Educational Gradient in Body Mass Index Trajectories across Cohorts of Indonesian Adults

Abstract

Globally, the number of obese adults has increased rapidly in many developing countries. The association between education and inequality in overweight/obesity across populations are highly studied. However, educational attainment can have a different association with BMI change at different levels of economic development, and these associations may vary by period and cohort. This study aims to provide evidence on the shifting of educational gradients in mean BMI of the Indonesian population using a growth curve approach on five waves of the Indonesia Family Life Survey.

Over successive cohorts, the educational patterning of the BMI gradient has shifted. In older generations, higher educational attainment was associated with higher BMI, but the gap between educational groups has shrunk in more recently-born cohorts. Mean BMI of lower educational groups is catching up with that of the tertiary educated, leading to an increased risk of overweight/obesity among low educated people. Having tertiary education lowers the risk of weight gain in women, but not in men. This phenomena suggest that the ongoing nutritional transition in Indonesia is leading to a shifting of educational gradients in mean BMI over time.

Keywords: BMI trajectories, age period cohort effects, longitudinal study, multi-level modeling.

Introduction

Global Obesity Epidemic

Adult obesity is a global public health challenge due to its negative implications for human well-being, as well as for countries' economic development. Systematic reviews and meta-analysis studies have documented the association between overweight/obesity with all-cause mortality (Aune et al., 2016; Donini et al., 2012; Flegal et al., 2013). People with obesity are vulnerable to infectious diseases and Non-Communicable Diseases (NCDs). During the Covid-19 pandemic, evidence suggests that people with overweight/obesity are at increased risk of contracting Covid-19, requiring care in an ICU, and at heightened risk of mortality as compared to people with normal weight (Lobstein, 2021; Mahase, 2020; Wadman, 2020). Previous literature has established that overweight/obesity is a major risk factor of morbidity from NCDs including high blood pressure, cardiovascular diseases, and diabetes (Abdullah et al., 2010; Mongraw-Chaffin et al., 2015; Sudharsanan, 2017). It is estimated that the medical costs for obese individuals are three times higher as compared to individuals with normal weight, and obesity accounted for 0.7-2.8% of a country's total health expenditures (Withrow & Alter, 2011). Clearly, the high cost of obesity-related diseases results in a substantial burden to health system and society (Tremmel et al., 2017). Further, overweight and obesity have indirect costs to the economic growth due to lost productivity among obese workers due to higher rates of sick leave, disability, and premature mortality (Goettler et al., 2017).

Health institutions and scholars have been sounding alarm on the global rise of overweight and obesity. A multi-country study shows the continued rise in adults' BMI in most countries in the world (Di Cesare et al., 2016). The global prevalence of obesity in world's adult population was estimated to have increased nearly threefold from 1975 to 2016 (World Health Organisation, 2020). The World Health Organization (WHO) estimated that 39% of the world's adult population (aged ≥18 years) were overweight and 13% obese in 2016 (World Health Organisation, 2020). If these trends continue, obesity will affect one in five adults globally by 2025 with predicted prevalence 18% in men and above 21% in women (Lobstein & Brinsden, 2020). The global burden of overweight adults aged over 20 years was expected to reach 2.16 billion or 38% world's adult population in 2030 (Kelly et al., 2008). Underscoring the serious public health implications of obesity epidemic, WHO calls countries to prevent the rise in obesity prevalence by 2025. However, the Global Obesity Federation reports that most countries fall short in halting the rise in obesity (Lobstein & Brinsden, 2020).

Obesity is commonly understood as a public health challenge in high-income countries, but the rate of increase in overweight and obesity is much faster in low- and middle-income countries (Di Cesare et al., 2016; Kelly et al., 2008; Lobstein & Brinsden, 2020; Strauss & Thomas, 2007). The top 10 countries with the most rapid increase in obesity prevalence during 1995-2016 are located in Asia-Pacific Region including Laos, Vietnam, Indonesia, and Timor-Leste (Lobstein & Brinsden, 2020). Major contributors to this rising burden of overweight and obesity include overall population growth, emerging population ageing, urbanization, changes in nutrition, and sedentary lifestyle (Kelly et al., 2008).

Although the prevalence of overweight and obesity are rising globally, the epidemic is not evenly distributed across population groups. Previous studies show notable gender, socioeconomic, ethnic, and spatial/geographical disparities in prevalence of overweight/obesity within and across countries (Ailshire & House, 2012; Clarke et al., 2009; Devaux & Sassi, 2013; Ford et al., 2005). These social inequalities reflect differences in the quality of people' living conditions, which in turn affect their opportunity to pursue a healthy life and maintain optimum weight. Reversing this rise of global obesity requires intervention across socioeconomic and cultural groups to reduce disparities in the prevalence of obesity (Lobstein & Brinsden, 2020; Robertson, 2014), rather than relying only on individual responsibility to maintain optimum weight. With regards to the complex root causes of obesity disparity, there is a need to understand social determinants of health contributing to the disparity within and between countries.

Education is a fundamental social determinant of health outcomes, and is associated with better health and lower risk of poor health behaviors (Hamad et al., 2018; Ljungdahl & Bremberg, 2015). Education also determines individuals' access to material resources, occupation, income, exposure to occupational hazards, and physiological and cognitive improvements leading to better health-related decision-making (Hamad et al., 2018; Lynch, 2003). The close link between education and obesity also notable. In European countries, disparity in educational status explained 50% of inequality in women's obesity and 26% of men's (Robertson, 2014). The high correlation between income and education causes some challenges to measuring the direct effects of education on health, but literature shows that education level significantly reduces the risk of obesity even after controlling for income or wealth status (Clarke et al., 2009; Insaf et al., 2014).

Educational Gradient of Obesity

The relationship between education and obesity manifests in different ways in different population contexts. A systematic review finds differences in both the magnitude and direction of the association between education attainment and obesity, and finds that these effects are modified by gender and level of economic development (Cohen et al., 2013). Studies in most high-income countries find that more educated individuals have lower risk of obesity (Cohen et al., 2013; Sassi et al., 2011). Examination of BMI trajectory by sex and across racial groups in the USA shows that higher education is associated with a lower BMI in all groups (Clarke et al., 2009; Insaf et al., 2014). However, the opposite association is often observed in lower-income countries—with more educated individuals at higher risk of obesity (Bollyky et al., 2017). Further, different patterns and directions of the education attainment—BMI association are also observed within countries (Cohen et al., 2013). Baker et al. (2017) argue that these different manifestations of the relationship between education and obesity suggest that the effect of education on obesity is contextual, and closely related with the nutritional transition across populations.

