is the line of equality between baseline survey and subsequent survey. Vertical reference lines (dash) represent the 5th, 50th, and 95th percentiles, with the value of BMI at the baseline survey at the top of each line. IFLS: Indonesian Family Life Survey.

We believe that this paper provides more comprehensive examination of changes in the distribution of BMI rather than estimation of limited parameters such as the mean level of BMI. For example, solely presenting the prevalence of overweight and obesity would not capture the fact that higher percentile BMI segments were gaining weight at an increased rate relative to lower percentile BMI segments, or that those who have low BMI (in the underweight range) have had little increase in their weight over time. Our finding implies that the concept of "average weight gain" in a population where variance is rapidly rising fails to give a true estimation of how these changes are distributed. The increased variance is a particularly important finding considering the U-shaped relationship between BMI and mortality with increased mortality risk at both low BMI and high BMI levels (Prospective Studies, 2009; Zheng et al., 2011). Consequently, it is important to prioritize interventions in both high-risk groups (underweight and overweight/obese) to improve the health of both tails of the BMI distribution. A population-based strategy solely relying on changing the overall mean BMI in a population would fail to accomplish this dual benefit (Razak et al., 2013).

Moreover we have focused on the idea of within- versus between-group inequalities, as we believe that it is a novel and informative way of exploring how population level changes in BMI are occurring. To our knowledge this is the first application of this approach in a LMIC setting and is we believe an important finding to contrast (and compare) against a similar analysis in the US where both between and within social and demographic group inequalities are widening (Krishna et al., 2015). We observed between group inequalities in BMI, with higher expenditure and more educated groups having higher BMI than low expenditure and lower educated groups. The important finding is that, these between group inequalities (e.g. comparing mean BMI across educational and per capita expenditure strata) decreased over time, while there were growing inter-individual inequalities within groups (increasing SD or variance).

Our findings are both in contrast and in line with the US study (Krishna et al., 2015). In Indonesia, between group inequalities are narrowing, while they are widening in the US population. However, in both countries within group inequalities are increasing over time. In the US study, the authors reported a 30% increase in overall population SD of BMI from 1993 to 2012, while we found an increase of 25% in SD from 1993 to 2008. This shows that inequalities in BMI in the Indonesian population are increasing approximately at the same rate over time as the US population, a high-income country with a much higher prevalence of overweight and obesity.

The fact that increasing socioeconomic inequalities in Indonesia did not drive the observed inequalities or dispersion in BMI is another important finding of our study. A growing number of recent studies showed the link between socioeconomic inequality and health inequality, i.e. inequalities in non-communicable disease (Di Cesare et al., 2013; Sommer et al., 2015; Vellakkal et al., 2013; Kien et al., 2016). In our study the contribution of these socioeconomic factors in explaining the variability in BMI substantially decreased over time. In addition, the generally low R-squared values in Table 4 confirm the fact that very low percentages of the variation in BMI are explained by these variables in all models. However, decreasing between socioeconomic group differences in BMI do not necessarily mean that inequality is improving. Rising within group inequality implies that there must be other under-recognized characteristics in the population such as social, physiological, or genetic variables affecting BMI than conventional socioeconomic factors. Nutrition transition and the exposure to the same obesogenic environment in LMICs might be a useful tool in explaining our findings as the burden of obesity is shifting towards low socioeconomic groups due to rapid social, economic, and technological changes (Popkin, 1998). Even though, the poor and the disadvantaged are catching up, still in LMICs the burden of many non-communicable diseases and their risk factors – particularly overweight and obesity – is on higher socioeconomic groups (Hanandita & Tampubolon, 2015), while this situation is reverse in high-income countries. Whether the same trend will be observed in Indonesia and if socioeconomic differences could better explain the variation in BMI in the future requires follow up studies.

We observed a large gender gap in the variation of BMI in this study. In general men had a lower BMI but became more variable (higher percentage of change in the variance) over time compared to women who had higher BMI but lower percentage of change in

Table 2
Between- and within-group differences in the mean BMI over time for education (no schooling, elementary, secondary, and university) and per capita expenditure quartiles.

	Education						**Per capita expenditure**					
All individuals	**No schooling**	**Elementary**	**Secondary**	**University**	**Mean differences (University vs. No schooling)**		**1st Lowest**	**2nd**	**3rd**	**4th Highest**	**Mean differences (Highest vs. Lowest)**	
	MeanBMI	Mean BMI	MeanBMI	MeanBMI	Absolute	Relative	Mean BMI	Mean BMI	Mean BMI	Mean BMI	Absolute	Relative
IFLS1	21.09	21.55	22.25	22.85	1.762	1.084	20.87	21.36	21.97	22.75	1.883	1.090
IFLS4	22.34	22.81	22.64	23.36	1.020	1.046	21.98	22.49	23.03	23.58	1.594	1.073
P-value	< 0.001	< 0.001	< 0.001	0.021	0.008	0.008	< 0.001	< 0.001	< 0.001	< 0.001	0.824	0.824
% Change	**5.9%**	**5.9%**	**1.8%**	**2.2%**	**−42.1%**	**−3.5%**	**5.3%**	**5.3%**	**4.8%**	**3.6%**	**−15.3%**	**−1.6%**
Men												
IFLS1	20.52	20.92	21.92	22.74	2.221	1.108	20.55	20.90	21.50	22.36	1.808	1.088
IFLS4	21.34	21.54	21.99	23.37	2.027	1.095	21.14	21.55	22.35	22.98	1.842	1.087
P-value	< 0.001	< 0.001	0.554	0.017	0.635	0.635	< 0.001	< 0.001	< 0.001	< 0.001	0.913	0.913
% Change	**4.0%**	**3.0%**	**0.3%**	**2.8%**	**−8.7%**	**−1.2%**	**2.9%**	**3.1%**	**3.9%**	**2.8%**	**1.6%**	**−0.1%**
Women												
IFLS1	21.31	22.01	22.58	23.05	1.736	1.081	21.10	21.71	22.34	23.07	1.970	1.093
IFLS4	22.73	23.81	23.30	23.35	0.622	1.027	22.73	23.33	23.65	24.12	1.390	1.061
P-value	< 0.001	< 0.001	< 0.001	0.422	0.008	0.008	< 0.001	< 0.001	< 0.001	< 0.001	0.774	0.774
% Change	**6.7%**	**8.2%**	**3.2%**	**1.3%**	**−64.2%**	**−5.0%**	**7.7%**	**7.4%**	**5.9%**	**4.5%**	**−29.4%**	**−2.9%**