One particular challenge to observing the relationship between education and health is that the access, quality and value of education change over time in ways that that may change the education-health relationship (Lynch, 2003). Literature shows significant decline in educational inequality globally (Benaabdelaali et al., 2012), meaning that younger cohorts tend to have better access to and quality of education as compared to older cohorts. These changes across cohorts may have substantial effects on the education-obesity relationship over time. Thus, there are likely to be complex age, period, and cohort effects on the relationship between education and obesity that need to be investigated (Ailshire & House, 2012; Cohen et al., 2013; Gutiérrez-Fisac et al., 2002). Despite many studies that have investigated the association between education and health, there are few studies that investigate whether the relationship between education and health varies over life course and across birth cohorts (Lynch, 2003). Ignoring age and cohort effects on the relationship between education and health can lead to incorrect conclusions or biased estimation of the true underlying relationship using both cross sectional and longitudinal data (Lynch, 2003). Therefore, careful examination is needed in considering the effect of education on changes in BMI across cohorts.

Most published literature on education gradients and obesity comes from developed countries, and research specifically investigating the effect of education on BMI remains scarce in developing countries (Cohen et al., 2013; Jeon et al., 2015). The available evidence is almost entirely based on cross-sectional data. These cross-sectional data can only measurer social differences in obesity at a single point of time based on distribution of observations characteristic (Clarke et al., 2009). However, BMI is not a fixed characteristic, and instead varies within individuals across their life course. As such, cross-sectional has only limited ability to examine how characteristics such as education attainment are linked to individual's changing risk of obesity over the life-course.

In addition, few studies consider how changing access to education across cohorts may affect educational gradients to BMI. The present study aims to fill this important gap in the literature on individual BMI trajectories over the life-course by investigating how the association between education and BMI changes across cohorts in a low-middle income setting. Further, this research explores potential factors that may modify the association between education and BMI by applying an age-period-cohort model.

Environmental Change and the Overweight/Obesity Epidemic

The obesity epidemic is fueled by environmental changes known as obesogenic changes affecting whole population (Hruby & Hu, 2015; Sturm & An, 2014). Examples of obesogenic changes include economic growth, policies aiming to improve food supplies and accessibility, automatisation leading to a more sedentary lifestyle, social norms, a lack of nutritional education, declines in active transportation, urban designs lacking in recreation space, and the proliferation of fast food availability.

Changes in this obesogenic environment over time exposes all social groups to risk of obesity, but in ways that depend on individual genetic, socioeconomic, and sociocultural factors (Hruby & Hu, 2015; Sturm & An, 2014). Social gradients of weight gain are also associated with social and environmental contexts, which vary across time (Clarke et al., 2009).Changes in the environment also affect men and women differently. Sociocultural contexts drive gender differences in dietary intake, physical activities, and gendered cultural values favoring large body shapes (Kanter & Caballero, 2012). During the nutritional transition, the increase in food availability and energy-dense foods worsen sociocultural effects on gender disparities in obesity (Kanter & Caballero, 2012). Thus, Sturm and An (2014) suggest study of change can provide insight on the effect of the environment on the obesity epidemic, and how the effect of obesogenic changes on the risk of obesity differs across social groups.

In many countries, data on obesogenic changes are very rare, which creates challenges for understanding the impact of environment on the obesity pandemic. However, the richness of longitudinal data tracking individuals over time allows scholars to study these changes. Longitudinal data allows researcher to investigate how the rate of change of an outcome may vary across population groups (Singer & Willett, 2003). Hence, longitudinal data tracking individuals' body mass index (BMI) over time permits investigation into the impact of historical period effects (obesogenic changes) on individual BMI trajectory. Analysis using longitudinal data also allows us to explore how the rates of BMI change vary across social groups over time.

Changes in BMI are often clearly patterned by birth cohorts (Hargrove, 2018). Studies in the USA find higher mean BMI among younger generations compared to older cohorts (Clarke et al., 2009; Insaf et al., 2014; Walsemann & Ailshire, 2011). Similarly, an investigation of age-period-cohort-effects on BMI change in Canada found cohort played a more important role on different BMI trajectories between Aboriginal and non-Aboriginal Canadians, and found that younger cohorts consistently have higher BMI from early to middle adulthood as compared to older cohorts (Ng et al., 2012).

There are methodological challenges to test cohort effects in the study of social change. The general practice is to include cohort as covariate in the modelling. However, inclusion of cohort as covariate into model creates collinearity issues between cohort and age as

Age=period-cohort (Siegel & Olshansky, 2012). (Siegel & Olshansky, 2012) argue that Age-Period-Cohort (APC) should be examined jointly to prevent errors of interpretation. The hierarchical age-period-cohort (HAPC) model has been proposed to jointly explore APC effects (Bell & Jones, 2015). This present study applies HAPC to test cohort effects on BMI trajectory.

Indonesian Context

Indonesia is the world's fourth most populous nation with about 260 million people, and is classified as a newly industrialized country. Currently Indonesia has a young population structure, but the population is projected to experience a rapid increase in the population of older adults (60 plus) from 9% (23.0 million) in 2015 to 19.7% (61.4 million) in 2045 (Bappenas et al., 2018). Consistent with the global rise in excess weight, Indonesia has experienced a rise in the proportion of the population overweight or obese in all ages over the past two decades (Oddo et al., 2019; Rachmi et al., 2017; Roemling & Qaim, 2012; Vaezghasemi et al., 2016). The Indonesia National Basic Health Research Survey (Riskesdas) has observed a rapid increase of overweight and obesity among adults age over 18 years old from 21.7% (combined overweight and obese) in 2010 to 35.3% in 2018 (National Institute of Health Research and Development (BALITBANGKES), 2010, 2019).

Prior evidence from Indonesia found heterogeneity in the prevalence overweight/obesity by age, gender, education status, income level, marital status, and urban/rural residential areas (National Institute of Health Research and Development (BALITBANGKES), 2019; Oddo et al., 2019; Rachmi et al., 2017; Roemling & Qaim, 2012). Behavioural factors such as sedentary lifestyle, increases in total food expenditure, increases in consumption of highly processed food, meat, and dairy products, and low intake of vegetables and fruits have been associated with obesity among Indonesians (Oddo et al., 2019; Rachmi et al., 2017; Roemling & Qaim, 2012). Further, rapid urbanization also increases access to highly processed food and adoption of a sedentary lifestyle, as most jobs now require sedentary rather than active labor (Oddo et al., 2019; Rachmi et al., 2017).

Recent studies on BMI in Indonesia have shown narrowing inequalities in the overweight/obesity distribution and a fairly even dispersal across socioeconomic groups (Oddo et al., 2019; Sudharsanan, 2017; Vaezghasemi et al., 2016). Overweight and obesity are rising rapidly among the poor, people with low education, and in rural populations (Vaezghasemi et al., 2016). The increase in the rate of overweight and obesity among rural residents is far faster compared to residents living in urban areas, where rises in obesity have been slowing down over time (Oddo et al., 2019; Roemling & Qaim, 2012).