Percentage change was calculated based on the differences between IFLS1 and IFLS4. Absolute difference was calculated by subtracting mean BMI among individuals with university degree from mean BMI among individuals with no schooling. Relative difference was calculated by dividing mean BMI among individuals with university degree by mean BMI among individuals with no schooling. Mean comparison test (t-test) was used to report p-values for each education subgroup and per capita expenditure quartiles. P-values for percentage change in absolute and relative differences was calculated by regressing BMI on the interaction between time (IFLS1 and IFLS4) and education or per capita expenditure. IFLS: Indonesian Family Life Survey.

Table 3
Within group differences in the variance of BMI over time for education (no schooling, elementary, secondary, and university) and per capita expenditure quartiles.

	Education				**Per capita expenditure**			
All individuals	**No schooling** Variance BMI	**Elementary** Variance BMI	**Secondary** Variance BMI	**University** Variance BMI	**1st Lowest** Variance BMI	**2nd** Variance BMI	**3rd** Variance BMI	**4th Highest** Variance BMI
IFLS1	9.6	9.6	11.9	12.8	7.3	9.2	10.7	13.2
IFLS4	15.2	16.2	15.8	18.0	13.8	15.5	16.0	18.5
P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
% Change	**59.1%**	**68.5%**	**33.5%**	**39.9%**	**88.7%**	**69.5%**	**49.1%**	**39.5%**
Men								
IFLS1	5.2	6.0	9.8	11.3	5.2	5.6	7.9	10.9
IFLS4	7.8	10.0	13.2	16.3	9.5	10.6	13.3	15.9
P-value	0.002	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
% Change	**49.0%**	**66.9%**	**35.1%**	**44.2%**	**81.9%**	**87.6%**	**67.6%**	**45.9%**
Women								
IFLS1	11.1	11.8	13.8	15.6	8.7	11.6	12.7	14.9
IFLS4	17.6	18.8	17.7	19.6	16.5	18.6	17.7	20.2
P-value	< 0.001	< 0.001	< 0.001	0.079	< 0.001	< 0.001	< 0.001	< 0.001
% Change	**58.7%**	**60.1%**	**28.0%**	**25.4%**	**89.0%**	**59.3%**	**39.5%**	**35.5%**

Percentage change was calculated based on the differences between IFLS1 and IFLS4. Variance comparison test (sdtest) was used to report p-values for each education subgroup and per capita expenditure quartiles. IFLS: Indonesian Family Life Survey.

variance. Socioeconomic factors explained less of the variation in BMI among women compared to men. The differences in the explained variance among men and women could imply either the same variables have different effects on the two groups or there are entirely different sets of exposures that might drive these differences. Our analysis did not go beyond the disaggregation of the data by men and women, therefore, our ability in explaining the differences is limited. Future work should adopt a more gender oriented analysis (Morgan et al., 2016; United Nations Economic Commission for Europe, 2010) to describe the economic and social differences in BMI of women and men in the same population. For example, differences may be driven by the impact of maternity, body image, relative allocation of resources or gender relations within households.

Several studies have been conducted and multiple theories have been proposed to explain increasing dispersion at the individual level through both genetic and social factors. For instance, assortative mating and preferences for similar body habitus may determine partner selection and may account for rising variation in BMI between individuals (Dawson, Dhurandhar, Vazquez, Peng & Allison, 2013; Speakman, 2013; Silventoinen, Kaprio, Lahelma, Viken, & Rose, 2003). However, a 25% increase in inequalities in weight gain within 15 years in the Indonesian population is very unlikely to have been driven by assortative mating. Social norms may also cause dispersion by clustering body weight in individuals within groups, yet studies in the US showed little evidence of within group clustering and social multiplier effects on obesity and BMI (Krishna et al., 2015; Auld, 2011). To decouple gene-environment effects, twin and adoption studies have decomposed individual level variance into genetic and environmental components and shown the additive genetic and environmental variance is positively associated with prevalence of obesity, prevalence of overweight and the mean of the BMI distribution (Rokholm et al., 2011; Rokholm et al., 2011; Silventoinen, Rokholm, Kaprio, & Sorensen, 2010). Clearly, multidisciplinary approaches are needed to explain how social disparities, assortative mating, social norms, and genetic predisposition contribute to increasing inter-individual inequalities.

There are some limitations in our study. First, the analysis is based on the four IFLS repeated cross-sectional data and therefore cannot fully determine weight change within an individual over time. However, because our aim was to examine the changes at the population level, these four repeated cross-sectional data allowed us to make inferences at the population level and for segments of the population. Second, BMI was adjusted based on age and quadratic age. More complex age adjustment parameters may be used but are unlikely

Table 4
Multiple linear regressions on BMI across four different models.

	Model I	**R-squared**	**Model IV**	**R-squared**	**% Change in variance**
All	Variance (SE)		Variance (SE)		
IFLS1	10.41 (0.16)	1.9%	9.68 (0.15)	8.7%	**7.0%**
IFLS4	15.06 (0.15)	7.7%	14.61 (0.15)	10.4%	**3.0%**
Men					
IFLS1	7.87 (0.19)	0.7%	7.17 (0.17)	9.7%	**8.9%**
IFLS4	12.28 (0.18)	4.3%	11.55 (0.17)	10.0%	**5.9%**
Women					
IFLS1	12.36 (0.26)	0.8%	11.59 (0.24)	6.9%	**6.2%**
IFLS4	17.54 (0.25)	5.9%	17.22 (0.24)	6.7%	**1.8%**

Model I: $bmi_i=ß_0+ß_1\ (Age)_{1i}+ß_2\ (Gender)_{2i}+e_{0i}$;
Model IV: $bmi_i=ß_0+ß_1\ (Age)_{1i}+ß_2\ (Gender)_{2i}+ß_3\ (Occupation)_{3i}+ß_4\ (Education)_{4i}+ß_5\ (Per\ capita\ Expenditure)_{5i}+ß_6\ (Place\ of\ residence)_{6i}+e_{0i}$;
Percentage change in variance was calculated based on the differences between model I and model IV. For instance, we subtracted the variance in model I by the variance in model IV. We later divided this by the variance in model I and multiplied it by 100. This gives us the percentage of the variance attenuated or explained by inclusion of all the socioeconomic factors for each study wave. IFLS: Indonesian Family Life Survey.

to have a dramatic impact on findings in our sample population of individuals age 20-50. Third, we did not include the dietary pattern of households or the physical activity level of individuals into the analysis, which might better explain the variation in BMI. Finally, only 20–50 year old men and women were included in our analysis. However, this limitation in generalizability to the entire population also could strengthen the specificity of our findings. To tackle malnutrition effectively in LMICs, Uauy and Solomons proposed that international communities should consider five age groups across the course of life: fetal life, infancy and childhood, adolescence, adult life, and old age (Uauy & Solomons, 2006). We addressed adult life; thus alternative approaches i.e. decomposition analysis on other age groups could be a focus of future research.

5. Conclusion

Changes in BMI in Indonesia cannot be fully described by a single parameter such as mean BMI. Increasing within group variance compared with between group differences implies that growing inequalities are not merely driven by these socioeconomic factors at the population level. Future studies using the longitudinal data in IFLS and other datasets are needed to identify who in BMI distribution groups is gaining weight and to focus on further understanding of under-recognized characteristics of population-level weight change.

Conflict of interest

The authors declare no conflict of interest.

Authors contribution

The authors' contributions were as follows: MV and NN contributed reagents and materials; MV, FR, NN and SVS designed the experiment; MV, FR and SVS analyzed and performed the experiment; MV and FR wrote the first draft of the manuscript; MV, FR, NN and SVS contributed to the finalizing of the manuscript and MV had primary responsibility for the final content of the manuscript. None of the authors reported a conflict of interest related to the study.

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Appendix A

See Tables A1–A7.

Table A.1
General characteristics of the study population.

	IFLS1		IFLS2		IFLS3		IFLS4	
Covariates	**Men n (%)**	**Women n (%)**	**Men n (%)**	**Women n (%)**	**Men n (%)**	**Women n (%)**	**Men n (%)**	**Women n (%)**
	3539 (43.6)	4580 (56.4)	4875 (43.9)	6229 (56.0)	7407 (47.7)	8107 (52.3)	8957 (47.4)	9956 (52.6)
Education								
No schooling	343 (9.6)	876 (19.0)	407 (8.6)	1005 (16.4)	327 (4.4)	735 (9.1)	182 (2.0)	466 (4.7)
Elementary	1797 (50.8)	2452 (53.5)	2062 (43.4)	2912 (47.7)	2861 (38.6)	3718 (45.9)	2834 (31.6)	3603 (36.2)
Secondary	1129 (31.9)	1102 (24.1)	1237 (26.0)	1279 (20.9)	3309 (44.7)	2911 (35.9)	4664 (52.1)	4582 (46.0)
University	270 (7.6)	150 (3.3)	1043 (21.9)	912 (14.9)	881 (11.9)	718 (8.9)	1179 (13.1)	1216 (12.2)
Occupation								
Not employed	238(7.0)	2501 (54.6)	637 (13.1)	3272 (52.5)	994 (13.4)	3876 (47.8)	1051 (11.7)	5387 (54.1)
Employed	3313 (93.0)	2079 (45.4)	4238 (86.9)	2957 (47.5)	6413 (86.6)	4231 (52.2)	7906 (88.3)	4569 (45.9)
Per capita expenditure quartiles								
1st (Lowest)	850 (24.0)	1182 (25.8)	1426 (29.2)	1836 (29.5)	1801 (24)	2077 (25.6)	2218 (24.8)	2512 (25.2)
2nd	888 (25.1)	1141 (24.9)	1290 (26.5)	1635 (26.2)	1875 (25.3)	2003 (24.7)	2244 (25.0)	2486 (25.0)
3rd	899 (25.0)	1132 (24.7)	1158 (23.7)	1482 (23.8)	1880 (25.4)	1998 (24.6)	2244 (25.0)	2483 (25.0)
4th (Highest)	902 (25.0)	1125 (24.6)	1001 (20.5)	1276 (20.5)	1851 (25.0)	2029 (25.0)	2251 (25.1)	2475 (24.9)
Place of residence								
Urban	1696 (47.9)	2155 (47.0)	2213 (45.4)	2898 (46.5)	3739 (50.5)	4093 (50.5)	4784 (53.4)	5372 (53.9)
Rural	1843 (52.1)	2425 (52.9)	2662 (54.6)	3331 (53.5)	3668 (49.5)	4014 (49.5)	4173 (46.6)	4584 (46.0)

IFLS: Indonesian Family Life Survey.