Previous literature examining the trend of overweight/obesity in Indonesia have relied almost entirely on cross sectional analysis. The small number of studies using longitudinal data to explore changes in mean BMI across population groups (Roemling & Qaim, 2012; Vaezghasemi et al., 2016) do not consider variation on individual BMI growth patterns over the lifespan. To our knowledge, no previous study has used repeated measures of BMI to model BMI trajectories, and explore how BMI changes with age from early to late adulthood in Indonesia. By taking into account intra- and inter-individual differences in BMI changes over life-course, this study aims to identify how the trajectory of BMI differs by sex and cohort in this rapidly changing context. In addition, although previous studies have investigated the differences in BMI by level of education, none have specifically investigated educational gradients of BMI trajectories, or examined how changes in access to education across birth cohorts shape BMI trajectories (Oddo et al., 2019; Rachmi et al., 2017; Roemling & Qaim, 2012). Inequality in access to education in Indonesia has decreased over time (Idzalika & Lo Bue, 2020), meaning younger generations have experienced greater access to higher education than previous generation. This increasing access to schooling was accelerated by the enactment of universal basic education in mid 1990s, which made schooling compulsory through year 9, though the rate of improvement has stalled since the early 2000s (Suharti, 2013). Despite these improvements, Census 2010 shows that gender and household economic differences in access to education persist among cohorts over 30 years old (Jones & Pratomo, 2016). Educational access and quality also vary across region in Indonesia (Idzalika & Lo Bue, 2020; Jones & Pratomo, 2016). These changes in access to education may affect the association between education and obesity.

Research Questions

Using longitudinal analysis, this study attempts to understand the rising burden of obesity in low-middle income setting by examining individuals BMI trajectories and social gradient of weight gain in Indonesia. This research is guided by three key research questions:

1. Are there distinct gender differences in individuals' BMI trajectories over age?
2. What are the age, period, and cohort patterns of BMI trajectories in Indonesia?
3. How does the education-BMI relationship change over age and across cohorts?

Methodology

Data Source

Using longitudinal data from the Indonesian Family Life Survey (IFLS), this study examines how individual BMI trajectories have changed over two decades (from 1993 to 2014). There are five waves of IFLS until 2014, and data are available for public use at https://www.rand.org/labor/FLS/IFLS.html. During two decades of observations, there were new panel respondents added in each wave. The new panel respondents were included on IFLS to account for Indonesia's population structure. This present study includes both original and new panel respondents into analysis to increase sample power. Analysis in this study is conducted without longitudinal sample weighting because IFLS datasets only generated individual longitudinal weighting for original respondents who had been followed since the first wave.

IFLS has followed and collected information of households and individual respondents over time, including anthropometric measures (height and weight) from all individual respondents that are used to measure Body Mass Index (BMI). As a household survey, IFLS followed individual BMI from a wide range of cohorts over 20 years that allows examination of individual weight change as function of age, as well as the cohort shift in mean BMI over time. Only individuals with completed anthropometric measures (height and weight) are included in analyses. Pregnant women are excluded from observation to reduce bias on analyzing individual BMI trajectory. This present study also excludes observations with extreme outliers of height (<100cm or >200cm) and weight (<25 kg or >200kg). Overall, there are less than 0.6% of observations excluded due to extreme height and weight (see Supplemental Table 1).

This study focuses on examining the changes in BMI among adults who born before 1974 and at age 20 and over in 1993. To examine the change in BMI over time, this study only include panel respondents with a minimum three measures of BMI to permit more flexible BMI trajectory modelling. Supplemental Table 2 provides participation rates of each birth cohort under study. In total there are 14,810 individual panel respondents aged ≥20 with a minimum three BMI measures. Sensitivity analysis performed using all panel respondents with minimum one BMI measure, suggested no substantial change in significance and direction of association between covariates and BMI changes.

Measures

Body Mass Index (BMI)

The outcome interest of this study is BMI, which is a continuous time-varying variable. BMI is a general indicator to measure and classify individual adults considered as underweight, normal, overweight or obese. BMI is calculated from individual weight in kilograms divided by the square of the person height in meters (kg/m^2) (World Health Organisation, 2020). The risk of chronic diseases among Asian populations is increased at lower BMI cut points as compared to international BMI cut points (≥25-29.9kg/m^2 for overweight and ≥30kg/m^2 for obese) (Barba et al., 2004). Thus, the cut points for Asia-Pacific population are 23–27.4 kg/m^2 for overweight and ≥27.5 kg/m^2 for obese (Barba et al., 2004; World Health Organisation, 2020).

To explain variation in BMI trajectories across population groups, this study will examine whether BMI trajectory differs by age, sex, cohort, period and educational attainment over time.

Age

By observing how BMI change as a function of age, this study can reveal the true effect of age on BMI trajectories. In this analysis, individual's age in each wave represents time and is treated as a continuous variable. Age is centered at 20 in the models to facilitate meaningful interpretation of the intercept.

Sex

Gender is measured as a dummy variable (0=men and 1=women). Based on previous evidence, we hypothesize that BMI trajectories may differ substantially by sex, with the rate of change higher among women than men.

Period

To account for the effect of historical period when the surveys were conducted, a five-category period variable (1=1993, 2=1997, 3=2000, 4=2007, and 5=2014) is used.

Cohort

A continuous cohort variable is created to estimate the effect of birth cohort. The cohort variable is also centered at youngest cohort of panel respondents (respondents born in 1973).

Education

This study investigates the effect of education attainment by age 20 to shaping BMI changes across the population. Data exploration found that only 1.2% of panel respondents experienced changes on educational status over two decades of IFLS observation. Hence, education is treated as a time invariant variable with the assumption the level of educational attainment of panel respondents is unchanged after age 20. Level of education attainment is treated as a categorical variable with 1=no education, 2=primary school, 3=secondary school (junior and senior schools), and 4=tertiary.

Statistical Analysis

This study fits an individual growth model, and examines BMI trajectories using a mixed-effects approach to Growth Curve Modelling (GCM) that permits estimation of inter-individual variability by taking account of intra-individual trajectories of change over time (Curran et al., 2010). This model can fit unbalanced data, meaning that individual BMI trajectories can contain a unique number of BMI measures which were collected at unique times (Singer & Willett, 2003). The mixed-effect approach also can fit complex models containing two or three-level random-effects without difficulty (McNeish & Matta, 2018).

To describe the growth curve model, the three level model is defined as follows:

$$y_{ijk} = \beta_0 + \beta_1(Age_{ijk}) + \beta_n X_{ijk} + \upsilon_{0j} + \upsilon_{1j}(Age_{ijk}) + \gamma_k + \varepsilon_{ijk}$$

The outcome y_{ijk} represents BMI measures at time i, of individual panel respondent j, of k birth cohort. The $\beta_0 + \beta_1(Age_{ijk}) + \beta_n X_{ijk}$ represents the fixed portion of the model with β_0 for population average of BMI, $\beta_1(Age_{ijk})$ for estimated effect of age, and $\beta_n X_{ijk}$ for estimated effect of other covariates (including: age^2, sex, period, birth cohort, education level and their interactions). The $\upsilon_{0j} + \upsilon_{1j}(Age_{ijk}) + \gamma_k$ illustrates the random effect of the model with υ_{0j} as the random intercept of BMI between individuals, $\upsilon_{1j}(Age_{ijk})$ as the random slope of BMI changes as a function of age between individuals, and γ_k as the random intercept of BMI between birth cohorts. Then ε_{ijk} represents error term.

This study comprises two steps of analyses. First, we model trajectories of BMI and examine whether there is a significant variation within and between persons in BMI changes over the life-course. We further investigate whether the association between age and BMI follows a quadratic or curvilinear trend over age. The analysis will also test whether BMI trajectory differs by sex over the life-course. The mixed model consists of two-level random effects models that count for intra- and inter-individual differences in BMI trajectory.

In the second step of analysis, we develop separate models for men and women to investigate the effect of age, period, and cohort on changes in population BMI. These analyses additionally investigate how educational gradients in BMI trajectory have changed over time after controlling for period and cohort effects. Due to significant differences in access to education and in BMI trajectories between men and women, these analyses are conducted separately by gender.

This paper adopts the hierarchical age-period-cohort model (HAPC) by Bell and Jones (2015) to model age-period-cohort effects on BMI trajectories. Using HAPC analysis, the trend in BMI of the Indonesian population is evaluated according to three different dimensions of time: age (life course), period (historical time when the survey occurred), and birth cohort (historical effect of the year in which individuals were born).

The data structure of the ILFS comprises a wide range of birth cohorts who were observed through 5 wave of ILFS from 1993 to 2014. Based on the data structure, the effects of APC are investigated simultaneously by the inclusion of age, period, and cohort as covariates at fixed model. The APC collinearity also tested through an interaction effect. The mixed model with APC in this analysis is a three-level random-effects model taking account intra-and inter-individual differences in BMI changes at second level, as well as intra-and inter-cohort differences at the third level. The model also includes linear age as an individual random effect to allow the effect of age on BMI trajectory to vary across individuals.

The main effect of education is examined by including education covariates in the fixed model. Further, interactions between education and age and/or cohort are included to test differences in the effect of education over the life-course and across cohort after controlling for historical period. Statistical analysis was carried out using Stata, version 14.2.

Findings

Descriptive Analysis

In total there are 14,810 panel respondents with three or more BMI measures in the IFLS. The distribution of panel respondents in each wave is illustrated by Table 1. Table 1 shows the unweighted distribution of observations in this study for each wave based on respondent characteristics (sex, age group, education attainment and BMI category). The table shows a gradual increase of proportion overweight/obese over time from 1993 to 2014. The mean BMI also increased from 21.4 kg/m^2 in 1993 to 23.85 kg/m^2 in 2014. Overweight and obesity were more common in women than men.

(Table 1&2 will be here)

Table 2 provides cross-tabulations of the distribution of panel respondents by educational attainment based respondent's sex and birth cohort groups. The distribution of educational attainment varies substantially by sex and over birth cohorts. Women have lower education attainment compared to men, but the gap shrinks over successive generations as education became more accessible over time. This changing access to education by gender across successive cohorts needs to be accounted for when exploring the association between educational attainment and BMI trajectories.

BMI Trajectories of Men and Women

Table 3 shows summary model investigating differences in the BMI trajectories over age, separately for men and women. Age has significant effects on BMI trajectories, and follows a quadratic function. In early adulthood, BMI increased by 0.16 points with each year of age, but the rate of change in BMI declined by -0.002 points with increasing age leading to a declining trajectory of BMI by late adulthood. This declining of BMI at late adulthood demonstrates the effect of biological aging processes including sarcopenia (Cruz-Jentoft et al., 2010).

BMI trajectories are significantly different between women and men over age. The findings in Table 3 suggest that there are gender differences in the rate of change by age and in age-related declines BMI in later life. At age 20, mean BMI is 0.12 points higher for women as compared to men ($p<0.001$). Weight gain over age was more rapid for women, with BMI growing by 0.07 points per year more for women as compared to men. However, women also saw more rapid age-related declines with at higher ages, (as shown by the significant interaction between the female and age^2 terms).

Predicted mean BMI over age adjusted for other covariates at means for women and men is illustrated on Figure 1. The figure illustrates that women's BMI increases faster than men at middle age, and women overall are more likely to be overweight after age 40 based on Asia-Pacific BMI cut-off. Although men also saw increases in BMI over age, their average trajectory remains within the normal BMI spectrum.

Random effects from the above model show that individuals vary substantially in both their initial BMI (with variance=9.28) and in the rate of increase in BMI over time (with variance=0.01). The larger magnitude of variance on the BMI intercept as compared to the slope suggests that individuals' initial BMI plays a major role in determining BMI trajectory over age between individuals.

(Table 3 and Figure 1 will be here)

Given the potential gender differences in the social, biological, and life-course drivers of BMI trajectories (including differences in access to education between men and women), this study estimates separate models for men and women. Separate models can reduce the complexity of analysis on testing the effect of education attainment over the life course and across cohorts.

Age-Period-Cohort Effects on BMI Trajectories for Women and Men

Table 4 shows separate models for women's and men's BMI trajectories using Hierarchal Age-Period-Cohort growth curve modeling. The results suggest that age, period, and cohort independently affect the change of population mean BMI. The interaction between age, period and cohort is not significant, suggesting that there is no substantial correlation between APC.