Table A.2
Between- and within group differences in the mean BMI over time for education (no schooling, elementary, secondary, and university) and per capita expenditure quartiles.

	Education						Per capita expenditure					
All individuals	**No schooling**	**Elementary**	**Secondary**	**University**	**Mean differences (University vs. No schooling)**		**1st Lowest**	**2nd**	**3rd**	**4th Highest**	**Mean differences (Highest vs. Lowest)**	
	Mean BMI	Mean BMI	Mean BMI	Mean BMI	Absolute	Relative	Mean BMI	Mean BMI	Mean BMI	Mean BMI	Absolute	Relative
IFLS1	21.09	21.55	22.25	22.85	1.762	1.084	20.87	21.36	21.97	22.75	1.883	1.090
IFLS2	21.50	21.99	22.35	21.65	0.146	1.007	21.28	21.66	22.25	22.90	1.621	1.076
IFLS3	21.63	22.03	21.95	22.48	0.854	1.039	21.28	21.78	22.20	22.81	1.532	1.072
IFLS4	22.34	22.81	22.64	23.36	1.020	1.046	21.98	22.49	23.03	23.58	1.594	1.073
P-value	< 0.001	< 0.001	< 0.001	0.021	0.008	0.008	< 0.001	< 0.001	< 0.001	< 0.001	0.824	0.824
% Change	**5.9%**	**5.9%**	**1.8%**	**2.2%**	**−42.1%**	**−3.5%**	**5.3%**	**5.3%**	**4.8%**	**3.6%**	**−15.3%**	**−1.6%**
Men												
IFLS1	20.52	20.92	21.92	22.74	2.221	1.108	20.55	20.90	21.50	22.36	1.808	1.088
IFLS2	20.56	21.04	21.85	21.52	0.956	1.046	20.61	21.12	21.63	22.28	1.669	1.081
IFLS3	20.76	21.04	21.46	22.67	1.905	1.092	20.60	21.11	21.60	22.31	1.707	1.083
IFLS4	21.34	21.54	21.99	23.37	2.027	1.095	21.14	21.55	22.35	22.98	1.842	1.087
P-value	< 0.001	< 0.001	0.554	0.017	0.635	0.635	< 0.001	< 0.001	< 0.001	< 0.001	0.913	0.913
% Change	**4.0%**	**3.0%**	**0.3%**	**2.8%**	**−8.7%**	**−1.2%**	**2.9%**	**3.1%**	**3.9%**	**2.8%**	**1.9%**	**−0.1%**
Women												
IFLS1	21.31	22.01	22.58	23.05	1.736	1.081	21.10	21.71	22.34	23.07	1.970	1.093
IFLS2	21.88	22.65	22.84	21.80	−0.086	0.996	21.80	22.09	22.73	23.39	1.589	1.073
IFLS3	22.01	22.79	22.51	22.26	0.241	1.011	21.87	22.41	22.76	23.28	1.404	1.064
IFLS4	22.73	23.81	23.30	23.35	0.622	1.027	22.73	23.33	23.65	24.12	1.390	1.061
P-value	< 0.001	< 0.001	< 0.001	0.422	0.008	0.008	< 0.001	< 0.001	< 0.001	< 0.001	0.774	0.774
% Change	**6.7%**	**8.2%**	**3.2%**	**1.3%**	**−64.2%**	**−5.0%**	**7.7%**	**7.4%**	**5.9%**	**4.5%**	**−29.4%**	**−2.9%**

Percentage change was calculated based on the differences between IFLS1 and IFLS4. Absolute difference was calculated by subtracting mean BMI among individuals with university degree from mean BMI among individuals with no schooling. Relative difference was calculated by dividing mean BMI among individuals with university degree by mean BMI among individuals with no schooling. Mean comparison test (t-test) was used to report p-values for each education subgroup and per capita expenditure quartiles. P-values for percentage changes in absolute and relative differences were calculated by regressing BMI on the interaction between time (IFLS1 and IFLS4) and education or per capita expenditure. IFLS: Indonesian Family Life Survey.

Table A.3
Within-group differences in the standard deviation of BMI over time for education (no schooling, elementary, secondary, and university) and per capita expenditure quartiles.

	Education				**Per capita expenditure**			
All individuals	**No schooling** SD BMI	**Elementary** SD BMI	**Secondary** SD BMI	**University** SD BMI	**1st Lowest** SD BMI	**2nd** SD BMI	**3rd** SD BMI	**4th Highest** SD BMI
IFLS1	3.1	3.1	3.4	3.6	2.7	3.0	3.3	3.6
IFLS2	3.4	3.4	3.6	3.4	3.1	3.3	3.5	3.9
IFLS3	3.6	3.5	3.6	3.8	3.1	3.5	3.6	3.9
IFLS4	3.9	4.0	4.0	4.2	3.7	3.9	4.0	4.3
P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
% Change	**26.2%**	**29.8%**	**15.5%**	**18.3%**	**37.4%**	**30.2%**	**22.1%**	**18.1%**
Men								
IFLS1	2.3	2.4	3.1	3.4	2.3	2.4	2.8	3.3
IFLS2	2.3	2.6	3.2	3.3	2.4	2.8	3.1	3.4
IFLS3	2.7	2.7	3.3	3.8	2.5	2.9	3.3	3.6
IFLS4	2.8	3.2	3.6	4.0	3.1	3.2	3.7	4.0
P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
% Change	**22.1%**	**29.2%**	**16.2%**	**20.1%**	**34.9%**	**37.0%**	**29.5%**	**20.8%**
Women								
IFLS1	3.3	3.4	3.7	4.0	3.0	3.4	3.6	3.9
IFLS2	3.7	3.7	3.9	3.4	3.4	3.6	3.7	4.2
IFLS3	3.8	3.9	3.8	3.9	3.5	3.8	3.9	4.2
IFLS4	4.2	4.3	4.2	4.4	4.1	4.3	4.2	4.5
P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
% Change	**26.0%**	**26.5%**	**13.1%**	**12.0%**	**37.5%**	**26.2%**	**18.1%**	**16.4%**