Similar with first analysis, the results in Table 4 find significant linear and quadratic effects of age on BMI changes for women and men, meaning individual BMI changes over age following curvilinear function. Both models find significant differences in the effect of period from 1993 to 2014 to the changes of BMI in women and men. Compared to BMI in 1993, women's BMI gradually rose over the period from 0.34 point in 1997 to 1.49 in 2014. For men, BMI was significantly higher only in 2007 and 2014, with increments 0.51 and 0.82 points respectively. The significant effects of period suggest that changes in social and environmental context (or historical periods) from 1993 to 2014 contributed to the rise of population BMI in Indonesia. Centering birth cohort at younger cohort (born in 1973), both models show significant effects of birth cohort on individual BMI, meaning that more recently-born cohorts are heavier than previous cohorts. The effect of cohort prevails even after accounting for intra- and inter-birth cohort differences in the intercept of BMI as shown in the level three random effect. Predicted adjusted mean BMI when controlling the effect of period and cohort are illustrated in Figure 2. Further, Figure 3 illustrates adjusted BMI trajectories for six birth cohorts of women to visualize differences in BMI trajectories across cohort.

(Table 4 and Graph 2&3 will be here)

For both women and men, the random effects show that considerable individual variability in intercept and slope remains after the inclusion of the growth model (fixed effects). The large magnitude of variance around the intercept terms suggests that individual differences in initial BMI play a major role in determining BMI growth over time. The random model indicates that most of the variance in mean BMI (intercept) comes from the between individual level (10.99) rather than birth cohort level (0.16). These results suggest fairly significant variation between birth cohorts in mean BMI.

Educational Gradient of BMI Trajectories Across Cohorts for Women and Men

Table 4 illustrates the effect of education on women's and men's BMI. Education attainment has substantially different impacts on the BMI of women and men. In the women's model, the main effect of education on BMI diminishes after interacting education with cohort, as well as when age is included into model. This suggests that the effect of education on women's BMI depends on age (life-course) and individual birth cohort. Among women, inequality in mean BMI across the educational spectrums is wider over life-course. The negative interaction between education and cohort reveals that women from younger birth cohorts with high level of education tend to have lower BMI compared to low educated women. It also shows that women with higher educational attainment have lower BMI compared to previous generations of women with the same education level. The significant negative interaction between education and cohort to BMI suggests that the lower rate of weight gain among younger cohorts is associated with the increased level of educational attainment achieved by individuals in the same birth cohorts.

The model estimating the effect of education for men differs slightly from women's model, as it lacks an interaction between education and age due to convergence issues. This likely stems from the smaller sample of male panel respondents as compared to women. Thus, the men's model only tests the main effect of education and whether the effect of education on BMI varies across birth cohorts. Having secondary or tertiary education is associated a higher BMI among men, with increments 0.83 for men with secondary education and 1.91 for tertiary education. The negative effect of higher education on the change in BMI also observed in men, although at a much smaller magnitude compared to women.

(The figures 4 predicted margins BMI by education will be here)

Predicted adjusted mean BMI by educational spectrum across cohorts is illustrated in Figure 4. This figure illustrates the shifting effect of educational attainment on BMI across cohorts of men and women in Indonesia. Panel A of Figure 4 shows that inequalities in mean BMI across educational spectrum were wide among older generation in women, but diminish among younger generations. Among older generations, women with lower education have mean BMI around underweight to normal BMI cut-offs (<23 kg/m^2 for Asia-Pacific BMI cut-off). However, among the younger generation, the mean BMI of women with low education attainment are now at in the overweight classification of BMI (23-24.9 kg/m^2 for Asia-Pacific BMI). This suggests that the risk of overweight is more dispersed across the educational spectrum among more recently-born cohorts of women. The mean BMI of women with tertiary education shows a downward trend over cohorts, from obese ($\geq$ 25 kg/m^2) among older cohorts to overweight in younger cohorts. These trends suggest that, among younger cohorts, tertiary education is acting as a "social vaccine" to growth of BMI and obesity for women.

The educational gradient of mean BMI among men (Panel B of Figure 4) also narrows over cohort, but the gradient persists in younger birth cohorts. The predicted margin of mean BMI for men across the educational spectrum show that, in contrast to its protective effects among women, tertiary education is associated with weight gain among men in younger cohorts. Men with tertiary education tend to be overweight, and although the mean BMI of men with secondary education or lower increases over time, the mean BMI of these groups remain in the normal BMI range ($\leq$ 23 kg/m^2).

Discussion

Using panel data from the Indonesian Family Life Survey, this study provides evidence on how social inequalities in BMI are shifting over time and across cohorts in low-middle income setting. Analyses of both men's and women's BMI trajectories find that inequality in BMI by educational attainment has narrowed among younger generations, to the point of diminishing entirely among recent cohorts of women. Interestingly, this study finds a differential direction of the association between tertiary education and mean BMI between men and women. Having tertiary educational attainment after age 20 is a protective factor for overweight and obesity over life course for women in younger cohorts. However, men with tertiary education remain heavier compared to low-educated people over generations.

Based on the literature, there are several possible explanations of the educational gradients identified in this study. Firstly, the effect of educational attainment on BMI varies across birth cohorts. The narrowing gap in BMI by education attainment across generations for men and women in Indonesia may be the result of increasing access to and quality of education over time. Literature shows inequality in access to education in Indonesia has decreased over time, as younger generations enjoyed better access to education resulting from government programs supporting scholarship and financial support for education (Idzalika & Lo Bue, 2020). Secondly, declining inequality in mean BMI across the educational spectrum may reflect ongoing macro-level changes causing the Indonesian population to be exposed to new health risks (Baker et al., 2017). These macro-level changes include a rise in sedentary occupations, increasing access to high-calorie foods, and a reduction in active modes of transportation. The shifting effect of education attainment on BMI may reflect the ongoing nutritional transition in the country, characterized by rising access to western diets and processed foods containing high fat, salt and sugar (Baker & Friel, 2014). According to the population education transition (PET) hypothesis, a positive association between higher education and overweight/obesity is likely to be observed at the onset of nutritional transition (Baker et al., 2017) because high-educated people have better access to food. As the population becomes more widely exposed during the nutritional transition and the health risk of obesity becomes profound, a negative association between education and obesity emerges (Baker et al., 2017) because high-educated people are more aware of the risks of obesity for health, and more knowledgeable and capable on how to maintain optimal weight compared to socially disadvantaged people. The change in BMI over generations and the change in the association between education and BMI over cohorts suggests that these findings are driven by the ongoing nutritional transition in Indonesia. Future research focusing on macro-level analysis of the nutritional transition in Indonesia can provide more detailed explanations of the shifting effect of education on weight gain, and improve knowledge of environmental contexts that promote obesity in the country.

Thirdly, the different effect of tertiary education effect on BMI for men and women suggests that the present gender differences in weight gain are passing through education. Different effects of education by gender were also identified in previous research (Roemling & Qaim, 2012), with higher education found to be protective of obesity for women (Diana et al., 2013). Gender differences in higher education's effect on obesity are also observed in Korea (Sassi et al., 2011). For women, the negative effect of tertiary education on weight gain may reflect higher access to information and knowledge that help individuals maintain their body weight. Higher education is also related to better socioeconomic status, which provides advantages for people to access healthy food and pursue healthy lifestyles. The protective effect of education on health risk behaviors among women supports the "ceteris paribus" or "social vaccine" hypothesis/premise (Baker et al., 2017). If current trends in the educational gradient in BMI among Indonesian women continue, we may observe an inverse association between educational attainment and BMI in the near future, where women with low education are at higher risk of overweight/obesity.

Substantial differences in BMI trajectories over the life course were observed between females and males in the Indonesian population. In addition to social factors such as educational attainment, biological factors such as the proportion and distribution of body fat, hormones, reproductive histories, and the effect of menopause shape lead to different BMI trajectories between men and women over life course (Kanter & Caballero, 2012; Power & Schulkin, 2008). The steep increase in BMI observed in Indonesian women during middle-adulthood places women at risk to be overweight. The different effect of sex on BMI trajectory is also found by other studies in different population (Abarca-Gómez et al., 2017; Ailshire & House, 2012). These substantially different BMI trajectories between men and women suggest that conducting in-depth separate analysis for males and females may reveal different risk factors that affect their BMI trajectories. Kanter and Caballero (2012) suggest that investigation of sociocultural context of gender differences in employment status, occupations, pattern of physical activity, dietary intake, and norms on overweight/obesity can help to understand gender disparities in obesity.

Another important contribution of this study is the examination of age-period-cohort (APC) effects on BMI change in Indonesia. The results suggest that both biological and historical contexts simultaneously explain the change in BMI among Indonesians. This study reveals that the main effect of age is to determine the individual rate of increase in BMI, and the rate of age-related declines in BMI during the aging process. The APC analysis reveal significant cohort effects, with younger generations tending to have higher BMI compared to older generations. This suggests that historical conditions embedded in certain birth cohorts shape differences in BMI trajectory over adulthood and across cohorts.

The APC analysis also reveals that period of surveys from 1-5 waves also have significant different effect to population mean BMI. The mean BMI of Indonesia increased slowly from 1993 to 1997, then flattened between 1997 and 2000, before increasing sharply in 2007 and 2014. These period fluctuations may be related to the broad macro-economic changes occurring in Indonesia during these years. Indonesia experienced high rates of Gross Domestic Product (GDP) growth from 1990-96 (Nomaan & Nayantara, 2018). In the following years, the country's economy plunged due to the East Asian economic crisis of 1997-98, causing increasing unemployment and poverty and declining income in the country (Nomaan & Nayantara, 2018). Post the crisis, the country experienced stable growth of GDP and declines in the rate of poverty over time (Nomaan & Nayantara, 2018). Kinge et al. (2015) argue that

GDP has positive association with the obesity and the association might be mitigated by education.

Public Health Significance

Findings from this study provide important information and knowledge that can inform health policy related to increases in overweight/obesity in Indonesia. The findings show that women are at high risk of experiencing increasing BMI after age 30. Hence, prevention programs can focus on assisting women in early adulthood to maintain normal weight. Obesity prevention programs for women also can be integrated into child and maternal health programs in Indonesia. For example, a potential strategy would be monitoring women's BMI during and after pregnancy to prevent obesity among women in reproductive age. As younger cohorts tend to have higher BMI at early adulthood compared to previous generations, prevention programs also need to target younger generation at early ages. When developing policies and intervention programs, the government should consider obesity inequalities across population groups to ensure that prevention strategies are able to reduce inequalities. Obesity prevention program also need to focus on low educated men and women to prevent rising trends of obesity among these socially disadvantaged groups in future.

Strengths and Limitation of This Study

Analysis based longitudinal data is required to disentangle the effects of age, period, and cohort to reduce bias and improve robust estimation. This present study provides simultaneous examination of APC effects on BMI changes in Indonesia. The findings reveal important evidence on the actual effects of APC to BMI change in the country that can help inform better health policy to prevent future increases of overweight/obesity in Indonesia. This study also improves knowledge on the trend of associations between education and BMI changes in developing country context. The analytical approach in this study can be replicated in other low-middle income country settings to extend knowledge on obesity patterns in countries that remain understudied.

Despite the strengths, this present study only focus on examining social inequality in BMI trajectory based on a time-invariant measure of educational attainment. The substantial residual variation remaining around the individual intercept suggests that the inclusion of additional covariates such could improve explanation of inter-individual differences in BMI trajectories. Further analysis including time-variant variables such as changes in wealth index, income, or occupations can extend knowledge on the effect of the changes in economic status on BMI trajectories over the life course. There might be selection bias in this study as result of attrition due to mortality among oldest birth cohorts or drop-out among youngest cohorts with high mobility, and sample restriction that exclude individuals with extremes of height and weight or who have less than three BMI measures during the ILFS period. However, sensitivity analysis on the models (available upon request) shows estimation including all observations with a minimum of one BMI measure had consistent results.

The random effects in the estimation model find a wide variance of BMI intercept in this study. This suggests that further in-depth analysis is needed to investigate the different effects of initial BMI to the risk of obesity. The investigation of BMI trajectories in this study provides insights for future analysis exploring the effect of BMI trajectories for later-life health outcomes in Indonesia. BMI trajectory is an important predictor of later health outcome. In particular, the duration of time in obesity increases the risk of developing type 2 diabetes and hypertension, and instability in BMI has been associated with cardiovascular disease and metabolic risk (Ng et al., 2012). However, these relationships have not been systematically studied outside of high-income contexts.

Conclusion

In conclusion, this study identified different BMI trajectories between men and women in Indonesia, with the rate of weight gain higher among women compared to men. Age, period and cohort factors independently contribute to the increase of BMI in Indonesia. This study finds that the gap in BMI by educational levels is narrowing over cohorts in the Indonesian population, as the mean BMI of people with low education increases gradually across younger birth cohorts. Tertiary education has a protective effect on obesity among women in younger generations. Though having tertiary education is still associated with weight gain among men, this rate of BMI increase is much lower than for men with less schooling. These rising trends in overweight/obesity among low-educated people are a substantial concern for the future of public health and non-communicable disease risk in Indonesia, as these socially disadvantaged groups already face substantial barriers to receiving health care and effective treatment.