Variance comparison test (sdtest) was used to report the p-value for each education subgroup and per capita expenditure quartiles between IFLS1 and IFLS4. IFLS: Indonesian Family Life Survey.

Table A.4
Within group differences in the variance of BMI over time for education (no schooling, elementary, secondary, and university) and per capita expenditure quartiles.

	Education				**Per capita expenditure**			
All individuals	**No schooling** Variance BMI	**Elementary** Variance BMI	**Secondary** Variance BMI	**University** Variance BMI	**1st Lowest** Variance BMI	**2nd** Variance BMI	**3rd** Variance BMI	**4th Highest** Variance BMI
IFLS1	9.6	9.6	11.9	12.8	7.3	9.2	10.7	13.2
IFLS2	11.5	11.5	12.8	11.3	9.5	10.8	12.0	15.1
IFLS3	12.9	12.5	12.8	14.8	9.9	12.0	13.1	15.6
IFLS4	15.2	16.2	15.8	18.0	13.8	15.5	16.0	18.5
P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
% Change	**59.1%**	**68.5%**	**33.5%**	**39.9%**	**88.7%**	**69.5%**	**49.1%**	**39.5%**
Men								
IFLS1	5.2	6.0	9.8	11.3	5.2	5.6	7.9	10.9
IFLS2	5.4	6.6	10.0	10.7	5.7	7.6	9.5	11.3
IFLS3	7.4	7.4	10.7	14.3	6.0	8.2	10.6	13.2
IFLS4	7.8	10.0	13.2	16.3	9.5	10.6	13.3	15.9
P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
% Change	**49.0%**	**66.9%**	**35.1%**	**44.2%**	**81.9%**	**87.6%**	**67.6%**	**45.9%**
Women								
IFLS1	11.1	11.8	13.8	15.6	8.7	11.6	12.7	14.9
IFLS2	13.5	13.9	15.0	11.9	11.8	12.9	13.3	17.5
IFLS3	14.8	15.1	14.7	15.3	12.5	14.7	14.9	17.2
IFLS4	17.6	18.8	17.7	19.6	16.5	18.6	17.7	20.2
P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
% Change	**58.7%**	**60.1%**	**28.0%**	**25.4%**	**89.0%**	**59.3%**	**39.5%**	**35.5%**

Percentage change was calculated based on the differences between IFLS1 and IFLS4. Variance comparison test (sdtest) was used to report p-values for each education subgroup and per capita expenditure quartiles between IFLS1 and IFLS4. IFLS: Indonesian Family Life Survey.

Table A.5
Multiple linear regressions on BMI across four models.

	Model I	Model II	Model III	Model IV	% Change in variance
All	Variance (SE)	Variance (SE)	Variance (SE)		
IFLS1	10.41 (0.16)	10.40 (0.16)	9.80 (0.15)	9.68 (0.15)	**7.0%**
IFLS2	11.24 (0.15)	11.24 (0.15)	10.80 (0.15)	10.76 (0.15)	**4.3%**
IFLS3	11.96 (0.13)	11.95 (0.13)	11.59 (0.13)	11.56 (0.13)	**3.3%**
IFLS4	15.06 (0.15)	15.06 (0.15)	14.65 (0.15)	14.61 (0.15)	**3.0%**
Men					
IFLS1	7.87 (0.19)	7.87 (0.19)	7.24 (0.17)	7.17 (0.17)	**8.9%**
IFLS2	8.39 (0.17)	8.36 (0.17)	7.76 (0.16)	7.76 (0.16)	**7.5%**
IFLS3	9.53 (0.16)	9.51 (0.16)	8.94 (0.15)	8.94 (0.15)	**6.2%**
IFLS4	12.28 (0.18)	12.27 (0.18)	11.58 (0.17)	11.55 (0.17)	**5.9%**
Women					
IFLS1	12.36 (0.26)	12.35 (0.26)	11.75 (0.24)	11.59 (0.24)	**6.2%**
IFLS2	13.44 (0.24)	13.43 (0.24)	13.06 (0.24)	12.96 (0.23)	**3.6%**
IFLS3	14.11 (0.22)	14.11 (0.22)	13.85 (0.22)	13.77 (0.22)	**2.4%**
IFLS4	17.54 (0.25)	17.53 (0.25)	17.27 (0.24)	17.22 (0.24)	**1.8%**