Tables

Table 1 Descriptive proportion of respondents age 20 and over from each wave by sex, age group, education and BMI categories (N=14,810 panel respondents)

	Waves				
Characteristics	I	II	III	IV	V
	n=10,452	n=12,595	n=14,082	n=12,779	n=10,623
Sex					
Female	56.27	56.26	53.75	54.5	54.92
Male	43.73	43.74	46.25	45.5	45.08
Age Group					
20-29	18.52	16.2	9.04	0.05	0
30-39	30.28	30.64	30.64	21.28	1.04

40-49	20.89	22.31	25.48	32.31	36.40
50-59	17.61	16.41	16.41	22.33	31.86
≥60	12.7	14.44	18.43	24.02	30.71
Cohort					
1964 -1973	18.52	27.71	30.77	34.43	39.16
1954 -1963	30.28	28.43	27.77	29.42	31.52
1944-1953	20.89	18.21	17.45	17.36	17.17
1934-1943	17.61	14.93	14.02	12.36	9.22
≤ 1933	12.7	10.73	9.98	6.43	2.91
Highest education attainment					
Never/Not completed primary education	21.95	19.83	18.64	16.97	14.03
Primary	51.25	49.07	48.09	48.32	49.71
Secondary	23.29	26.70	28.46	29.84	31.12
Tertiary	3.51	4.40	4.81	4.88	5.14
International BMI Classification					
Underweight	17.16	15.90	16.40	13.27	11.18
Normal	68.29	66.28	63.30	57.62	52.71
Overweight	12.5	14.86	16.65	22.55	27.25
Obese	2.05	2.95	3.66	6.56	8.86
Asian BMI Classification					
Underweight	17.16	15.90	16.40	13.27	11.18
Normal	55.96	52.65	49.03	42.13	36.08
Overweight	20.96	23.57	25.40	29.74	33.45
Obese	5.91	7.88	9.17	14.86	19.29

Table 2 Distribution Panel Respondents Based on Education Attainment by Sex and Cohort (N=14,810)

	Never/Not completed primary	**Primary**	**Secondary**	**Tertiary**	**Total**
*Sex ****					
Female	24.5	47.45	24.52	3.52	100
Male	11.06	48.78	33.69	6.48	100
*Cohort - 10 years interval ****					
1964-1973	5.52	41.1	46.11	7.27	100
1954-1963	12.05	56.45	26.48	5.03	100
1944-1953	17.73	53.88	24.08	4.31	100
1934-1943	36.7	45.4	15.28	2.62	100
<=1933	53.5	40.13	5.53	0.84	100

Notes: *** p-value<0.001

Table 3 Model BMI Trajectories by Sex over Life Course

	Model BMI Trajectory by Sex with 95% CI	
# of obs	**60,531**	
# of groups	**14,810**	
Fixed effect		
Mean BMI (intercept)	19.218***	[19.070-19.365]
Rate of change by age - Centering age at 20	0.162 ***	[0.153-0.172]
Changing in rate by age	-0.002***	[-0.002-(-0.002)]
Sex-Female	0.121	[-.074-0.315]
Interaction Female-Age	0.067***	[0.054-0.079]
Interaction Female - Age square	-0.001***	[-0.001-(-0.0003)]
Random effect		

Level I - within person		
variance residual	2.750	[2.706-2.794]
Levell II - between person		
variance initial BMI (intercept)	9.275	[8.823-9.751]
variance rate of change (slope)	0.013	[0.013-0.014]
cov(intercept & slope)	-0.073	[-0.087-(-0.059)]
p-value random effect		
Goodness of fit		
Log likelihood	-143188.790	
Wald chi2(0)	6194.900	
Prob>chi2	<0.001	
AIC	286397.600	
BIC	286487.700	

Notes: *** p-value significant <0.001

Table 4 Summary Table Model for Male and Female

	Female Model with 95% CI		**Male Model with 95% CI**	
# of observations	**33,334**		**27,197**	
# of panel respondents	**8,003**		**6,816**	
# cohort group	**70**		**72**	
Fixed effect				
Mean BMI (intercept)	19.95***	[19.49-20.41]	***19.40	[18.94-19.85]
Rate of change by age	0.21***	[0.19-0.23]	***0.17	[0.15-0.18]
Changing in rate - aging effect	-0.003***	[-0.003-(-0.003)]	***-0.002	[-0.003-(-0.002)]
Cohort	0.07***	[0.05-0.10]	***0.06	[0.04-0.08]
Period (wave of survey)				
1993				
1997	0.34***	[0.26-0.43]	0.03	[-0.04-0.11]

2000	0.38***	[0.26-0.50]	0.02	[-0.09-0.13]
2007	0.98***	[0.77-1.19]	***0.51	[0.32-0.71]
2014	1.49***	[1.19-1.78]	***0.82	[0.54-1.10]
Education				
None				
Primary	0.70***	[0.25-1.15]	0.30	[-0.18-0.78]
Secondary	0.21	[-0.27-0.70]	0.83***	[0.35-1.31]
Tertiary	-0.61	[-1.42-0.19]	1.91***	[1.28-2.53]
Education#cohort				
None				
Primary	-0.01	[-0.03-0.01]	-0.005	[-0.02-0.01]
Secondary	-0.06***	[-0.08-(-0.03)]	-0.04***	[-0.06-(-0.02)]
Tertiary	-0.12***	[-0.18-(-0.06)]	-0.05***	[-0.08-(-0.02)]
Education#Age				
None				
Primary	0.01	[-0.005-0.017]		
Secondary	0.04***	[0.02-0.05]		
Tertiary	0.06***	[0.04-0.09]		
Random effect				
Level I - within person				
variance residual	3.27	[3.21-3.35]	2.07	[2.02-2.12]
Level II - between person				
variance initial BMI (intercept)	10.99	[10.29-11.74]	6.59	[6.10-7.13]
variance rate of change (slope)	0.01	[0.01-0.01]	0.01	[0.01-0.01]
Cov (intercept & slope)	-0.12	[-0.14-0.10]	-0.07	[-0.09-(-0.06)]
Level III-between cohorts	0.16	[0.08-0.34]	4.09E-12	[6.6e-17-2.5e-07]
Goodness of fit				
Log likelihood	-80852		-59833.76	
Wald chi2(0)	5887.79		3560.65	

Prob>chi2 - random effect	<0.001	<0.001
R2 Random effect	27640.22	21452.7
AIC	161748	119705.5
BIC	161933.1	119861.5
Likelihood-ratio test for model comparison	<0.001	<0.001

Notes: *** p-value significant <0.001

Figures

Figure 1 Predicted Mean BMI Trajectory for Male and Female over Life-Course

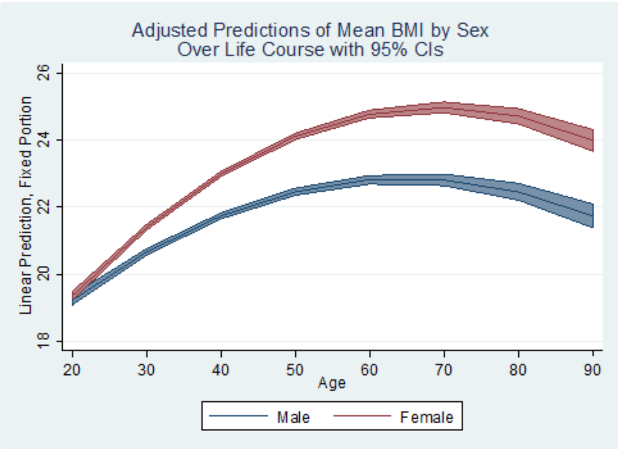


Figure 2. Predicted Period and Cohorts Effect to Population Mean BMI

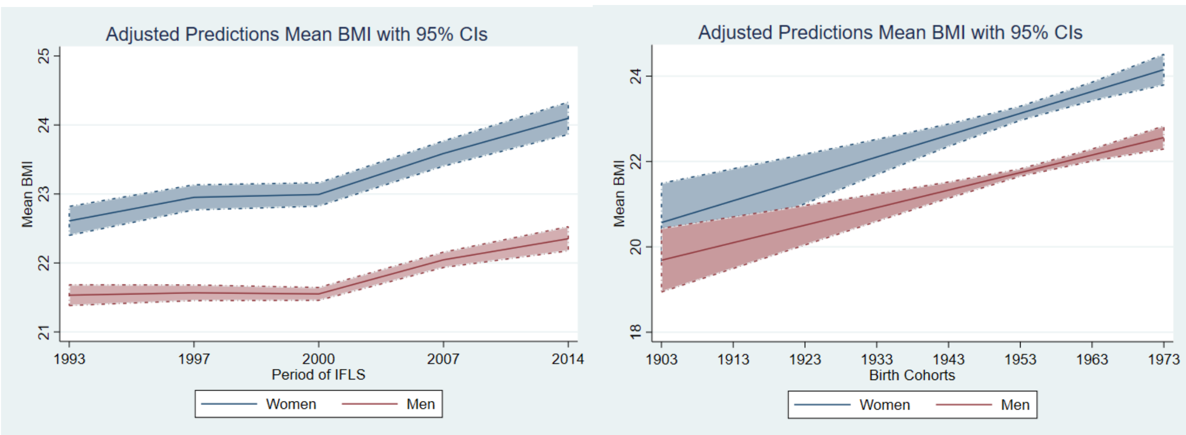


Figure 3. Predicted BMI Trajectories based on Birth Cohorts for Women

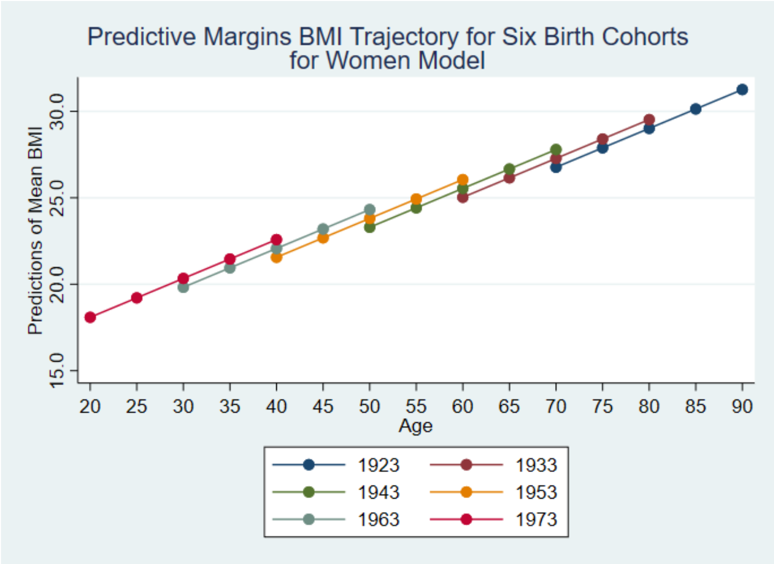
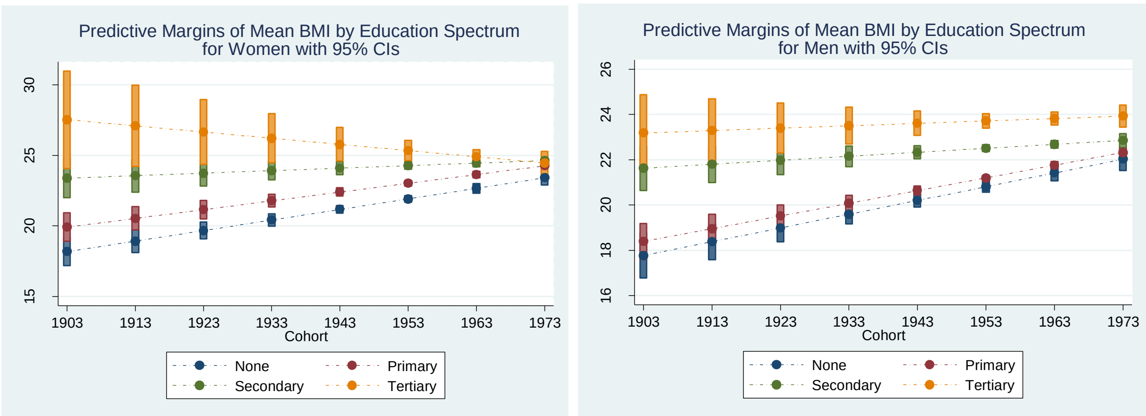


Figure 4. The effect of Education Attainment to Mean BMI across Birth Cohorts for Women and Men



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Supplementary Materials

Supplementary Table 1: Selection of Observations

	Wave				
	I	II	III	IV	V
Total individual age >=20 on each wave before exclude outlier	16,715	20,953	25,401	34,119	40,835
Obs. with extreme weight or height	29	9	14	205	17
% outlier	0.17%	0.04%	0.06%	0.60%	0.04%
Total observations after excluding outlier with minimum 1 BMI measures	16,686	20,944	25,387	33,914	40,818
Total observations included in analysis (born before 1974 and with minimum 3 BMI measures). Total =18,810 panel respondents	10,452	12,595	14,082	12,779	10,623

Supplementary Table 2: Participation rates for each birth cohort based on number of available BMI measures

	Number of BMI measures					
Cohort - 10 years interval (p-value <0.001)	**1**	**2**	**3**	**4**	**5**	**At least 3 BMI measures**
1964-1973	20.19	19.65	21.6	22.77	15.79	60.16
1954-1963	12.59	10.83	14.73	22.99	38.86	76.58
1944-1953	11.17	10.4	15.75	23.1	39.59	78.44
1934-1943	12.96	13	21.27	25.3	27.46	74.03
<=1933	29.5	18.87	26.21	17.17	8.24	51.62