Model I: $bmi_i=ß_0+ß_1\ (Age)_{1i}+ß_2\ (Gender)_{2i}+e_{0i}$
Model II: $bmi_i=ß_0+ß_1\ (Age)_{1i}+\ ß_2\ (Gender)_{2i}+ß_3\ (Occupation)_{3i}+e_{0i}$
Model III: $bmi_i=ß_0+ß_1\ (Age)_{1i}+ß_2\ (Gender)_{2i}+ß_3\ (Occupation)_{3i}+ß_4\ (Education)_{4i}+ß_5\ (Per\ capita\ Expenditure)_{5i}+e_{0i}$
Model IV: $bmi_i=ß_0+ß_1\ (Age)_{1i}+ß_2\ (Gender)_{2i}+ß_3\ (Occupation)_{3i}+ß_4\ (Education)_{4i}+ß_5\ (Per\ capita\ Expenditure)_{5i}+ß_6\ (Place\ of\ residence)_{6i}+e_{0i}$
Percentage change in variance was calculated based on the differences between model I and model IV. For instance, we subtracted the variance in model I by the variance in model IV. We later divided this by the variance in model I and multiplied it by 100. This gives us the percentage of the variance attenuated or explained by inclusion of all the socioeconomic factors for each study wave. IFLS: Indonesian Family Life Survey.

Table A.6
Univariate linear regression on BMI and each covariate separately.

All individuals	Fixed part		Random part			
	IFLS1 ß (SE)	IFLS4 ß (SE)	IFLS1		IFLS4	
			Variance	% Change from null model	Variance	% Change from null model
Null model			10.61	–	16.31	–
Gender	0.35 (0.04)	0.72 (0.03)	10.48	1.2%	15.79	3.2%
Age	0.03 (0.01)	0.10 (0.01)	10.55	0.6%	15.61	4.3%
Occupation	−0.42 (0.08)	−0.48 (0.06)	10.57	0.4%	16.26	0.3%
Education	0.61 (0.05)	0.13 (0.04)	10.39	2.1%	16.30	0.1%
PCE	0.63 (0.03)	0.53 (0.02)	10.12	4.6%	15.96	2.1%
Residence	−1.28 (0.07)	−0.73 (0.06)	10.20	3.7%	16.18	0.8%
Men						
Null model			7.93	–	12.84	–
Age	0.03 (0.01)	0.09 (0.01)	7.87	0.7%	12.28	4.4%
Occupation	0.30 (0.19)	0.77 (0.09)	7.92	0.1%	12.78	0.5%
Education	0.82 (0.06)	0.63 (0.05)	7.53	5.0%	12.63	1.6%
PCE	0.60 (0.04)	0.63 (0.03)	7.48	5.7%	12.34	3.9%
Residence	−1.17 (0.09)	−0.78 (0.07)	7.59	4.3%	12.69	1.2%
Women						
Null model			12.46	–	18.45	–
Age	0.04 (0.01)	0.11 (0.01)	12.36	0.8%	17.54	4.9%
Occupation	−0.13 (0.10)	0.05 (0.09)	12.45	0.1%	18.45	0.0%
Education	0.61 (0.07)	−0.14 (0.05)	12.26	1.6%	18.44	0.0%
PCE	0.65 (0.04)	0.45 (0.04)	11.92	4.3%	18.20	1.3%
Residence	−1.37 (0.10)	−0.68 (0.09)	11.99	3.8%	18.34	0.6%

Percentage change in variance for IFLS1 and IFLS4 was calculated based on the differences between null model and the variance after inclusion of each covariate. This gives us the percentage of the variance attenuated or explained by inclusion of all the socioeconomic factors for each study wave. IFLS: Indonesian Family Life Survey; PCE: Per-Capita Expenditure.

Table A.7
Prevalence of underweight, normal weight, overweight, and obesity among 20–50 year-olds across the four Indonesian Family Life Survey (IFLS) waves.

All individuals	Cross-sectional data								Panel data							
	Underweight		Normal weight		Overweight		Obese		Underweight		Normal weight		Overweight		Obese	
	WHO	*ASIAN*	*WHO*	*ASIAN*	*WHO*	*ASIAN*	*WHO*	*ASIAN*	*WHO*	*ASIAN*	*WHO*	*ASIAN*	*WHO*	*ASIAN*	*WHO*	*ASIAN*
IFLS 1	12.7	12.7	71.4	58.0	13.8	22.8	2.1	6.4	12.8	12.8	73.9	61.8	11.7	20.5	1.5	4.9
IFLS 2	12.2	12.2	70.6	56.4	14.3	23.8	3.0	7.6	9.2	9.2	70.9	55.8	16.7	26.5	3.1	8.5
IFLS 3	13.1	13.1	68.4	54.0	15.2	24.8	3.2	8.2	8.9	8.9	66.8	49.7	20.1	29.8	4.2	11.6
IFLS 4	10.7	10.7	63.7	48.1	20.0	28.5	5.5	12.6	7.1	7.1	56.3	38.9	27.6	34.6	8.9	19.4
Men																
IFLS 1	12.0	12.0	76.9	69.9	10.2	19.3	1.0	3.8	11.9	11.9	81.1	70.9	6.7	14.9	0.3	2.3
IFLS 2	13.1	13.1	75.9	63.1	9.8	19.8	1.1	4.0	10.0	10.0	79.7	65.7	9.7	21.0	0.6	3.3
IFLS 3	14.4	14.4	72.9	60.3	11.3	20.5	1.4	4.8	10.0	10.0	75.6	62.3	13.2	22.7	1.2	5.0
IFLS 4	12.3	12.3	69.5	55.1	15.1	24.5	3.0	8.0	7.4	7.4	68.9	51.2	20.0	30.7	3.7	10.7
Women																
IFLS 1	13.3	13.3	67.2	52.7	16.5	25.6	3.0	8.5	13.4	13.4	69.8	56.7	14.6	23.6	2.2	6.3
IFLS 2	11.5	11.5	66.4	51.2	17.7	27.0	4.4	10.4	8.8	8.8	65.9	50.1	20.7	29.6	4.5	11.4
IFLS 3	12.0	12.0	64.3	48.1	18.8	28.7	4.9	11.2	8.3	8.3	61.9	42.5	24.0	33.8	5.9	15.4
IFLS 4	9.3	9.3	58.6	41.7	24.4	32.2	7.7	16.8	7.0	7.0	49.0	31.8	32.0	36.8	11.9	24.4

References

Auld, M. C. (2011). Effect of large-scale social interactions on body weight. *Journal of Health Economics*, 30, 303–316. http://dx.doi.org/10.1016/j.jhealeco.2010.09.002.

Dawson, J. A., Dhurandhar, E. J., Vazquez, A. I., Peng, B., & Allison, D. B. (2013). Propagation of obesity across generations: The roles of differential realized fertility and assortative mating by body mass index. *Human Heredity*, 75, 204–212. http://dx.doi.org/10.1159/000352007.

Deurenberg, P., Deurenberg-Yap, M., & Guricci, S. (2002). Asians are different from caucasians and from each other in their body mass index/body fat percent relationship. *Obesity Reviews*, 3, 141–146.

Di Cesare, M., Khang, Y. H., Asaria, P., Blakely, T., Cowan, M. J., Farzadfar, F. et al. (2013). Inequalities in non-communicable diseases and effective responses. *Lancet*, 381, 585–597. http://dx.doi.org/10.1016/S0140-6736(12)61851-0.

Finucane, M. M., Stevens, G. A., Cowan, M. J., Danaei, G., Lin, J. K., Paciorek, C. J. et al. (2011). National, regional, and global trends in body-mass index since 1980: Systematic analysis of health examination surveys and epidemiological studies with 960 country-years and 9.1 million participants. *Lancet*, 377, 557–567. http://dx.doi.org/10.1016/S0140-6736(10)62037-5.

Flegal, K. M., & Troiano, R. P. (2000). Changes in the distribution of body mass index of adults and children in the us population. *International Journal of Obesity and Related Metabolic Disorders*, 24, 807–818. http://dx.doi.org/10.1038/sj.ijo.0801232.

Gakidou, E. E., Murray, C. J. L., & Frenk, J. (2000). Defining and measuring health inequality: An approach based on the distribution of health expectancy. *The Bulletin of the World Health Organization*, 8, 42–54.

Hanandita, W., & Tampubolon, G. (2015). The double burden of malnutrition in indonesia: Social determinants and geographical variations. *SSM – Population Health*, 1, 16–25. http://dx.doi.org/10.1016/j.ssmph.2015.10.002.

Jones-Smith, J. C., Gordon-Larsen, P., Siddiqi, A., & Popkin, B. M. (2011). Cross-national comparisons of time trends in overweight inequality by socioeconomic status among women using repeated cross-sectional surveys from 37 developing countries, 1989–2007. *American Journal of Epidemiology*, 173, 667–675. http://dx.doi.org/10.1093/aje/kwq428.

Julia, M., van Weissenbruch, M. M., Prawirohartono, E. P., Surjono, A., & Delemarre-van de Waal, H. A. (2008). Tracking for underweight, overweight and obesity from childhood to adolescence: A 5-year follow-up study in urban indonesian children. *Hormone Research*, 69, 301–306. http://dx.doi.org/10.1159/000114862.

Kien, V. D., Van Minh, H., Giang, K. B., Dao, A., Weinehall, L., Eriksson, M. et al. (2016). Socioeconomic inequalities in self-reported chronic non-communicable diseases in urban Hanoi, Vietnam. *Global Public Health*, 1–16. http://dx.doi.org/10.1080/17441692.2015.1123282.

Krishna, A., Razak, F., Lebel, A., Smith, G. D., & Subramanian, S. V. (2015). Trends in group inequalities and interindividual inequalities in BMI in the United States, 1993-2012. *American Journal of Clinical Nutrition*, 101, 598–605. http://dx.doi.org/10.3945/ajcn.114.100073.

Merlo, J., Chaix, B., Ohlsson, H., Beckman, A., Johnell, K., Hjerpe, P. et al. (2006). A brief conceptual tutorial of multilevel analysis in social epidemiology: Using measures of clustering in multilevel logistic regression to investigate contextual phenomena. *The Journal of Epidemiology and Community Health*, 60, 290–297. http://dx.doi.org/10.1136/jech.2004.029454.

Morgan, R., George, A., Ssali, S., Hawkins, K., Molyneux, S., & Theobald, S. (2016). How to do (or not to do)... Gender analysis in health systems research. *Health Policy Planning*. http://dx.doi.org/10.1093/heapol/czw037.

Murray, C. J. L., Gakidou, E., & Frenk, J. (1999). Health inequalities and social group differences: What should we measure? *The Bulletin of the World Health Organization*, 77, 537–543.

Ogden, C. L., Yanovski, S. Z., Carroll, M. D., & Flegal, K. M. (2007). The epidemiology of obesity. *Gastroenterology*, 132, 2087–2102. http://dx.doi.org/10.1053/j.gastro.2007.03.052.

de Onis, M., & Lobstein, T. (2010). Defining obesity risk status in the general childhood population: Which cut-offs should we use? *International Journal of Pediatric Obesity*, 5, 458–460. http://dx.doi.org/10.3109/17477161003615583.

Popkin, B. M. (1998). The nutrition transition and its health implications in lower-income countries. *Public Health Nutrition*, 1, 5–21. http://dx.doi.org/10.1079/PHN19980004.

Prospective Studies, Collaboration, Whitlock, G., Lewington, S., Sherliker, P., Clarke, R., Emberson, J. et al. (2009). Body-mass index and cause-specific mortality in 900 000 adults: Collaborative analyses of 57 prospective studies. *Lancet*, 373, 1083–1096. http://dx.doi.org/10.1016/S0140-6736(09)60318-4.

Razak, F., Corsi, D. J., & Subramanian, S. V. (2013). Change in the body mass index distribution for women: Analysis of surveys from 37 low- and middle-income countries. *PLoS Medicine*, 10, e1001367. http://dx.doi.org/10.1371/journal.pmed.1001367.

Roemling, C., & Qaim, M. (2012). Obesity trends and determinants in indonesia. *Appetite*, 58, 1005–1013. http://dx.doi.org/10.1016/j.appet.2012.02.053.

Roemling, C., & Qaim, M. (2013). Dual burden households and intra-household nutritional inequality in Indonesia. *Economics and Human Biology*, 11, 563–573. http://dx.doi.org/10.1016/j.ehb.2013.07.001.

Rokholm, B., Silventoinen, K., Angquist, L., Skytthe, A., Kyvik, K. O., & Sorensen, T. I. (2011). Increased genetic variance of bmi with a higher prevalence of obesity. *PLoS One*, 6, e20816. http://dx.doi.org/10.1371/journal.pone.0020816.

Rokholm, B., Silventoinen, K., Tynelius, P., Gamborg, M., Sorensen, T. I., & Rasmussen, F. (2011). Increasing genetic variance of body mass index during the Swedish obesity epidemic. *PLoS One*, 6, e27135. http://dx.doi.org/10.1371/journal.pone.0027135.

Silventoinen, K., Rokholm, B., Kaprio, J., & Sorensen, T. I. (2010). The genetic and environmental influences on childhood obesity: A systematic review of twin and adoption studies. *International Journal of Obesity*, 34, 29–40. http://dx.doi.org/10.1038/ijo.2009.177.

Silventoinen, K., Kaprio, J., Lahelma, E., Viken, R. J., & Rose, R. J. (2003). Assortative mating by body height and BMI: Finnish twins and their spouses. *American Journal of Human Biology*, 15, 620–627. http://dx.doi.org/10.1002/ajhb.10183.

Sommer, I., Griebler, U., Mahlknecht, P., Thaler, K., Bouskill, K., Gartlehner, G. et al. (2015). Socioeconomic inequalities in non-communicable diseases and their risk factors: An overview of systematic reviews. *BMC Public Health*, 15, 914. http://dx.doi.org/10.1186/s12889-015-2227-y.

Speakman, J. R. (2013). Evolutionary perspectives on the obesity epidemic: Adaptive, maladaptive, and neutral viewpoints. *Annual Review of Nutrition*, 33, 289–317. http://dx.doi.org/10.1146/annurev-nutr-071811-150711.

Strauss, J., Witoelar, V., Sikoki, B., & Wattie, A. M. (March 2009).*The fourth wave of the Indonesia Family Life Survey (ifls4): Overview and field report*. Wr-675/1-nia/nichd

Uauy, R., & Solomons, N. W. (2006). The role of the international community: Forging a common agenda in tackling the double burden of malnutrition. *SCN News*, 32, 24–37.

United Nations Economic Commission for Europe (2010). *Developing gender statistics: A practical tool. Reference manual prepared by UNECE Task Force on Gender Statistics Traning for Statisticians with contrinution from various experts*. Geneva: United Nations.

Usfar, A. A., Lebenthal, E., Atmarita Achadi, E., Soekirman, & Hadi, H. (2010). Obesity as a poverty-related emerging nutrition problems: The case of Indonesia. *Obesity Review*, 11, 924–928.

Vaezghasemi, M., Öhman, A., Eriksson, M., Hakimi, M., Weinehall, L., Kusnanto, H. et al. (2014). The effect of gender and social capital on the dual burden of malnutrition: A multilevel study in Indonesia. *PLoS One*, 9, e103849. http://dx.doi.org/10.1371/journal.pone.0103849.

Vellakkal, S., Subramanian, S. V., Millett, C., Basu, S., Stuckler, D., & Ebrahim, S. (2013). Socioeconomic inequalities in non-communicable diseases prevalence in India: Disparities between self-reported diagnoses and standardized measures. *PLoS One*, 8, e68219. http://dx.doi.org/10.1371/journal.pone.0068219.

WHO (1995). *Physical status: The use and interpretation of anthropometry*. *Report of a WHO Expert Committee*. *Who Technical Report Series 854*. Geneva: World Health Organization.

WHO Expert Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet. 2004;363(9403):157-63. PubMed PMID: 14726171. doi: 10.1016/S0140-6736(03)15268-3.

Wilk, M. B., & Gnanadesikan, R. (1968). Probability plotting methods for the analysis of data. *Biometrika*, 55, 1–17. http://dx.doi.org/10.1038/sj.ijo.0801232.

Winkvist, A., Nurdiati, D. S., Stenlund, H., & Hakimi, M. (2000). Predicting under- and overnutrition among women of reproductive age: A population-based study in Central Java, Indonesia. *Public Health Nutrition*, 3, 193–200. http://dx.doi.org/10.1017/S1368980000000227.

WHO (2000). Obesity: Preventing and managing the global epidemic. Report of a WHO consultation. *World Health Organization Technical Report Series*, 894, 1–253.

Zheng, W., McLerran, D. F., Rolland, B., Zhang, X., Inoue, M., Matsuo, K. et al. (2011). Association between body-mass index and risk of death in more than 1 million Asians. *The New England Journal of Medicine*, 364, 719–729. http://dx.doi.org/10.1056/NEJMoa1010679.